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Lectures

Climate-change analyses used for river-basin management in the Rivers Danube and Elbe

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Increasing global temperatures as indicated by climate projections of the Fourth Assessment Report of the IPCC may lead to changes in the hydrological cycle. This triggered a discussion among experts how aquatic systems and water-resources management practices can be adapted to become “climate proof”. However, an appropriate evaluation of adaptation options requires (1) the assessment of regional climatic and hydrological effects taking into account different sources of uncertainties in data and methods, and (2) the integrated assessment of the main impacts on water quality, water quantity as well as ecological and economic functions of waters.

This contribution shows concepts and preliminary results from ongoing research projects in the Danube and Elbe River Basins (AdaptAlp, KLIWAS and ECCONET). For instance, there is no – and most likely never will be – a single “true” climate-model run in face of an uncertain future. Hence, a “multi-model approach” must be used to account for the uncertainties that lead to a range of possible changes. There is a large span by using various climate projections for one region, different bias-correction methods and diverse hydrological models. Against this background, the present state-of-the-art of climatic and hydrological changes and their impacts on aquatic systems is evaluated.

Hydrological and ecological responses of the Lobau floodplain to climate change

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Due to river regulation, flood control measures and intense agricultural activities, most Central European floodplains have been destroyed during the past 150 years. Although most of the remaining floodplain fragments are degraded nowadays, they still fulfil important ecological functions acting as resorts for rare species and purifying river water. Global change factors like temperature increase and meteorological extreme events exert additional pressure on such fragile yet important ecosystems. In the present study, hydrological and ecological responses of the Lobau floodplain downstream of Vienna to changing climatic conditions are investigated. This relies firstly on predicted climate scenarios for the Danube valley and secondly on data from meteorologically extreme periods in the past: 2002, a year with two exceptionally high floods and 2003, an exceptionally dry year. In addition to the altered hydrology, the ecological response of the floodplain ecosystem is studied by considering the shift and/or disappearance of characteristic habitats like deep water, shallow water and semi-aquatic areas. Because of the significant impacts of global change factors on ecosystems, the results of this study are relevant for conservation and restoration measures to be carried out in the Lobau.

Are climate impacts already discernable on European Rivers? The River Danube example

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Impacts of global warming on the world's major rivers remain uncertain. Decreased precipitation in the mid- and lower latitude will lead to reduced run-off while higher water temperatures might lead to increased evaporation. As a result many rivers could change their run-off regime and may decrease in flow. Long-term water temperature data from the River Danube collected by the Austrian Hydrographic Survey are analysed. To show trends unequivocal, monthly mean water temperature data are investigated from four stations in the Austrian river section covering the period 1901–2006. These data are related to air temperature, precipitation and discharge. Significant relations between air and water temperature are established at all stations. Time trends are analysed using the non-parametric Kendall test and robust regression. All data are pre-whitened to remove noise. Results indicate a highly significant increase of about 1.4°C, equivalent to 0.01°C per year. The increase in water temperature is related to long distance climate signals. Predictions for the time horizon 2050 are developed from multiple regression analyses and scenarios of future changes in air temperature and discharge.

Vulnerability of floodplain areas along middle Elbe river in Germany in view of climate change induced flow alterations – scenarios and adaptability

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The floodplains along the Elbe River in Saxony-Anhalt are still in a near natural state with vast valuable old floodplain forests and the eldest well-known floodplain meadows. The Elbe River bed has undergone significant alterations by different river training measures (bank reinforcements, groynes) for more than two centuries. One of the main impacts has been severe river bed incision by more than one meter. This process is on-going and water levels at low and mean flow are further decreasing. In consequence, flooding frequency of floodplains is reduced. Hydrological models considering climate change effects indicate further reduction of mean and low flow as well as prolongation of low flow periods. Floodplain habitats are facing changes in their water balance. For a specific floodplain section near Dessau future changes of groundwater table, flooding frequencies and duration of low flow periods are considered in relation to terrain elevation and alluvial layer thickness concerning water balance. Some scenarios on the expected development of floodplain vegetation are described. Finally, adaptability for mitigation of habitat alterations is illustrated.

Consequences of climate change and river bed erosion on the utilization of the Elbe and its flood plain

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During the past two decades, the Elbe has experienced drastic changes which have had an impact on the river and flood plain ecology as well as on their utilization. Verifiable changes in the water level, especially declining discharge, can be attributed to the effects of climate change on the Elbe. Not only have regional temperatures increased, leading to increased evaporation, but this trend has been intensified due to a substantial reduction in air pollution. At the same time, erosion of the river bed has accelerated.

These factors are heavily impacting the water balance of the fluvial landscape. The ever-increasing periods of low water, enhanced by riverbed erosion, influence the river's flood plain, especially during the growing season. The changes in the water level of the Elbe have negatively affected its role as a waterway and the cultural and natural heritage along the river.

Environmental organizations and the German water and shipping authorities are struggling to find a suitable solution to the resulting management problems of sediment and detritus on the Elbe. However, the German Federal Government demands an almost year-round minimum depth of 1.60 metres for shipping. The paper will discuss whether this goal is realistic or not and what alternatives can be proposed.

Towards Risk-Based Management of European River basins: key-messages of the EC FP6 project RISKBASE

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RISKBASE (www.riskbase.info) advocates that the actual improvement of the ecological quality of our river basins, and thus sustaining of the ecosystem services they provide, calls for a different management approach. This approach involves the integrated application of the three key-principles to risk-based management: informed, adaptive and participatory.

Informed: a sound understanding of the functioning of the soil-sediment-water (ecological) system and its interaction with the social system is the basis to river basin management. EC projects, like AquaTerra and Modelkey, have delivered new, natural system understanding, relevant to support the achievement of the WFD objectives, i.e. for improving the effectiveness of measures.

Adaptive: we have to learn-by-doing as social/ecological systems are extremely complex and dynamic and can respond in non-linear and unexpected ways.

Participatory: involvement of stakeholders will improve management, e.g. because they may bring in local knowledge. The use of a common language will enable participation. ‘Ecosystem services’ may provide that language.

Leading initiatives, like the management of the Llonsko-Polje catchment (Sava), already demonstrate some of these aspects. However, more, well coordinated and monitored ‘learning catchments’ (a.o. aimed at stepwise improvement of the effectiveness of measures) are needed to transform our general framing and develop best practice.

Implementation of the WFD from the Perspective of Nature Conservation: Analysis of the Programmes of Measures and the River Basin Management Plans of the Danube and the Elbe River Basins

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In all river basins of the European Union, the 3rd phase of the Water Framework Directive (2000/60/EC, WFD) had to be concluded by the end of 2009. In this course, programmes of measures (Article 11 WFD) and river basin management plans (Article 13 WFD) have been established.

Due to its ecological approach, the WFD interferes with nature conservation in various aspects. This overlap is especially reflected in the content of the programmes of measures and the river basin management plans. Examples are the biological criteria for the assessment of the water status, the list of protected areas and certain measures for achieving the objectives of the WFD.

The present contribution will elaborate the links between WFD and nature conservation in river basin planning. Based on the content of the Danube and Elbe River Basins management plans, it will be investigated which recommendations can be given for emphasizing the aspects of nature conservation in the practical implementation of the plans starting in 2010. Moreover, proposals for strengthening the concerns of nature conservation will be made for the scheduled revision of the plans in 2015.

The Implementation of the Water Framework Directive in the Danube River Basin and the Idea of a Danube Biodiversity Strategy from the Perspective of Environmental NGOs

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Members and member organizations of the Danube Environmental Forum (DEF) are committed to water and biodiversity protection and contribute to the implementation of the Water Framework Directive in the Danube River Basin. They have got different views and experiences compared to responsible authorities. International, national, and regional levels of the development of management plans including programmes of measures are assessed. Positive and negative elements and examples from the viewpoint of environmental NGOs are presented.

The analysis gives hints what is important for realization of the plans and programmes, and what issues should be included and improved in the next cycle. The implementation of plans and programmes gives opportunity to improve public participation and to direct prioritization towards ecology, including biodiversity.

A most important issue for further work to implement plans and programmes is the conservation of biodiversity in rivers and wetlands. European biodiversity policy should have a clear focus on the Danube as a lifeline including a coherent network of habitats and protected areas. A Danube Biodiversity Strategy should be an indispensable part of the evironmental pillar of the European Danube Strategy. Elements and phases of a possible Danube Biodiversity Strategy are characterized.

2010 – beginning of an new era of water management by river basin management planning

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EUWMA, the European Union of Water Management Associations, represents public local and regional water authorities from, currently, eight EU member states. EUWMA members are public entities, authorized by national law to perform water management tasks, including water supply, waste water treatment and discharge, flood and coastal protection, water quality management, drainage regulation and irrigation. Based on public interest and available scientific and technical data on both ecological and economic aspects EUWMA contribute to more effective collaboration and design in sustainable water management and identify all potential benefits and costs of action or non-action.

The river basin management plans, describing the programme of measures to realize WFD objectives, starts a new era of water management with obligations in assessment, setting realistic objectives and measurement strategies in 6 year planning cycles.

Organizing enhanced status of water based on biodiversity / ecosystem approaches in bottom up processes is the most efficient way to act sustainable, reflecting affordability and willingness to pay as well as cost recovery by internalizing environment and resource costs.

Cultivated landscapes are a reality in many areas in Europe, which include mostly artificial and heavily modified water bodies – these require an EU-wide coherent procedure for setting normative values for their ecological potential.

The Danube River Basin Management Plan (DRBMP) – challenges of an integrative policy

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The adoption of WFD (2000/60/EC) was a step forward in the holistic approach of integrated water management. However, its implementation is a real challenge for the stakeholders, especially in the most international Danube River Basin (19 countries) with different economic, cultural, and environmental heritage. Further, non-EU member states must be integrated into the provisions of EU WFD and related directives. The DRBMP (2009) with the Joint Programme of Measures developed by the ICPDR provides a milestone towards the "good ecological status" required by WFD.

Based on our review as stakeholders, we emphasize that topics such as climate change, invasive species, sediments, groundwater, land use (spatial planning), overexploitation of natural resources, wetlands and biodiversity conservation, and ecosystem services should receive increasing attention in the DRB. In the context of EU strategy (EU SDS – COM 2009, 400) the sustainable approach is still biased towards economy, while environmental and social aspects need to be strengthened. Practical aspects such as transposing EU policy into national legislation, filling data gaps, harmonizing methods (monitoring, sampling, data quality, environmental impact assessment, etc.) and evaluating environmental and resource values/costs should follow common guidelines across the whole DRB.

Increased transparency and active involvement of stakeholders in the decision making process play a crucial role in local, regional and national policy.

Intercalibration of biological assessment methods for very large rivers

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The European Water Framework Directive stipulates ecological quality assessment against near natural reference conditions specific for each type of water body. For very large rivers with a catchment size larger than 10,000 km^2, reference biocoenoses can be described only incompletely because of the long-lasting anthropogenic utilization, sometimes over centuries. Although individual countries are in charge of developing new assessment methods concerning fish, macrofauna, macrophytes, benthic algae, and phytoplankton, the quality classification at the European level is harmonized by intercalibration. This guarantees the consistency of quality classifications despite the diverse assessment methods applied by the countries. The presentation shows first results of the “Very Large River Intercalibration Group” that, since April 2009, deals with the specific problems of very large rivers within the EU.

A strategy to enhance migratory fish species in the Weser River Basin according to the aims of the European Water Framework Directive

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The Water Framework Directive has revolutionised the European water resource management in the last decade. A milestone has been achieved by the end of 2009 with the river basin management plans containing, amongst other, the programme of measures.

One of the basin wide strategies in the Weser River Basin is the new approach of enhancing the self reproduction of migratory fish species. This strategy, decided by the River Basin Commission in 2009, integrates significant water quality issues with the need for enhancing the river continuity and developing the hydromorphology. It comprises different elements with special functions. The geographical elements are the main migration route, the connection routes and the spawning and juvenile habitat areas.

To maintain river continuity a transboundary and interdisciplinary approach must be combined with the different interest of users, especially hydropower companies, waterway administration and fishery. In this context, for each barrier in the main River Weser and the lower parts of the two tributaries Fulda and Werra the continuity was investigated and recommendations of better solutions were developed. Each element will be explained with an additional remark on its relevance.

MODELKEY DSS as supporting tool for River Basin Management Plan definition: results from application to Elbe and Danube

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Recent definition and submission of WFD-compliant River Basin Management Plans requires large efforts of water managers and highlighted a number of data, knowledge and methodological gaps that need to be fulfilled during the next management cycle. The complexity of the WFD implementation process requires easy-to-use, reliable and scientifically sound decision support tools that help in considering any environmental or socio-economic aspect of the basin of concern. For this purpose, a Decision Support System (DSS) for risk-based assessment and management of river basins was developed within the EU MODELKEY project. The DSS is organized into three separate modules, providing users with multiple functionalities: ecological and chemical status classification, identification of biological communities at risk, key stressors and key toxicants, socio-economic evaluation of water usage and hot spots prioritization. In this paper, main results obtained by DSS application to Elbe and Danube Rivers are presented and discussed. A set of biological, chemical, physico-chemical, and hydromorphological indicators have been evaluated in relation to available reference sites and then integrated according to a set of fuzzy rules implemented in the software system. Results at basin and site-specific scales for both river basins were visualized on GIS maps through the DSS's output visualization interface.

The macrophyte – floodplain habitat relationship: implications on WFD and river restoration

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Aquatic macrophytes in floodplain water bodies are one of the most important structural elements in these environments. Aquatic floodplain habitat types were earlier characterised and classified for several faunal elements as a conceptual “Floodplain Index”. A set of different backwater types of the Danube River in Eastern Austria was selected to work out the relationship between the macrophyte vegetation and the five types of water bodies characteristic for this river reach. Indicative species compositions and aspects of biodiversity are presented. Findings are related to requests deduced from WFD requirements and from multi-factorial river restoration demands.

Large Rivers under Stress

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Large rivers are human-dominated ecosystems impacted through multiple stressors such as land reclamation, floodplain drainage, navigation, water pollution, and species invasion. Today, large rivers are novel, domesticated ecosystems – with no analogous state in the past. Native aquatic communities are being rapidly replaced by exotic-dominated assemblages leading to a homogenization of the biota.

Because of these drastic alterations it is becoming evident that most management strategies probably do not achieve their goals because of non-linear relationships and time-lags between the causes and the effects of biodiversity change; similar to what is observed for human demographic development and CO^2 increase. Concurrently, restoration targets compete with other targets and directives implemented at national, continental, and global scales.

In this presentation, I will discuss the formation and establishment of novel large river assemblages and its related ecosystem services. Innovate ideas and concepts are presented on how to potentially manage large rivers as cultural freshwater ecosystems and to develop synergies among presently competing targets such as biodiversity conservation, navigation, water use, and flood control.

Mean residence time (MRT) of baseflow water in the Upper Danube Basin derived from decadal climatic signals in long-term isotope records of river water

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Long-term stable isotope records of precipitation water exhibit significant decadal changes in the isotopic composition of H and O. Since evaporation has minor influence on the isotopic composition in river water it can be neglected in most parts of the Danube Basin. Hence, isotopic signals of precipitation water are transmitted through the whole catchment and reflected in the isotopic record of river water. A comparison of long-term stable isotope records of precipitation and river water, therefore, should provide information on the residence time of precipitation water in the catchment. First evaluations show a shift of about 3 years for the climatic signal in Danube water at Vienna, most probably the MRT of base-flow water (groundwater discharge to the river) in the Upper Danube Basin. Typical alpine rivers – e.g. Inn, alpine section of the Rhine – exhibit a more pronounced climatic signal, the time-shift of the signal is similar to that of the Danube (except River Drava). The age distribution – residence time of river water in the catchment area – is responsible for the shape of the signals in river water. Decadal stable isotope signals may be used to determine MRTs of river and ground waters by model calculations in a similar way like tritium input by nuclear weapons in the past.

Flood risk management services in support of the implementation of the EU Flood Directive – First results for test sites in Romania and Bulgaria

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Within the framework of the European initiative “Global Monitoring for Environment and Security” (GMES) several flood related geo-information services have been developed during the past few years. The project “Services and Applications For Emergency Response” (SAFER) contributes to this initiative by providing rapid, reference and thematic mapping services relevant to an effective support for natural disaster management.

This presentation focuses on the further development of a flood risk management service portfolio which is intended to provide up-to-date flood relevant products for test sites in Romania (Timis catchment) and Bulgaria (Rousse region) and which can be transferred to other catchment areas. The products are derived from Earth Observation data, in-situ and ancillary data. The applied methodologies comprise hydrodynamic modelling, assets mapping and damage estimation. By providing flood, hazard and risk maps and a flood information system the service portfolio contributes to the implementation of the EU flood directive.

The substantial benefit of this service portfolio results from the combination of Earth observation data with regional / local data and enhanced modelling techniques. The former enables a European-wide harmonised and cross-border approach, the latter contributes to the provision of tailored solutions considering, e.g., specific geographical / hydrological circumstances of the river basin.

Restoration of River/Floodplain Interconnection and Riparian Habitats along the Embanked Danube between Neuburg and Ingolstadt (Germany)

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The Upper Danube was embanked and straightened since the 19th century and disconnected of its floodplain besides high floods. Additionally, in the 1970s hydropower stations disrupting the longitudinal continuum were built. But still, a high biodiversity mainly of species of the hardwood riparian forest could be conserved on the project area of 2,100 ha. The goal of the presented project is to bring back new "controlled" dynamics to the floodplain (water, groundwater and morphological features) which is the key process to vitalize floodplain habitats and species. The project consist of three measures: 1) a permanent flow of water (up to 5 m^3/s) bypassing the dam of the upper power station. The new river will develop on the floodplain partly flowing in old oxbows. 2) Controlled flooding (up to 30 m^3/s) of parts of the floodplain during peak discharge of the Danube. 3) Temporary drainage of the floodplain in summer, where the groundwater level is constantly high due to the dams. The measures, conducted by the Bavarian Water Authority, were finished in spring 2010. A comprehensive monitoring program including vegetation, fauna, hydrological and morphological data was established and will be presented together with some of the previous results.

Dynamics of trace element pollutants during flood events: Hungarian Tisza and German Mulden Rivers – A comparison

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Intensive and long-term mining activities in both river catchments cause heavy metal and arsenic contamination of the river sediments. Extreme events like the cyanide accident in Baia Mare (2000) and/or the extreme flood in 2002 led to relocation of pollutants. Long-term investigations on the Tiza from 2000 to 2005 showed that the dilution effects decreased the pollution in the sediments and/or flood plains. In contrast, still high concentration of characteristic heavy metals and arsenic are observed in the sediments of the Mulden Rivers. Different procedures of the mining industry may account for this discrepancy. Different water use concepts of the mining reservoirs located in the neighbourhood of the rivers show pro and cons of different management strategies in relation to the pollutant dynamics. However, similarities are observed for chemical and physical behaviour of the pollutants. While lead, for example, is transported predominantly in particulate form in both catchments, arsenic is mainly transported in solution. In principle the same is valid for the concentration distributions of all investigated heavy metals in different extraction steps of the BCR procedure.

Contemporary geomorphological-sedimentary consequences of flooding – the Bratislava reach of the Danube River

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The studied river reach represents the inter-dike area of the Danube River downstream of Bratislava. It has been designated as the "flood way" under the flood protection measures of the town and, hence, stores floodwaters. The floodplain's vertical accretion was investigated by sedimentological and dendrochronological methods. The lithofacies of three flood deposits (March 2002, August 2002, and September 2007) were examined by analysis of 10 bore-holes and 20 pit exposures. The overbank deposits differ from the older gravels, consisting of a fine-grained alluvium varying in thickness from 0.5 m to 1 m. Three main phases of energy flow changes of floods are recognised and, thus, the complete flood record can be expressed as the set of three layers. Conditions of the overbank sedimentation based on the shape and grain size of sediments were analysed, too. Investigation of landform and floodplain roughness changes and the bank retreat rate is based on the multi-temporal interpretation of aerial photographs (1949, 1969, 1985) and orthophotomaps (1997, 2004) and field work. The bank retreat of about 100 m during 1949–2007 was caused by flood events as well as by artificial channel straightening. The bank shift resulted in the development of the new levee.

Hydromorphology of Mures River (Romania, Hungary)

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The Mures River (largest tributary of the Tisza River, 760 km long, catchment area 28,000 km^3, mean discharge 180 m^3/s) was investigated from its headwaters to the mouth by a CEN conform hydromorphological method (assessment of channel, banks and floodplains). Field work by boat and on surface was supported by excellent historical maps (beginning from 1780) and high resolution satellite images. Moreover, recent river and catchment studies (hydrology, land use, pollution) and WFD assessment were considered.

The Mures is still a relatively natural river and only few dams influence water and sediment regime. The strongest river regulation is in towns (flood protection) and the straightened lower course (70 km in Hungary, navigation). Recent bank reinforcements for flood protection are evident in the middle course (some 50 km). However, the strongest impact is by mostly commercial sediment extraction along the middle and lower sections, potentially favoring channel incision.

In total 15 % of the river are strongly altered (corresponding WFD class 4 and 5), 55 % are moderately changed (class 3) and 30 % are in good or near natural condition (class 1 and 2). The CEN assessment, however, does not respect appropriately the intensive sediment extraction. We discuss how sediment management can be improved to achieve “good ecological status”.

Assisting integrative planning on waterways by modelling techniques – the Integrated Floodplain Response Model INFORM

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Construction and maintenance works on waterways may cause interference with the environment due to functional hydro-ecological interrelations. In an integrative planning a sound expert methodology is needed for involving relevant stakeholders and considering impact related pathways, finally leading to a commonly agreed plan. Modelling techniques can essentially assist this process; especially ecological modelling can provide valuable input for decision making.

The German Federal Institute of Hydrology (BfG) developed the software system INFORM (Integrated Floodplain Response Model). Its main goal is to support the decision process during planning stages of measures along German Waterways. The modelling framework allows to predict impact on habitats of plants and animals due to natural or anthropogenic interference in riverine hydrology and morphology.

Applying INFORM in a stretch at the Middle Elbe affected by river bed erosion will help the Waterways- and Shipping Administration (WSV) for selecting counteracting solutions to mitigate the decline in water levels. Model predicted change in floodplain vegetation or in habitat quality for fish in groyne fields for example will give clear evidence on ecological impact. Evaluation of predicted ecological change will assist the WSV in taking optimum decisions targeting at only weak interference with nature or even promoting nature.

Spatio-temporal patterns of zooplankton densities according to water chemical characteristics and hydrological events in a river-floodplain system at the Danube (rkm 1498–1469)

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The Gemenc is the largest active floodplain in Europe with an area of 180 km^2. The various characteristic side arms and backwaters provide a great opportunity to investigate the dynamics of hydro-ecological interactions of an intact river-floodplain system. The aim of the study was to explore the links between different functional units (eu-, para-, plesio- and paleopotamal), hydro-ecological events, water chemical characteristics and patterns of zooplankton densities. The densities of all examined zooplankton groups (Cladocera, Copepoda, Rotifera) in the main arm were always lower than in the side arms. Differences were found between the density patterns of Crustaceans and Rotifers among the functional units, which correlated with the water retention time. Specific hydrological events (increasing and decreasing flow, flood peaks) affected the density of Crustaceans and Rotifers differently. The main factors influencing the densities of different zooplankton groups were flow intensity, water retention time, frequency of flood events and predation by planktivorous fish. Most of these factors depend on the hydrological conditions of the side arms or backwaters.

Modeling hydrological processes to evaluate alternatives for ecological reconstruction in the Danube floodplain near Braila, Romania

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Hydrological modeling is a current and future objective of the interdisciplinary research of complex ecosystems. A mathematical approach is needed to quantify transport processes of particulate matter in rivers. Specific models using cellular automata, such as CAESAR and TRACER, allowed the numerical modeling of hydrological processes such as erosion and deposition, important in complex dynamic wetland systems. For a specific sector of Fundu Mare Island (near Braila, Romania), we tested two hypotheses: the first one implies an increase of erosion near the shallow lakes and channels, achieved by opening connection channels with the upstream Danube arms; the second hypothesis implies that natural erosion and deposition will balance the retention and mobilization of heavy metals. The extension and intensity of hydrological processes was validated by numerical modeling of historical flood events and multispectral satellite images of LANDSAT ETM type. Measured heavy metal concentrations were used to calibrate the model. The first hypothesis was validated and was recommended for reconstruction. The second hypothesis will need more attention, we will need more data for complete testing and it remains subject of our future research.

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Long-term prognosis of discharge in selected rivers of the Danube and Elbe basins

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Since the very inception of hydrology as a scientific discipline, hydrologists and climatologists around the world have been trying to make science-based prediction of future development in the hydrosphere. Long-term predictions for 10–20 years must be based on detailed statistical analyses of time-series recorded in historical annals. First, we performed a statistical analysis of the monthly and yearly discharge time-series of the Elbe River (at Decin and Dresden stations), and of the Danube River (at Bratislava and Orsova stations, as well as of other Slovak tributaries of the Danube). We used the time-series analysis, the auto-correlation analysis and the spectral analysis to identify inter- as well as intra-annual variability of selected discharge series. The second part of this study is devoted to the long-term prediction of the yearly discharge of the Danube River, and Elbe River by applying stochastic methods.

Nutrient dynamics in complex river floodplain systems: effects of restoration

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Floodplains are key components within river ecosystems controlling nutrient cycling by promoting transformation processes and thus, act as biogeochemical hot spots. The deterioration of these systems due to regulation and land use change has prompted restoration measures aiming to improve the ecological conditions at landscape scale. At this scale, three interrelated principles of hydromorphological dynamics can be formulated regarding the cycling and transfer of carbon and nutrients in large rivers: a) The mode of carbon and nitrogen delivery affects ecosystem function; b) Increasing residence time and contact area impact nutrient transformation; c) Floods and droughts are natural events that strongly influence the pathways of carbon and nutrients. All three factors can be affected by natural disturbances or anthropogenic impacts including restoration, through a change in either water regime or geomorphologic setting. These changes in turn will affect the biogeochemistry of riparian zones and floodplains.

The paper analyses the effects of river side-arm restoration on ecosystem functions in a large river, the Danube River. We demonstrate that principles of hydromorphological dynamics control potential gas emissions and nutrient status in the water column and sediment compartments and can be used as proxies to assess environmental changes.

Groyne modifications – an appropriate approach to support riparian species?

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At the River Elbe in Germany the Federal Waterways Engineering and Research Institute (BAW) and the German Federal Institute of Hydrology (BfG) have developed two groyne modifications to induce higher hydro-morphological dynamics at the riverbanks compared to the standard inclined construction. To assess if groyne modification is an appropriate approach to support riparian species, the ground beetle *Bembidion velox* (L., 1761) was chosen as target species and has been studied from 2000 to 2008.

Habitat analysis and laboratory experiments with immature stages show that the population development of *B. velox* is not only adapted to, but also dependent on, hydro-morphological processes. High sand content, sparse vegetation and proximity to the water line are the key habitat factors for successful offspring performance. Based on these findings the habitat availability for *B. velox* was simulated with digital maps considering different discharges and groyne forms. Results show that groyne modifications with clefts can form scours and small sand banks, which lead to an extension of the shoreline and increase the habitat availability for *B. velox*.

Riparian Forests and Riverine Vegetation – Risk Factors in Case of Flooding?

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One of the objectives of the European Water Framework Directive is to achieve a good ecological status of surface water bodies. Ecological status refers to the quality of the structure and functioning of the aquatic ecosystems. In this context the development of riverine vegetation and riparian forests is a most important factor for the ecological improvement of our regulated and modified rivers. Since an uncontrolled development of vegetation might result in higher water levels in case of flooding it is often argued that the development of riverine vegetation can not be tolerated.

Therefore, riparian trees and bushes are often cut down although this is expected to have little or no effect on the water levels. Such actions actually took and take place not only on the Elbe and the Danube River but also on smaller rivers. To find the balance between flood control and ecological needs competent analysis of the given boundary conditions is necessary. The causal connections and the hydraulic requirements will be discussed on the basis of mathematical modelling of flow conditions including results and examples. Finally, conclusions for a better understanding of the discharge behaviour will be given and an approach concerning the mathematical modelling will be presented.

Sediment origin and dispersal dynamics in the lower Danube Basin

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The dispersal of contaminant metal-bearing sediment through the lower Danube Basin is of key concern for basin management and the implementation of the EU WFD. We report on the use of Pb isotopes and multi-element geochemical data to track the source of metal-enriched sediments in the Lower Danube and on the use of mixing models to quantify sediment contributions from Serbian, Romanian and Bulgarian tributaries to River Danube channel and floodplains. It is possible to differentiate between metal ore deposits within the Danube Basin based upon $^{208/207}Pb$, $^{207/206}Pb$, $^{208/204}Pb$ and $^{206/204}Pb$ signatures and therefore track sediments in catchments draining differing mineralization types. For example, 31–95 % of river channel sediment within the lower reaches of the Rivers Ogosta and Iskar are sourced from mining-affected tributaries within these catchments. In the Lower Danube, enriched Cu concentrations (250–280 mg kg^{-1}) mirror peaks in sediment contribution from two key tributaries, Rivers Timok and Iskar, with multivariate mixing model data indicating sediment delivery from these catchments contribute 10–24 % of the channel sediment load of the Lower Danube. Here Pb isotopic data is used not simply for identifying potential contaminant sources, but for the quantification of sediment-associated metal dispersal at the catchment scale.

Selecting the appropriate set of methods for evaluating ecosystem functions and services in ecological risk assessment. Lessons learned from the River Tamis (Danube River Basin)

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Ecological risk assessment, focused on individual level toxicity data, has been widely criticised, which in turn stimulated the development of an alternative risk assessment approach – the integrative evaluation of ecosystem functions, which would be supportive of many services aquatic ecosystems are expected to provide to humans. This paper aims at evaluating the current state of methods for determining the effects of various stressors on biodiversity and ecosystem functions, and at predicting the relevance for ecosystem services, taking the River Tamis as a case study.

The transboundary Tamis River (Romania/Serbia), one of the larger tributaries (359 km long) of the Danube River was not covered by the recent ICPDR JDS 2. Furthermore, monitoring programmes of the two countries have not been harmonised yet, so data are lacking even for the traditional environmental risk assessment. One of the objectives of the EU funded Neighbouring Programme Romania/Serbia was, therefore, sound environmental risk assessment, necessary for scientifically based decision making in water management. Hydromorphological, chemical (including WFD but also the River Danube specific priority pollutants), biological and ecotoxicological methods have been combined to identify major pressures and to evaluate their individual and combined impact to ecosystem functions, and consequently, ecosystem services.

Hydrographical Network of the Danube Delta Biosphere Reserve – Modelling the Morphological Dynamics

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The paper presents the Danube Delta Biosphere Reserve (DDBR) hydrographical network (canals, brooks, and lakes) morphological dynamics. This is investigated and presented as geospatial data which result from field measurements. Subsequently these data are modelled in a 3D mathematical model using the Delft3D hydraulic program (DELTARES), a product of The Netherlands Hydraulic Institute. Based on morphological parameters, hydro-morphological changes can be evaluated by analyzing the DDBR hydrographical network zones where fluvial processes, erosion and, especially alluvial sedimentation, are active. The DDBR hydro-morphological (bathymetric and topo-hydrographical), as well as hydrological regime measurements were performed by the Danube Delta National Institute, Tulcea, during 1998–2009 by using research equipments of high accuracy, compatible with GIS. Numerical /geospatial maps visualize the state of the DDBR aquatic ecosystems, mostly dependent on the Danube River hydrological regime, and how these changes generate ecological disequilibrium with negative impact on some flora and fauna species. The gained knowledge on ecosystem function provides a scientific tool for decision making on a sound management of a complex environment. The aim is to improve the quality of aquatic life by restoration of habitats and hydrographical network and overall ecological reconstruction.

Sediment Management in the Elbe from the Perspective of the Port of Hamburg

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Continuous maintenance dredging is necessary in the Port of Hamburg to safeguard water depths for navigation. In the last year the annual amount of dredged sediments was about 6 Million cubic meters. The challenges for sediment management are manifold: contamination of Elbe sediments decreased over the last decades; nevertheless, sediment quality still needs to be improved. On the other hand, nature protection regulations and marine policy requirements demand management plans and limit placement of dredged sediments in open water. Although Hamburg safely disposes annually 1 Million cubic meters of contaminated Elbe sediments on land most dredged sediments have to be brought back to the aquatic system. The presentation will give an overview of these challenges and the concepts developed to manage sediments in the port and the estuary. This takes into account also international and European experience.

Danube meets Elbe meets …: homogenization of the freshwater fish fauna across Europe

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A network of > 28,000 km of navigable rivers and canals connects all major European rivers. Moreover, most European rivers are heavily fragmented, canalized, and polluted, leading to a higher extinction rate of freshwater than of terrestrial or marine species. Within this new “meta-catchment” non-native species may rapidly spread across the continent forming novel communities and leading to faunal homogenization.

We quantified the former and present distribution of the freshwater fish fauna of 167 European river catchments covering 75 % of the European continent.

Up to 25 % of the native fish species disappeared per catchment. This loss has often been compensated by a rapid increase in non-native species; their proportion can be as high as 40 % of the total species richness and is often caused by widespread, cosmopolitan species. Concurrently, long-distance migrating species such as sturgeons (*Acipenseridae*), allis shad (*Alosa alosa*) and lampreys (*Petromyzontidae*) got lost at the catchment scale. Increased total species numbers (gains > losses of species) are rare, while homogenization across catchments has increased.

We conclude that the frequently observed gain of species at spatial scales smaller than primary catchments can be misleading. The catchment scale enables to detect losses of native species although faunal homogenization took place.

New manual on integrated planning of waterways as a tool for river management

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Inland waterway transport (IWT) is one of the strongest drivers exerting new pressures on large rivers, notably the Danube. While various waterways in western Europe have been developed in the 20th century into an intensively used network, the Danube and some of its tributaries (Sava, Tisza) are still largely under-developed and ecologically intact. Beside some well-known conflict cases of the Upper Danube (Straubing-Vilshofen, east of Vienna), several major IWT projects are currently under preparation (Hungarian Danube, middle and lower Sava, Romanian-Bulgarian Danube, Ukrainian delta).

Even though waterway transport is a rather environment-friendly transport mode, these plans are expected to conflict with the Water Framework Directive and the growing Natura 2000 network. As a response, the concept of integrated planning was jointly discussed and endorsed in 2007 by Danube basin governments and various stakeholders in form of the *“Joint Statement on guiding principles for navigation and environment protection”*.

The further illustration of integrated planning is provided in the *“Manual on Good Practises in Sustainable Waterway Planning”* (EU PLATINA project, 2010). This new guide explains the needed scope, organisation and implementation of this planning process that aims at providing security for waterway planners and river protection managers at local and international levels.

Identifying key pollutants in the Elbe and Danube by applying new assessment tools on monitoring data

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The complexity of current monitoring programs as outcome of the Common Implementation Strategy is very basic with respect to frequency, number of stations, matrices and parameters, compared to previous national or regional monitoring programs. This favours the success of method intercalibration, but reduces the overall ambition. Within the MODELKEY project, new assessment tools were tested and applied to existing monitoring data from four river basins including Elbe and Danube. The SPEAR index, the Toxic Unit approach for contaminants in water and sediment, and the integration of biotic and chemical assessment tools enable to identify the major stressors and key pollutants that affect different trophic levels used as ecological quality indicators in the WFD. Both biotic and chemical data indicate the high organic load as one of the major stressors in the Danube River Basin, but the biotic community seems to be affected also by nutrients, which is not reflected by their concentrations. In the Elbe nutrient concentrations are much higher and it is clear that eutrophication is an important stressor here. The impact of contaminants is in both river basins clearly reflected by the biotic community, and several key pollutants can be identified that have an impact either on algae, macro-invertebrates or fish.

Selected measures towards integrated land and water management on Upper Tisza, Ukraine – local community involvement to support implementation of ITRBMP

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In the framework of a micro-scale project funding of UNDP/GEF/ICPDR different community-based projects for improved land and water management along the whole Tisza River Basin are in implementation. In the Upper Tisza Basin in Ukraine and Romania specific attention is focused on pollution reduction and solid waste management. Numerous uncontrolled disposal sites of plastic waste along mountain river banks and Tisza floodplains are the most visible indicator of poor waste management, traditional habits and new socio-economic developments. The paper describes practical examples of cooperation with the local population via communal institutions and regional state administration to increase awareness, clean-up uncontrolled disposals, establish separate collection of waste, and to initiate recycling facilities. The main result achieved is treating PET bottles not as a general waste but as a resource to be sold and further reused.

The ecological value of natural and near natural floodplain habitats along the Lower Danube and their importance for the European Natura 2000 Network and recent planning processes

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Despite of the large loss of floodplains beginning from the 1960s, the Lower Danube still presents, in the remained recent floodplain areas subject to regular floods, numerous site- typical habitats with a high biodiversity. These habitats located on still natural river stretches with natural banks and near natural islands are of outstanding importance for the ecological network Natura 2000 and for the sustainable development along the Lower Danube.

The site-typical habitats of community interest are analysed for their biodiversity and importance for a natural and sound functioning floodplain ecosystem. Studied were also the possibilities for habitat improvement and restoration in relation with flood protection measures. The needed conservation and sustainable development measures are analysed in the context of the European Natura 2000 network, the Water Framework Directive and in relation to the planned navigation projects in the Green Corridor. The latter causes severe problems in stretches with sites of high ecological value. Possibilities to find a way for different user interest are discussed.

Challenge in inferring causality between exposure and impact in river biomonitoring – Trait-based methods and advanced statistics can help

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In biomonitoring inferring causality of exposure and biological impairment is difficult because of the pronounced natural variability that is especially high at large spatial scales (e.g. species composition differs between ecoregions), and also natural and anthropogenic confounding factors (e.g. hydromorphological alterations mask contaminants effects). The promising solutions for this challenge include trait-based methods and sophisticated statistical techniques. Statistical techniques developed for ecological research at large spatial scales include multivariate methods designed to isolate factors of interest non-experimentally. These techniques include, e.g. variance partitioning, path analysis, partial ordinations, and forward selection of predictors. The trait-based methods represent techniques describing and analysing biological systems. Traits are ecological, biological, and other attributes of species and higher taxonomic categories (e.g. breathing type, feeding type, life-cycle duration). Describing of biological communities in terms of traits represents the basically ecological view on such systems, that is, in comparison to taxonomic view, can provide more complete and rather simplified description of the systems. In biomonitoring the use of traits provided a wide range of tools and indices that are stressor-specific and independent of geographical and geomorphological factors. Examples demonstrating applicability and efficiency of these methods and future needs will be discussed.

Specific organic pollutants in Serbian rivers-current state and actions required

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Specific pollutants are all priority substances and other substances identified as being discharged in significant quantities into water bodies in accordance with the WFD (2000/60/EC). The list has to be identified during development of the River Basin Management Plan. Although the WFD has still not been implemented in Serbia, a certain amount of data relating to specific pollutants is obtained by official monitoring programmes of the Republic Hydrometeorological Service of Serbia (RHMS) and GC/MS surveys performed in recent years by the Faculty of Sciences, University of Novi Sad.

This paper presents results relating to the specific organic pollutants officially obtained in the period 2004–2008. During 2009, the official monitoring programme was changed and new additional parameters introduced: pentachlorophenol, octylphenol, nonylphenol, hexachlorobutadiene, pentachlorobenzene, terbutryne, prometryne, desethylatrazine, desisopropylatrazine, chlorphenvinphos, chlorpyriphos, alachlor, diuron, linuron, monuron, isoproturon, α-endosulphane, β-endosulphane, isodrin and trifluralin. Additionally, the results of several GC/MS screening surveys will be presented.

In conclusion, further revision of the Serbian list as well as the frequency and objectives of the monitoring program is needed in accordance with EU lists and EU water policy.

Prioritisation of Emerging Substances as River Basin Specific Pollutants to support River Basin Management Plans for the Elbe and Danube

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Besides the 33 priority substances representing chemical status of European river basins, an undefined number of River Basin Specific Pollutants (RBSP) is considered for the assessment of ecological status. The lists of RBSPs naturally differ between river basins and will be subject to change. It is expected that many emerging substances will be added to the lists.

In this paper, we analyzed the detection frequencies for a total of 420 organic compounds measured in the Elbe and Danube Basins. We evaluated their potential risk for the aquatic fauna using experimental and predicted acute toxicity data for the green algae *Selenastrum capricornutum*, the crustacean *Daphnia magna* and the fish *Pimephales promelas*. For the Elbe, polycyclic aromatic hydrocarbons (PAHs) were most frequently detected, while pesticides were the most important chemical group concerning toxicity for the test organisms. Many of the compounds responsible for potential adverse effects in both basins are currently not considered as RBSP, while priority pollutants were not relevant in terms of toxicity for the selected test organisms. We conclude that the management of pesticide input and other organic toxicants should play an important role during the next cycle of RBMPs.

The impact of chemical stressors on the invertebrate communities of a heavily polluted river in central Europe (River Bílina, Czech Republic)

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The River Bilina is a tributary of the River Elbe and is considered to be the most polluted stream in the Czech Republic (urban waste waters and industrial effluents). In order to find indicators for certain stressors (hydromorpholgy, organic waste, toxic and geochemical compounds) and to evaluate their contributions in determining the ecological status of the river, a multidisciplinary study was performed in 2006–2008 (EU project MODELKEY 511237-GOCE). Along a stretch of 80 km, two reference sites and six impacted sites were investigated using a wide range of metrics for aquatic macro- and meiobenthic invertbrates including ecotoxicological indices such as SPEAR. In this study, the effects of anthropogenic pollutants on community structure and ecological functions (feeding type, dweller type) are elaborated, looking at priority pollutants and other relevant substances that might be responsible for the community response apart from organic or background pollution.

An obvious drop of the biological quality was indicated by clearly changed communities downstream of the inflow of industrial sewage. We discuss which substances and to what extent chemical contaminants affect the biota and which tools might be helpful for their description and prediction.

Effects of environmental variables on mussel assemblages along a second order stream – large river continuum in North Hungary

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The longitudinal distribution of mussel fauna in relation to environmental variables was investigated along a second and third order stream – medium-sized river (Ipoly) – large river (Danube) continuum at 15 sites in 2007. In total 1662 specimens from 22 species were identified, which presents 79 % of the nationwide fauna. Two species (*Pseudoanodonta complanata*, *Unio crassus*) are protected, three species (*Pisidium amnicum*, *Sphaerium rivicola*, *S. solidum*) are rare, and five species (*Dreissena polymorpha*, *D. rostriformis bugensis*, *Corbicula fluminea*, *C. fluminalis*, *Anodonta woodiana*) are invasive in Hungary.

Canonical correspondence analysis was performed to investigate the relationship between the mussel fauna, sampling sites and environmental variables (river continuum, physicochemical parameters, organic matter content and grain size characteristics of sediment, current velocity and bottom texture). Bottom texture and current velocity mainly determine the spatial pattern of mussel assemblages, but the longitudinal gradient and sediment grain size were also significant abiotic factors. Based on species composition three water types along the studied longitudinal profile can be distinguished: the streams; the River Ipoly and the Ráckevei-Soroksári side-arm characterized by similar water discharge; and the main arm of the River Danube. In accordance with mussel composition sections in the main arm of the River Danube cannot be detected, which contributes to the discontinuity concept of large rivers.

Thymallus thymallus (Linnaeus, 1758) threats and conservation in the Romanian Carpathians

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The main Romanian hydrographic basins have a long history of human impact. Especially during the last seven decades, they have been affected mainly by water pollution, hydro-technical works, overexploitation of mineral resources and poaching. This has occurred even in those geographical areas which are considered wildlife sanctuaries, owing to their special characteristics, such as the Romanian Carpathians.

The most reliable assessment of the actual situation is provided by bioindicators. One of the fish species present in the most fragmented/protected Carpathian habitats is *Thymallus thymallus* (Linnaeus, 1758). Seemingly protected in these remote river systems, this species should be at least in a steady state of conservation, but it is not.

Some populations from Gutâi, Maramureş, Harghita, Retezat and Apuseni mountains were analyzed in terms of their habitat and trophic resources status in the last decade, revealing an obvious decreasing trend where human impact is present and where no mitigation and restoration activities were carried out for conservation of the habitat of this species.

Mitigation, restoration, monitoring and management elements are proposed for each of the identified sites where grayling are suffering lately a significant decline.

Functional diversity of heterotrophic flagellates (protozoa) in the plankton of the river Danube at Göd (Hungary)

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We studied the local functional diversity of the probably most important planktonic protozoan consumer group of the River Danube, the heterotrophic flagellates. Flagellates were observed during 37 days by high resolution video micrography following the microbial succession of a single unchanged plankton net sample. Altogether 130 heterotrophic flagellate and other nano-eukaryotic species were found. Instead of grouping species according to their feeding strategies, we measured 7 functional variables for each species from the videos, which determine the utilised resources or influence the method of resource utilization. According to the utilized resources, 15 groups belonging to different realized niches could be found. If the method of resource utilization is also taken into account, 27 guilds could be *a posteriori* differentiated. This huge number of different coexisting functional groups expands our view about the functional diversity of heterotrophic flagellates and confirms that they cannot be handled as a simple 'bacterivorous'-tagged black box in ecosystem research. The detailed analysis of the functional traits of species revealed some novel interesting strategies, some of which seems to be hardly advantageous and adaptive for the species.

Sterlet (*Acipenser ruthenus* L.) as an object of research, fishery and aquaculture in Serbia

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This paper represents a review of research conducted on wild sterlet populations in Serbian waters, the commercial sterlet fishery and the efforts to develop sterlet aquaculture in Serbia. More thorough scientific investigation of sterlet commenced in the early 1950s, focusing mostly on growth, diet and reproductive cycle of this species. While further research was performed less regularly, new research projects on sterlet were initiated at the beginning of the 21st century focusing mostly on its use as bioindicator of freshwater ecosystems. Data concerning sterlet commercial fishery are relatively reliable for the period 1965–1998, but the following period of political and economic transition led to significant changes in holders of fishing rights, with negative consequences on fish catch statistics that have remained unresolved until today. With the market demand for sterlet that is present throughout the year, and the sterlet fishery that is only seasonal, there is a need for the development of sterlet aquaculture in Serbia. Even with the increased attention given to this valuable species in Serbia during the last few years, there are still many problems that have to be solved to achieve good status and sustainable use of sterlet natural populations.

Status, distribution and infection rate of the invasive crayfish species, *Orconectes limosus*, in the River Danube and its tributaries in Hungary

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Large rivers such as the Danube or the Elbe function as natural migration corridors for freshwater invasive species. *Orconectes limosus* had been introduced to Hungary for farming purposes in the 1950s but the first wild population was only found in 1985 in the River Danube in the northern part of Budapest. Since then, it has spread with considerable speed and colonized several hundred kilometres of the Danube downstream reaching Serbia and Romania, and at least 70 km upstream of Budapest. It can be also found in backwaters, side arms, lower parts of some of the Danube tributaries (such as Rivers Ipoly and Tisza) and canals. Besides good competitive abilities against indigenous species, *O. limosus* is a natural host of the oomycete *Aphanomyces astaci* Schikora, 1903, which causes crayfish plague, a fatal disease for European crayfish. Infection rates considerably varied at different sites; the highest was detected south of the Danube Bend, close to the site of the first record of the country.

Posters

Topic 1
Climate change affecting the ecology of big rivers, especially biodiversity

Gastropoda populations in the Danube-Carpathian hydrographic space: possible impact of climate change

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The hydrographic space between the Danube and the Carpathians includes all the aquatic ecosystems within the lower river basin. This area neighbours the arid zones of the Near East, which may expand to the north due to global warming and, hence, change future trends of evolution and patterns of aquatic ecosystem structure.

Presently, 135 species of Gastropoda within the Danube-Carpathian hydrographic space have been identified.

We hypothesize that global climate change will lead to significant alteration of the structure of Gastropoda populations, as some species may disappear, while others may increase in number and frequency. For example, cryophilic and aerophilous species such as *Bythinella austriaca*, *B. cylindrica*, *Stagnicola palustris* ssp. *flavida* adapted to clean water may be limited in space or may disappear. In contrast, ubiquist species, *Lymnaea stagnalis*, *Radix ampla*, *Planorbis planorbis*, *Planorbarius corneus*, adapted to highly eutrophic and poly-saprobic water, may spread and become abundant since an increase in temperature will change hydrological features and water quality. If brackish waters extend the species *Theodoxus (Th.) euxinus*, *Pseudamnicola razelmiana*, *Turricaspia (Laevicaspia) lincta*, *T. dimidiata* tolerant to salt water will be favoured and become more frequent.

Investigation of the isotopic composition of Danube water as indicator for hydroclimatic changes in the Danube Basin. Establishment of a representative isotope monitoring near the mouth of the river

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Isotopes of particular interest for hydrological studies in general include the stable isotopes of water (^{18}O, ^{2}H). They are incorporated within the water molecule and exhibit systematic variations in the water cycle as a result of isotope fractionation that accompanies phase changes and diffusion. Precipitation variability is related mainly to air-mass source and evolution including temperature-dependant equilibrium fractionation effects. River discharge signatures provide insight into the basin-integrated hydroclimate forcings on water cycling such as precipitation variability (e.g. changes in condensation temperature, latitude/altitude of precipitation, air mass mixing and recycling, distance from ocean source, and seasonality) and evaporation from the catchment by rivers, soil water, wetlands, lakes, and reservoirs. Since evaporation has little effects on the isotopic composition of river water within the Danube Basin, the isotopic composition in Danube water reflects mainly the isotopic composition of precipitation in the whole basin and so provides an integrated isotope signal for hydroclimatic conditions and changes in the whole basin. A 40-years record from the Upper Danube exhibits decadal changes in the isotopic composition of river water. It is intended to establish a routine isotope monitoring of river water in the delta region, representative for the whole Danube Basin.

The effects of climate change on Danubian phytoplankton communities in Hungary

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Based on the results of international studies, increased global warming is expected by the end of this century. This change might seriously affect aquatic ecosystems. One possible approach to this problem might be the simulation modelling of aquatic community which depends on meteorological factors. The basis of our work was the long-term (24 years) phytoplankton database of the Hungarian Danube Research Station, collected in the Danube at Göd. This database that was based on frequent (weekly) sample collection has given a great opportunity for the modelling of seasonal dynamics. When establishing the model we supposed that the seasonal dynamics of the phytoplankton in the Danube can be described based on daily temperature and the availability of the light. The seasonal phytoplankton changes were simulated by a linear combination of theoretical species characterized by different temperature optima. According to our field data set from 1979–2002, the model has generated patterns similar to the ones observed. The model was run with the daily temperature data series projected by climate change scenarios for the period of 2070–2100. This way, an estimation of the direction of the changes of phytoplankton in the Danube – as a reaction to global warming – has become possible.

Topic 2
Implementation of the EC Water Framework Directive (WFD), scientific, practical and political problems

Spatial variability of heavy metal pollution in groyne fields of the middle Elbe – implication for sediment monitoring and risk assessment

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Many European rivers like Danube, Elbe and Rhine have been regulated by training works for navigation and bank erosion protection. Such near bank structures (so called groyne fields) are shallow areas which exhibit high sediment trapping efficiency. Depending on the river discharge these still water zones act as temporary sinks or sources of suspended particulate matter. In the past organic and inorganic pollutants have been discharged to the river system and are still present in deposited sediments due to industrial and municipal activities and development in the river basin. To implement remediation projects required by the EC Water Framework Directive (WFD), appropriate monitoring is necessary for assessing the effect of countermeasures. As for the monitoring, the spatial distribution of deposited sediments and contaminants has to be considered. Therefore, the heavy metal contamination of sediments of a groyne field in the middle part of the River Elbe was investigated. In June 2008, within an area of about 1034 m^2, sediment cores up to 50 cm depth were taken at 12 locations. Depth profiles of the critical erosion shear stress and heavy metal concentrations were determined. Sediment stability and contaminant inventory generate consequences for monitoring and environmental risk assessment that will be discussed.

The WFD as a tool for sustainable development in the Danube River Basin

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An international multidisciplinary group of students is analysing whether the implementation of the WFD in the Danube River Basin is in line with the principles of sustainable development. This analysis is done within the European Virtual Seminar on Sustainable Development (EVS), an international course with students from all over Europe. As integrated water management is the translation of sustainable development in river basins aiming for the protection of all goods and services provided, this should be reflected in the river basin management plans and the program of measures that have been developed. Especially in the transboundary river basin district of the Danube with so many countries involved, the most downstream country, Romania, depends strongly on the management upstream. The analysis is focusing on the sustainability of the RBMP and especially of the program of measures and on the specific difficulties Romania is confronted with and the way how the overall program of measures will have its impact on these difficulties. Based upon this recommendations will be made for the different stakeholders involved.

Implementation of EC Nitrate Directive in the Czech Republic

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The Council Directive 91/676/EEC (Nitrate Directive) as part of the WFD aims to reduce and prevent water pollution caused by nitrates from agricultural sources. To implement respective requirements the vulnerable zones were designated in the Czech Republic (2003). Vulnerable zones represent diffuse sources of nitrate. The measures to reduce nitrate concentrations in water are implemented in the vulnerable zones. In particular, fertilisation practice was modified – maximum limits for adding nitrogen fertilisers, limits for the individual crops and unfertilized 3 m wide strips along water courses were introduced. The vulnerable zones are revised regularly in four years intervals.

Ecohydrological modeling was carried out to assess the effect of various measures and changes in fertilization regime under the conditions of climate change in the meso-scale basin Jizera (Czech Republic). The model SWIM (Soil and Water Integrated Model) simulates water and nutrient fluxes in soil and vegetation, as well as their transport to and within the river network. The regional climate change model was used for the assessment of the climate change impact.

Room for the river in cat's bend – application of the Sketchmatch Method in Romania

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The project *"Room for the River in Cat's Bend, Romania"* is a pilot-project, initiated by the Romanian Ministry of Environment and financed by the Dutch Government. In an interactive process together with regional partners (i.e. policymakers and other stakeholders), this project aims to draw up integrated regional plans for the Cat's Bend region, based on the flood protection strategy as defined in the Romanian REELD feasibility study – carried out by the Danube Delta National Institute in 2007 and 2008 – and using the Dutch "Room for the Rivers" approach. This project works out spatial concepts, i.e., the space needed by the Danube River in the Cat's Bend region by combining diverse methods: socio-anthropological research (stakeholder interviews), SketchMatch (interactive design) workshop, hydraulic modeling and 3-D GIS visualizations. One of the main goals of this project was to stimulate support and involvement from stakeholders for the implementation of flood protection measures in the Cat's Bend region by consulting and involving these people in the design process and making use of a coherent package of interactive methods.

Critical review of floodplain restoration projects in the Elbe River Basin, future challenges and opportunities in the framework of WFD, Flood Risk Directive and other biodiversity objectives

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The German Elbe River section is one the few regions in Europe where several large-scale restoration projects have been or are being implemented. Together with other flood protection or risk management measures which require access to former floodplain areas (i.e. polder or retention basins) all projects are listed in the flood action plan of the International Commission for the Protection of the Elbe River (ICPER/MKOL). Furthermore, the effects of all spatial measures on hydrology and flood wave propagation were investigated. The presentation illustrates how many of the nature oriented measures have been selected by pragmatic reasons or specific nature conservation interest. Based on this background additional aspects will be described from the nature conservation point of view as well as how far these measures affect other objectives set, e.g., by WFD, Flora-Fauna-Habitat Directive (FFH), Flood Risk Directive (FRD), and Convention on Biological Diversity (CBD). Subsequently, opportunities and challenges for a long-term restoration strategy for the German Elbe section are elaborated.

Defining biological benchmarks for the intercalibration of the Danube River

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According to the WFD, European member states are obliged to harmonize their definitions of good ecological status for similar types of aquatic ecosystems. Status classification is based on the deviation from reference conditions and as it is rather obvious that these conditions no longer exist for very large rivers, other methods have to be developed. This paper provides an important contribution to the international discussion on intercalibration of large rivers by defining biological benchmarks for the Danube River.

We generated a complex gradient of anthropogenic disturbance using abiotic data from the Second Joint Danube Survey (JDS2) and set a threshold on this gradient based on chemical and hydromorphological quality. This allowed for the assignment of sites in Least Disturbed Conditions (LDC). Based on biological data (phytoplankton, phytobenthos, macrophytes and macroinvertebrates) and currently existing typologies, we then identified four Danube Intercalibration Stretches. The pressure gradient appeared to be significantly influencing the macrozoobenthos and macrophyte communities. Within each stretch, we identified biological metrics that showed significant differences between LDC and non-LDC sites. We also developed a macrophyte sensitivity metric composed of 13 macrophyte indicators for the Southern Pannonian Danube Intercalibration Stretch. These metrics provide an essential tool for intercalibration within the Danube River.

Topic 3
Flooding, meadows, floodplains, actual conditions and restoration measures (riparian landscapes), hydrological modelling, risk assessment

Actual status of biota of the Beregove transboundary polder system (the Tisa River Basin) as instrument for ecological status/potential assessment

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Actual status of biota in the Beregove transboundary polder system, located between the Tisa and Latoriza Rivers, at the Ukrainian-Hungarian border, was investigated. Water bodies were overgrown by macrophytes dependently on their genesis and exploitation. At some stretches occurred wetland complexes comprising 142 plant species. 126 algae species were found, the most diverse were Bacillariophyta (53 species). Zooplankton was poorly developed, 71 species were found (Rotatoria – 31, Copepoda – 14 and Cladocera – 26). Bottom fauna was presented by 82 species, mostly Chironomidae larvae (40 species). Molluska were also quite diverse (20 species). 15 fish species were registered; most abundant were *Rutilus rutilus*, *Scardinius erythrophthalmus* and *Ictalurus nebulosus*. Four invasive fish species were found (*Percottus glenii*, *Ictalurus nebulosus*, *Lepomis gibbosus* and *Carassius auratus*). On the whole, aquatic communities were well developed and quite diverse. By biological parameters channels connected with Tisa achieved good ecological potential, rivers' ecological status varied between moderate and poor, Charonda former riverbed was in good status.

Leaching losses from five leaf litter species in a side arm of the Danube at Gemenc flodplain, Hungary

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Leaf litter from floodplain vegetation represents an important energy input for aquatic organisms. Its breakdown involves two main phases: leaching of soluble compounds and decomposition of structural components.

Leaching of C, N, P and S out of leaves of five characteristic floodplain forest tree species was studied by a litter bag method in the Rezéti-Holt-Danube parapotamon type side arm, along which the patterns of leaf litter transport depends on the hydrological regime. During leaching (48h) ash leaf litter lost 26 %, poplar 25 %, elm 24 %, willow 21 % and oak 3.5 % from their initial dry mass and an important amount of C (0.8-25.6 %), N (11.3–24.2 %), P (23.1–52.4 %) and S (34.4–76.7 %) were washed out. The decreasing order in the amount of nutrient released was: *Ulmus*>*Populus*>*Quercus*>*Salix*>*Fraxinus* for P and *Ulmus*>*Populus*>*Fraxinus*>*Salix* for N; while on the decomposing *Quercus* leaf litter N and S immobilization occurred.

The examined leaf litter species contributed in different degree to the allochthonous nutrient input of the side arm in their initial decomposition phase.

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Actual state and fish production of Sasyk Reservoir

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The Sasyk Estuary before the 1970s was among the most productive water bodies of the Ukrainian Danube region. During 1979–1980 it was separated from the Black Sea by a dam and connected with the Danube River by the 14 km long channel Danube-Sasyk. The new reservoir with a fresh water volume of 50 km^3 was mainly designated for irrigation including transport via Danube-Dniester canal systems to supply the dry South Ukrainian regions with fresh water.

After technical modification (1984–1990) the reservoir featured high primary, secondary and fish (about 50 kg/ha) production. Later, commercial over-fishing and minimum stocking led to a significant decline of valuable fish species (European carp, silver carp, crucian carp, pike perch, etc.) and fish catch. Further, evaporation, construction mistakes and changes in water management enhanced salt concentrations up to 4 mg/l. The reservoir became eutrophic and silted up, the landscape deteriorated. Hence, the ecological, economic and social situation in the region was negatively affected. Local people demand reconstruction of the salt marine liman.

The study presents results of complex hydro-biological investigations carried out during 2008–2009. The actual state of Sasyk Reservoir is reflected by structural indices and biomass of macro-invertebrate assemblages. The potential of fish yield is estimated.

Morphological evolution of riverbeds case study: inferior sector of CIBIN RIVER upstream of sibiu (Olt basin – Romania)

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The analysis of river evolution is based on the systemic and diachronic approach stating that riverbeds are the result of geomorphological and hydrological mechanisms. Natural processes and anthropogenic impacts interact dynamically forming the fluvial relief that is in permanent change.

Spatial and temporal river configurations documented in historical or actual cartographic maps can be characterized and classified according to dominant phenomena, either anthropogenic or natural. In addition, historical flow data are fundamental in the diachronic study of riverbeds. The modifications are continuous and accelerated in recent times. In the Cibin River case, the old maps from the beginning and the end of the 19th century provide an important data basis for the interpretation of the evolution of the floodplain landscape. These references are compared with the situation presented on recent maps (1970–1975) and actually found in the field. An interpretation of the changes to explain the dynamic evolution of the Cibin riverbed and its floodplain are given.

Water chemical characteristics and the spatio-temporal patterns of zooplankton assemblages in a side arm of the Danube (rkm 1437–1440, Hungary)

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The Project *"Development of the active floodplain at South Hungarian Danube River Stretch"* of the Hungarian Danube Research Station includes investigations of water bodies in the active floodplain with different hydrological character. The hydrobiological research in the plesiopotamal side arm Külső-Béda (4.2 km long) started in 2007; it contains detailed water chemical surveys as well as the faunistic and ecological analysis of zooplankton assemblages.

Notable differences were found between water chemical parameters of the main arm and the side arm and among the sampling sites of the side arm as well. These differences are dependent on the water level of the main arm which influences the hydrological connectivity between the Danube and the side arm.

During 2007–2008 24 Rotifer and 17 Crustacea taxa were found; these are the first zooplankton data of this side arm. The zooplankton density and diversity is higher in the side arm than in the Danube, the differences increase parallel with the distance from the mouth of the side arm. Negative correlation was found between zooplankton density and water level of the main arm. The zooplankton assemblages are influenced by the seasonal changes and the water regime of the main arm.

Experience from and challenges for development and implementation of a large scale floodplain restoration – the dyke relocation in Lödderitzer Forst, Elbe River, Germany

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In the framework of a National Nature Conservation Programme a large scale floodplain restoration project in the forest of Lödderitz on the Middle Elbe River near Dessau was planned and is being implemented since 2003. The main component is a dyke relocation with construction of a new dyke of 7 km length and an enlargement of the Elbe floodplain over 600 ha. The affected new floodplain area is to 90 % covered by different forest habitats, with some oxbows and currently some arable land. The whole project area is designated as Natura2000 site within a biosphere reserve. The presentation will focus on the critical steps to manage the process of plan approval, the facilitation of public participation and the implementation of construction works which have to meet much higher technical standards after the recent big floods. Special emphasis is put on the necessary approach to EU environmental legislation and public participation to achieve a timely and transparent implementation process as well as to secure political and stakeholder support.

The status report on German floodplains

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Floodplains are hotspots of biodiversity and central elements of an ecological network. They are also flood protection areas, greenery of waterways, and areas of agricultural as well as urban use. The Federal Agency for Nature Conservation (BfN) funded a number of projects which aimed to raise an inventory of the remaining active floodplains of the larger rivers in Germany and their status. For about 10,000 kilometres of larger rivers and streams of Germany dimension, loss of flooding areas and status of the remaining active floodplains are presented in three maps. These maps and the status report on floodplains show that at large parts of rivers like Rhine, Elbe, Danube, and Odra only 10–20 % of the former floodplains can be inundated now. The floodplains' status is expressed in five classes of modification relative to a potentially natural status – from "nearly unmodified" to "very heavily modified". Only 10 % of the German floodplains are nearly unmodified or slightly modified; however, 54 % are heavily or very heavily modified. These results show that there is an urgent need of floodplain restoration. The report and the maps shall be an useful information source for administrations, planners and nature conservation organisations.

Concept for monitoring zoocoenotic changes due to restoration of fluvial dynamics in Danube floodplain forests between Neuburg and Ingolstadt (Germany)

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To achieve a near natural state in the former floodplain forests along the River Danube, fluvial dynamics were restored in an area of 1200 ha between Neuburg and Ingolstadt (Germany) (see Stammel et al., this volume). In this project, a comprehensive study of the effects of flooding on the present zoocoenoses in the affected areas is performed. We compare the fauna before the first flooding (reference) to that in the two consecutive years and after more than fife years (temporal scale). An experimental design, adjusted to the landscape model, with four treatments differing in the water regime after restoration, i.e. probability and duration of flooding, was used (qualitative scale). Moreover, faunistic studies are performed at three spatial scales: landscape, stand of trees and micro-habitat. Accordingly, birds are the target group at landscape level, birds and arboricolous insects at stand level and insects and slugs at micro-habitat level. All target groups are studied in three height levels of forest trees: on the forest floor, two to three meter above ground level and in tree crowns. The initial fauna was recorded between 2007 and 2009. Faunistic monitoring of the effects of restoration and flooding will start in spring 2010.

Plankton communities of the transboundary Ukrainian-Romanian section of the Tisa River

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The Tisa River is the main tributary of the Danube River. The headwaters are located in the Ukrainian Carpathians. Along 64 kilometers (from Dilove to Tiachiv) it serves as a state boundary between Ukraine and Romania. In 2009 phytoplankton and zooplankton was studied in the main channel of the Tisa River and in the mouth areas of its tributaries: right-bank Kisva, Shopurka, Apshytsia, Teresva and left-bank Iza, Vişeu and Săpânța. 65 algae species were found; Bacillariophyta represented the most diverse group (61 species). 47 taxa of zooplankton were collected, including 28 species of Rotatoria. The number of algae species in different sites of the main channel was fairly constant (21–22), while in the tributaries it varied between 15 and 36. The most abundant were periphytic forms of the genera *Gomphonema*, *Didymosphenia* and *Rhoicosphenia*. 26 and 34 zooplankton species were present in the main river channel and in the tributaries, respectively. Density and biomass of both phyto- and zooplankton in the main channel were significantly lower than in the mouth areas of the tributaries. Since all tributaries are subject to human activity, pollution in particular, they influence the development of plankton communities in the Tisa.

Changes of plant diversity in riparian grassland after extreme hydrologic events

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Riparian grasslands dominate the floodplains along the River Elbe. In a monitoring project, vegetation data of a riparian grassland site were collected in three different periods over 12 years. The effects of two extreme hydrologic events, the summer flood of 2002 and the extreme low water of 2003 on plant diversity, were analysed.

Between 1999 and 2003, species richness and Shannon diversity declined in all classes while Simpson's dominance increased. In the following years and in 2009, species richness increased and reached even higher levels than before the 2002 flood and 2003 drought in wet and moist grassland. In these classes Shannon diversity and Simpson dominance reached values similar to those of 1998 and 1999.

Diversity and dominance were most strongly affected in the vegetation of flooded depressions. Due to the higher disturbance regime, even after six years, species composition remained less balanced and more dominated by single species as compared to 1999. However, it remains uncertain if the flood event of 2002 or the drought of 2003 or both led to the observed changes in vegetation. A yearly monitoring (KLIWAS project) of these sites at least until 2013 may provide further understanding of the effect of extreme hydrologic events.

First records on effect of renewed flooding of three wetlands from Belene Island (Lower Danube, Bulgarian stretch)

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Three marshes situated on Belene Island, permanently separated from the Danube River for many years started to be frequently flooded by irregular opening of installations operated by man at times of high river water level during 2009 as part of a large wetland restoration project.

To investigate possible early effects and efficiency of the new hydrological regime on the marsh status we compared several sporadic samplings for water chemistry, phytoplankton and zooplankton from 1997, 1998, 2000 and 2004 with those of 2009. Main nutrients and oxygen showed similar concentrations and large scattering of measurements before and after the restoration start. A lack of oxygen seems to be responsible for the continuing poor fish presence and occasional fish kills. Similarly, phytoplankton and zooplankton composition and abundance did not show significant changes after renewed flooding. Since the flushed water could not remove the thick anoxic layer of mud and the intense coverage of macrophytes during summer, the applied flood regime seems to have a low restoration effect on the marshes. The artificial flood regime must be improved and additional measures such as dredging of mud and/or macrophyte control may be needed.

Diversity of beetle communities from ground level to canopy in the Danube floodplain forests between Neuburg and Ingolstadt (Germany)

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In Germany, most of the flood plain forests along the Danube River lost their typical character since the 19th century due to river regulations and embankment. A remaining forest area between Neuburg and Ingolstadt will be restored by a particular flooding management starting in 2010 (see Stammel et al.). In order to get faunistic baseline data prior to changes by the water regime beetle communities were studied since 2007. Beetles were collected in four habitat classes according to the relief: (1) close to a water-bearing ditch, (2) in areas which will be flooded irregularly (0–4 times per year) depending on the Danube water level, (3) in areas expected to be flooded only once in 100 years, and (4) in special sites which are dry stands due to gravel deposits. On each site beetles were sampled from the ground layer to the canopy using a variety of automatic traps. The main objectives of the study are (1) beetle diversity in relation to soil moisture, (2) beetle diversity in relation to their vertical distribution (ground level, lower part of the trunk, tree crown), and (3) horizontal and vertical distribution of feeding guilds. The presented results characterize beetle communities typical for different hardwood forest habitat classes.

Spatial differences of the zooplankton assemblages and chemical characteristics of water in a plesiopotamal side-arm of the active floodplain at the Danube (rkm 1442–1440)

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The Gemenc floodplain and the Béda-Karapancsa (Gemenc-Béda-Karapancsa wetlands, Duna-Dráva National Park) represent an exceptional example of a larger old floodplain with big meanders, oxbow lakes, marshland and extended hardwood forests. Due to river regulation works in the 19th century this area has changed: the floodplain remained more or less isolated from the main channel and the length of the side-arms decreased. Detailed investigation was carried out in one of the plesiopotamal side-arms of the area to monitor phyto- and zooplankton assemblages and the chemical characteristics of the water. The Mocskos-Duna (rkm 1442–1440) is situated in the active floodplain of Karapancsa area, approximately 3.4 km long, 60 m wide and shallow (average water depth 1.5 m), a side-arm with very dense macrophyte vegetation. An artificial channel connects the side-arm with the Danube. Diverse zooplankton assemblages (Cladocera, Copepoda, Rotifera) developed in the side-arm. The composition, density and taxon number of assemblages as well as the number of the macrophyte-associated species showed large variations in the different habitats. Our results demonstrate that these side-arms are important storage zones for zooplankton and play an important role in the river-floodplain system.

Influence of environmental factors on riparian forests and scenarios of changes in the vegetation after restoration in the Danube floodplain between Neuburg and Ingolstadt, Bavaria

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The main focus of this work is the observation of the effects of the restoration project (see abstract by Stammel et al.), especially of the ecological flooding, on alluvial forest vegetation using a system of stratified and randomly selected permanent plots. In plot selection, the following parameters were combined in a GIS:

1) position between the two subsequent barrages Bergheim and Ingolstadt (6 sections)

2) situation in the zone of projected ecological flooding (yes or no)

3) relative elevation above the depth contour of the projected water course (</>1.25m)

4) horizontal distance to the projected water course (</>25m)

Within each stratum (unique combination of parameters 1–4), three plots were placed randomly in the GIS, located in the field and sampled in 200 m2 plots (in total 117 plots). The baseline survey of vegetation took place in 2008/2009 prior to the onset of restoration. Besides the study of vegetation types, we analysed relationships between site factors (soil moisture, nutrients, water storage capacity and flooding events as well as groundwater depth and flooding regime as modelled in GIS) and vegetation gradients. The resulting environment-vegetation model will serve as basis to project expected vegetation dynamics as induced by restoration measures.

1D hydrological model as a predictive tool for the assessment of aquatic habitat changes in floodplain rivers

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Predictions of future changes of floodplain habitats are essential for planners and decision-makers of river restoration programmes. In the Szigetköz section of the Danube, several alternative scenarios were proposed to improve the ecological status of the river-floodplain system impacted by the operation of the Gabčikovo hydropower station. The rehabilitation scenarios were ranked by a preliminary quantitative benchmark system considering the areal extent and proportion of aquatic habitats, with the reference of historical habitat distribution. The typology of the aquatic habitats followed the 'functional sets' concept with minor modifications. The recent distribution of the aquatic habitats was analyzed using areal photographs and direct field observations. The future changes in structure and areal extent were predicted using results of 1D hydrological models produced by the MIKE 11 software. Discharge, flow velocity and water depth data were used for habitat typology. The results were presented on GIS habitat maps according to the rehabilitation scenarios of the river-floodplain ecosystem.

The herbaceous vegetation of the terrestrial-aquatic zones of Danube River oxbows

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Both plant zonation and plant interaction are initiated by environmental gradients in floodplains. The important first step in understanding the relationship between environmental factors and zonation is to gain knowledge at the community level about species composition along gradients of riverine areas. In Austria the zonation pattern of herbaceous plants in riverine areas are rarely investigated. The present study focuses on the vegetation zonation and species composition along former side channels of the River Danube, the "Mühlwasser-Großenzendorfer Arm" oxbows, influenced by the surrounding urban environment and different leisure activities, and water bodies with negligible urban influences which belong to the "Lobau Donau-Auen" national park. For each site the floristic, quantitative and life form structure of the herbaceous vegetation along the terrestrial-aquatic zones were analyzed by transects. The community structure on each transect studied is characterised by ordination and classification methods. Resulting communities are then compared to determine differences in the vegetation structure for sites with urban influence and those with negligible urban influence. The final results and conclusions contribute to the basic knowledge needed for the specific management of the terrestrial-aquatic transitional zones within the oxbow system.

Floodplain restoration by dike relocation along the Elbe River and the need to monitor the effects

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In the last centuries, the Elbe lost 80 % of its retention areas due to dyke constructions for flood prevention. This led to severe damage or destruction of many essential wetland habitats. Furthermore, dike raisings have proved to be insufficient to ensure protection in case of extreme flood events. The creation of new retention areas by dike relocation is a major task in European river basin management. Also in the Middle Elbe stakeholders have attended to this challenge and fifteen dike relocation projects (2,600 ha of retention surfaces) are planned. To give more room for the river by opening former floodplains is a chance to combine flood risk management with biodiversity functioning.

The restoration of the hydrological connectivity is expected to improve the dynamics and functions of these floodplain ecosystems and restore their biodiversity. Thus, a long-term monitoring of the effects is a prerequisite for successful restoration.

In the poster we will present the sampling design and the first results of the interdisciplinary monitoring of dike relocation and floodplain restoration project carried out at Rosslau (Saxony-Anhalt). This dike relocation project offers the unique opportunity to follow the first implemented floodplain restoration project in the biosphere reserve Riverine Landscape Elbe.

Pre-restoration analysis of soil seed bank patterns in the backwater system of the Danube floodplain between Neuburg and Ingolstadt

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In spring 2010 a new watercourse will flow through old oxbows of the Danube between Neuburg and Ingolstadt (Bavaria) to enhance fluvial dynamics in the floodplain forest (see abstract of Stammel et al.). Vegetation monitoring has already started to get exact baseline data. The aim of this study is to investigate the potential of the seed bank to contribute to the restoration of stream vegetation along the new watercourse in different parts of the Danube backwater system. These parts differ in the actual water regime (before restoration) from totally dry, over temporarily flooded to deep oxbow lakes. Approximately 350 soil samples were taken in autumn / winter 2009 and in spring 2010. Sampling plots were distributed along 22 transects across the backwater system, with transect sections stratified by geomorphology and plant communities. Seed bank samples will be concentrated (according to the Ter Heerdt method, 1996), stratified and brought to the greenhouse to germinate. The results on seed numbers and species composition will be discussed. To compare the soil seed bank with the input of hydrochoreous seeds transported by the inflowing Danube water seed traps will be installed in 2010 as soon as the water runs.

Topic 4
Waterway- and river management, sediments, transport dynamics, ecological functions, fish migration, TEN-T (Trans European Networks) Rhine, Meuse-Main-Danube with special regard to the ecology of the rivers

Ship-induced waves alter the macrozoobenthos community composition of the river Havel

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Ship-induced waves impact littoral invertebrates, e.g. by displacing individuals. However, the long-term effects of ship-induced waves on the littoral macrozoobenthos community composition have rarely been quantified.

Macrozoobenthos was sampled at a stretch of the river Havel between Potsdam and Brandenburg, comparing sites highly exposed to ship-induced waves with sites which are intermediately exposed and reference sites without wave disturbance. A gradient of wave exposure was verified by monitoring wave heights from April to October 2008.

At the highly exposed sites species richness and individual abundances were reduced in comparison to not exposed reference sites. However, invasive species such as *Dikerogammarus villosus* occurred in higher densities at highly exposed sites. Hence, ship-induced waves impact the community composition of littoral macrozoobenthos.

Can we find parallels between a temperate large river and a tropical small stream?

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In the framework of different projects in Austria on the end of the last century, the Austrian part of River Danube ecosystem was investigated with its structural and functional units of this ecosystem to recognize and understand its ecological functioning.

Within the framework of the cooperative project IRESA (**I**nitiative of **R**iver **E**cology in Sri Lanka: from **S**cience to **A**pplication), two tropical low order streams in different climatic zones in Sri Lanka Island (wet and dry) were investigated, for the first time with an ecological approach. This project was a cooperation between Austria and Sri Lanka, mainly financed by Austrian Agency for Development Studies and Austrian Agency for Academic Exchange, supported by Universities in Kelaniya and Innsbruck, as well as by the Institute for Limnology Mondsee of the Austrian Academy of Sciences.

We try to present in this poster the comparison of important results, and the comparison of ecological factors influencing these ecosystems, searching for parallels and differences in temperate and tropical climatic zones, or in large and small running water ecosystems.

Comparative assessment of the ecological state of sediments in the Ukrainian part of the Danube Delta, Dnipro and Boh Estuary

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This study focuses on identifying impaired and unimpaired areas within the Ukrainian part of the Danube Delta, Dnipro and Boh Estuary using recently developed environmental diagnostic approaches and tools. To characterize the state of these areas, a triad approach was used including (1) chemical analysis of priority contaminants in sediments (e.g., heavy metals, PCBs, DDTs, PAHs), (2) toxicity tests on whole sediments and water-sediment elutriates, and (3) assessment of zoo- and phytobenthos community characteristics. Sediment samples were collected in September/October 2006–2008 at the same stations across the delta and estuary (31 stations with three replicates at each station).

Moderate sediment contamination reflected adverse biological effects of toxicity tests. As expected, increased contamination and toxicity were often related to urban development while undeveloped areas were less impacted. However, a direct relationship between contamination, toxicity and benthic community structure was not always identified. The large spatial and temporal scale data set provided a comprehensive comparative assessment of the ecological state of sediments in two important Ukrainian water bodies. The study will be extended for several years.

The study was carried-out by several dedicated Ukrainian scientists with financial and technical support from the United States Department of State and Environment Protection Agency.

Benthic organic matter dynamics along a stream–middle size river–large river continuum

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After investigations performed at lower spatial scale (i.e. riverbank section, river section) we determined the organic matter content of the sediment along a stream, middle size river, large river continuum. Samplings were carried out in a second and third order stream (Hosszúvölgyi, Börzsöny), in a medium size river (River Ipoly) and in a large river (River Danube) 7 times during 2007–2008 (altogether 12 sampling sites). Bed sediment samples were collected by core sampler (4 cm in diameter) to the depth of 5 cm. Samples were washed through a series of sieves to separate fractions as follows: coarse (2360–710 µm), fine (710–250 µm), very fine (250–63 µm) and ultra fine (63–0.45 µm). Benthic organic matter was analysed in each fraction by loss on ignition (550 Co, 4 hrs).

During the investigation period average organic matter content was 1973±651 (streams), 2087±700 (River Ipoly), 1480±1082 (River Danube) g AFDWm-2.

Similarly to results of our earlier studies, lowest organic matter content occurred at high current velocity sites of the river, highest organic matter content was recorded at deposition zones characterized by low current velocity, where silt and clay dominated in the sediment.

Topic 5
Water quality, new emerging pollutants, biomonitoring, ecotoxicology

The dragonfly *Gomphus flavipes* and mayfly Palingenia longicauda as indicators of the Danube River basin

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Till now, altogether 50 species of dragonflies were found in the Danube River and its arms in Slovakia. One of the most important indicator species is *Gomphus flavipes*, its occurrence in Slovakia was confirmed in the past and present. Today, large populations of Gomphus flavipes are found in the Malý Dunaj River called Danube's "inland delta". In 2007–2008 sampling of dragonflies in the Danube Delta (Romania) demonstrated another large population of this species.

The Gabčíkovo power plant (in operation since 1992) represents a significant impact on the functioning of the Danube ecosystem. Since 1994, we perform a long-term monitoring of dragonflies aiming at evaluating the influence of the dam on biota. During this monitoring we found only one larva of *Gomphus flavipes* at the site downstream of the dam.

In 2009 we observed emergence of giant mayfly *Palingenia longicauda* in the Danube Delta in Romania. This species disappeared totally in the 1930s from many European rivers.

In suitable conditions indicator species are more resistant to disturbances as well as to climatic changes.

This study was carried out within the project 2/0059/09.

The influence of pH and temperature on the enzymatic activity of acidophilic heterotrophic microorganisms of the genus *Acidiphilium*

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Acidophilic heterotrophic bacteria are one important component of the biodiversity in extreme environmental conditions and have a high biotechnological potential: they contribute to the biogeochemical cycling of elements, preventing the accumulation of environmental contaminants and, thus, creating the potential for the restoration of affected sites (former mining areas, decontamination of galvanic wastes or animal farms wastewater, etc.). Although they are adapted to grow in acidic conditions, their enzymatic activity is highly dependent on environmental parameters.

This study presents the influence of pH and temperature on starch hydrolysis of mesophilic and acidophilic *Acidiphilium* strains isolated from mining effluents of Ilba area (Maramureş, Romania).

Growth experiments were carried out at different temperatures (15°C, 28°C, 37°C, 42°C) and pH values (1.5, 2.0, 2.5, 3.0, 3.5), at different starch concentrations. The optimum substrate concentration was 0.1 %; at higher concentrations growth was inhibited. The highest metabolic activity was found at 28°C and pH 2.5, meaning that these would be the best conditions in the natural environment for maximum decomposing activity of the bacteria. In comparison with the regular laboratory cultures, the isolated strains proved to be more active due to their adaptation to the acidic conditions of the mine.

Monitoring the ichthyofauna in Nature Park Kopački rit (Croatia) in 2008

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Nature Park Kopački rit is one of the largest natural areas for spawning and breeding of freshwater fishes in Europe. The ichthyofauna was monitored at 8 sites in June and October 2008 by using fishing nets and electro-fishing gear. The total catch of fish was 371 individuals, classified in 6 families and 12 species. Total biomass was 468 kg. The most diverse family was Cyprinidae with 7 species. Prussian carp dominated in abundance and biomass with 47 %, followed by Common carp (30 %), and predatory fishes, such as Pike and Catfish (16 % each). Beside fish, 3 individuals of crayfish *Astacus astacus* were recorded. The American crayfish (*Orconectes limosus*) was not found, although its occurrence in Kopački rit was confirmed. Absence of fishes in size up to 20 cm and weight up to 300 g was noticeable in the catch, caused by direct impact of the predating Great Cormorant's colonies. A comparison between abundance and biomass indicated that fish communities in Kopački rit are under moderate stress.

ß-HCH sediment eco-toxicity for crustacean Gammarus fossarum – chemical analyses and risk assessment in the Elbe River

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ß-HCH as a waste isomer of the Lindane production is a pollutant in the Elbe River catchment for a long time. Presently, this pollutant still remains a concern, although the insecticide production was stopped more than two decades ago. In a laboratory experiment crustacean *Gammarus fossarum* was exposed to natural sediment spiked with different β-HCH concentrations (0, 1, 10, 100, 1000 $\mu g.kg^{-1}$) for two weeks. *Gammaridean* amphipods are common epibenthic invertebrates in European inland waters and are known to be sensitive to a wide range of pollutants. This research addresses linkages between laboratory findings and results found in Elbe River and tributaries in our previous study. Results should lead to significant improvements in understanding the possible environmental stress factor on the lower trophic level and potentially for the fish community. At the endpoint of sub-chronic exposition the mortality of males and females are discussed. Selected chemical biomarkers of organochlorine pesticides will be established: glutathione-S-transferase (GST) activity and (EROD).

Monitoring of algal blooms and eutrophication processes in the River Danube

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In Bavaria two monitoring stations control the water quality of the River Danube. One of the near-continuous automated stations is located near Regensburg at Bad Abbach (rkm 2400). Raw river water is analysed and subsamples are treated immediately by continuous filtration (mesh size 30 µm and 20 nm) to remove suspended matter for further analysis. The online monitoring emphasizes 9 chemical and physical sensors including chlorophyll and nutrients. Online-biomonitors detect the presence of toxic substances.

Biomass of phytoplankton is quantified by measurement of chlorophyll-a using delayed fluorescence. Algal blooms are indicated by a maximum of chlorophyll-a concentration of about 100 µg/L as well as by high amplitudes of chlorophyll due to the light dependent diurnal rhythm of algal growth affecting the balance of, e.g., oxygen, pH-value, nutrients and suspended solids. In the German stretch of the Danube phytoplankton growth is often limited by the availability of phosphorus, a crucial nutrient for water plants. In general algal blooms in the Upper Danube are controlled by (1) phosphorus, (2) an abrupt decrease of light intensity as a consequence of adverse weather, (3) rising discharge caused by torrential rain, or (4) water temperatures above 20 °C with respect to the diatoms.

Monitoring of selected drugs in surface waters of the Vltava River Basin

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For the first time contamination of active ingredients of OTC medicines such as NSAIDs (ibuprofen, diclofenac), anticonvulsants (carbamazepine), antibiotics (erythromycin, sulfamethoxazole) and contrast agents (iopromide and iopamidol) was investigated in the Vltava River Basin. Sources of these chemicals are municipal waste water treatment plants (WWTP). Selected drugs were included to the monitoring in January 2009. Samples were collected at monthly intervals at 28 sites of the Vltava River Basin and analyzed by LC-MS/MS with direct injection of large volume water sample. Data were statistically processed (average, minimum and maximum concentration) and compiled in a map of pollution. Most of the measured concentrations were below analytical detection limits; however, in some cases, concentrations greater than 1000 ng/l were found. This situation can occur when waste water from municipal WWTP in big cities discharges into small rivers with insufficient dilution of pollutants (for example Rakovnik city – Rakovnik stream, Kladno city – Zakolany stream, Pribram city – Pribram stream etc.). At present, maximal limits of drugs in surface water are not yet established in the Czech Republic. Increased concentrations of these substances are the reason for continued monitoring focusing on sites with permanent pollution especially in highly populated regions or in regions with specific industrial production.

Riverine Transport and Sources of Polyfluoroalkyl Compounds (PFCs) along the Rivers Elbe and Rhine

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Polyfluoroalkyl compounds (PFCs) are currently one of the most elucidated emerging pollutants due to their extreme persistence in the environment, high bioaccumulation potential and several adverse effects on humans and animals. They have been detected in various environmental compartments including air, water, sediment and biota. Sources of PFCs in surface waters are, e.g., industrial effluents, release of treated wastewater and diffuse sources like precipitation.

The purpose of this study is to understand the riverine transport behaviour of PFCs and to identify sources discharging PFCs into the Elbe and Rhine river basins. Surface water samples were taken along the River Elbe and from the German Bight in 2007. A comparative sampling campaign took place along the River Rhine and the Dutch Coast in 2008.

The total PFC concentration ranged from <1 ng/L in the open North Sea up to a few hundred ng/L in river sections with high industrial density. The Rivers Elbe and Rhine showed a different composition profile pointing to the influence of diverse sources located in the river basins. The results show that both rivers are important sources discharging PFCs into the North Sea where they are transported along the coastline via the ocean currents.

New methods in estimating biodiversity: a case study on aquatic and semi-aquatic heteroptera in the Arieş river basin (Romania)

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This paper is part of a study to assess the quality of water resources in the Arieş River Basin. The aim was to establish an inventory of habitats (number and quality) of aquatic and semi-aquatic Heteroptera considering the human intervention in the area. Further, biodiversity was investigated by using two different methods (the classical, index-based one, and a new emerging method: Jost's number equivalent) that estimate both α-, β- and γ-biodiversity. Samples were taken from 16 sampling stations along the hydrographic basin. We found at least 17 species, most of them eurivalent; however, some species were rare sightings in the Romanian fauna, such as *Gerris gibbifer* Schummel 1832, *Hebrus pusillus* (Fallén, 1807) or *Hesperocorixa sahlbergi* Fieber 1848. The α-biodiversity was low but counterbalanced by higher β-biodiversity for most of the hydrographic basin (the gradient chosen was altitude). Both methods used for diversity estimation show more or less similar results; however, Jost's method is easier to use and the results are comparable with any other area.

Assessment of Water Quality in the Upper Course of Siret river (N-E Romania)

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With a length of 599 km, Siret River is the third longest tributary of the Danube and drains a catchment area of 46289 km^2 (90 % belonging to Romania and 10 % to Ukraine). It encompasses different landscapes, including Eastern Carpathians, the Sub-Carpathian hilly region, the Moldavian Plateau, the Siret Meadow and Plain; all its major tributaries originate from the Eastern Carpathian Mountains.

The paper presents a water quality assessment in three sections of the Upper Siret River (upstream Siret city, Hutani, Lespezi), based on physico-chemical and biological parameters, during 2005–2009. Samples were taken monthly for physico-chemical parameters, three times a year for biological quality elements (phytoplankton, macroinvertebrates) and once every three years for fish populations.

Ammonium (0.053–0.108 mg $N\text{-}NH_4$/L) and total phosphorus concentrations (0.040–0.047 mg P/L) reflected category I of water quality by Romanian standard. However, nitrites showed higher concentrations equivalent to quality class II (0.017–0.024 mg $N\text{-}NO_2$/L).

Phytoplankton showed an average abundance between 627777 and 724722 individuals/L, and the respective Saprobic index ranged between 2.04 and 2.22. Macroinvertebrates showed low densities: 122 individuals/m^2 (upstream Siret), 138 individuals /m^2 (Hutani), 139 individuals /m^2 (Lespezi). The corresponding Saprobic indices were: 2.03, 2.06 and 2.16. In 2006, 77 fish specimens of 8 species were collected.

Wastewater disinfection at River Ilz to improve bacteriological water quality: effects and constraints

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Contamination with fecal bacteria often hampers the use of surface waters for bathing purposes. Different sources may deteriorate water quality including wastewater, agricultural runoff, or wildlife. If fecal input mainly results from wastewater treatment plants (WWTPs) disinfection of secondary effluents is supposed to noticeably improve hygienic water quality.

Along the River Ilz, a tributary of the Danube from the Bavarian Forest, five WWTPs between Hutthurm and Passau have recently been equipped with UV irradiation (3 WWTPs), membrane filtration (1 WWTP), and ultrasound/ozone-treatment (1 WWTP) for wastewater disinfection. Fecal indicator organisms (*E. coli*, Enterococci) were determined by cultivation-based methods to evaluate the disinfection efficiencies and monitor the effects on the microbiological quality of the Ilz. The disinfection systems mostly revealed satisfying reduction rates of the fecal indicators. Thus secondary effluents no longer account for a considerable fecal pollution in this stretch. Intense rain events, however, led to a significant impairment of bacteriological water quality possibly caused by sewer overflows or agricultural runoff. For tracing back the origin of these contaminations a quantitative MST-(microbial source tracking) method will be applied identifying genetic *Bacteroidetes markers* from the 16S rRNA gene of populations specific to human or ruminant hosts.

Bioindication and biotesting of water and bottom sediments of water bodies of the Danube Biosphere Reserve

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The transboundary Ukrainian-Romanian UNESCO Danube Delta Biosphere Reserve encompasses one of the largest wetland complexes in the world. Continuous ecological monitoring of the aquatic ecosystem includes the assessment of water and sediment toxicity.

The aim of the study was to characterize the benthic community as bioindicators of water and sediments pollution and to perform toxicity tests in water and sediments. The results allowed a comparative assessment of the state of water bodies in three main arms of the Ukrainian part of the Danube Delta. The conventional bioindication and biotesting techniques have been used. Bioindices provided information on the degree of pollution and contamination.

The obtained data are indicative of moderate state of benthic communities of the Danube biosphere reserve. There was a gradient of toxicity from Ochakivskyi arm (“poor”) to Bystryi arm (“moderate”) and Vostochnyi arm (“good”). These differences will be discussed. We hypothesize that sources of pollution are located mostly upstream and not in the Delta area.

Distribution of organic UV-filters in surface water of the River Elbe

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Organic UV-filters are commonly employed in sunscreens to protect the user skin against solar radiation. They are further applied as UV-stabilizer in several personal care products and in formulations of textiles, varnishes and plastics. The major input pathway of UV-filters into the aquatic environment is assumed to be the washing off from skin and clothes after superficial application in households or during swimming in lakes, rivers and the Sea. Other sources of contamination are, e.g., leaching from plastics, varnishes etc.

In this study, the most commonly used UV-filters are investigated in the surface water along the River Elbe. The analytical method was validated for the determination of UV-filter using gas chromatography and mass spectrometry (GC-MS). The extraction methods liquid-liquid-extraction with dichloromethane and solid phase extraction using PAD2-cartridges were validated. This study shows the concentration and distribution of the dissolved and particulate phase of UV-filters in the surface water along the River Elbe.

Topic 6
Trophic relations (nutrients-bacteria-algae-benthos-fish-birds-humans)

Spatio-temporal changes of benthic organic matter and macroinvertebrate communities in the Danube Bend (Hungary)

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Spatio-temporal changes in benthic organic matter, composition and abundance of benthic macroinvertebrate communities and functional feeding groups were investigated on depositional and erosive riparian zones of the River Danube between river kilometres 1688 and 1668 in 2005. Depositional zones were characterised by the dominance of ultra fine and very fine sediment, while erosive zones showed a significant amount of coarse bed material. The average organic matter content was 6.3 %. The macroinvertebrate fauna was represented by 30 species within 10 higher taxonomic groups (species number in bracket): Gastropoda (8), Lamellibranchiata (15), Polychaeta (1), Oligochaeta, Isopoda (1), Amphipoda (3), Trichoptera (1), Diptera, Chironomidae, Nematomorpha (1). Bed sediment and organic matter fractions and total benthic organic matter are strongly determined by the flow velocity and grain size distribution, while species composition, taxon and functional feeding group distribution significantly differ according the depositional or erosive character of the riparian zone. The results confirm our knowledge about the discontinuity in large rivers and the phenomena of structural simultaneousness (coexistence of different spatial patterns).

Topic 7
General limnological themes following the IAD traditions, flora and fauna

The actual state of relict Pontic-Caspian invertebrate fauna of the Lower Danube within the area of Ukraine

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Long-term investigations on relict Pontic-Caspian invertebrate fauna for more than a century have been reflected in the Ukrainian Danube research. Especially the Lower Danube and its tributaries serve as complex habitat for this peculiar species community, being inhabited since the tertiary period. The Pontic-Caspian Basin restricted the area of these species for a long time, but in the last decades many representatives of this group became active invaders occupying new habitats far away from their home waters.

The specified list of Pontic-Caspian macroinvertebrate fauna for the Ukrainian part of the Lower Danube is represented; ecological characteristics of some species are considered; comparative analysis with retrospective materials in relation to distribution of relict Pontic-Caspian fauna in a region is carried out.

Spatial patchiness and similarity of macrophyte assemblages along a cut-off channel of the River Danube in Linz (Austria)

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Distribution of aquatic plant assemblages along a cut-off channel of the River Danube in Linz was surveyed four times a year during the vegetation periods 2001 and 2002. To illustrate spatial changes in macrophyte communities, Bray-Curtis Similarity and species turnover rates were calculated between each pair of 17 successive stream stretches. Results of both species change measures showed a significant inverse relationship. Floristic heterogeneity was highest at the stream source, resulting in lowest Bray-Curtis similarity value (6.85 %) and highest species turnover rate (0.65). With increasing stream length, uniformity of macrophyte communities also increased resulting in the trend of raising similarity values. The similarity index, however, did not exceed values of 80 % illustrating that at least 20 % floristic change was occurring between consecutive survey units. Similarity values were associated with trends of abiotic parameters. 'Survey unit length' and 'water temperature' were positively related with similarity while 'substrate type' and 'flow velocity' showed inverse negative relationships. These trends, however, were statistically not significant and could not explain sufficiently the spatial patchiness of plant communities. Our study indicates that the establishment of macrophyte assemblages in streams could also be influenced by ecological processes such as transport of propagules to downstream sections.

Phytoplankton composition and abundance in Srebarna Lake and adjacent temporary wetlands (Bulgarian floodplain of the Lower Danube River)

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Species composition, numerical and biomass abundance of phytoplankton were determined from 15 wetland sites in the Bulgarian part of the Lower Danube floodplain. Five sampling sites were located in the aquatic area of Srebarna Lake and several other water bodies in its vicinity, representing small ponds of rather temporary than permanent character. The sampling campaign during 2004–2006 encompassed 12 visits in the vegetation period (March–October). The sampling sites were additionally characterized by their min, max and average depths, water temperature, transparency, degree of surface coverage by macrophytes, sediment type, distance from the middle of the lake, etc.

Cluster and multidimensional analyses yielded different wetland site groups based on algal species, division and functional group composition. These algal groups were related to the environmental parameters mentioned above. In particular, periods of high and low lake levels depending mainly on the Danube level variations but also on man's regulation of inflow influence algal communities. The effects of interactions between main lake aquatic area and surrounding small water bodies on algal biodiversity and lake trophic status are discussed.

Recent drastic changes in the amphipod and mysid fauna (Crustacea: Malacostraca: Amphipoda, Mysida) of the Hungarian Danube stretch

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Amphipod and mysid crustaceans are among the most prominent groups of aquatic invaders. In the main arm of the River Danube in Hungary all species currently occurring are Ponto-Caspian immigrants. The rate of colonisation has undergone a drastic increase in the last two decades, which – along with the more intensive research – resulted in the doubling of the number of species in this section of the river in these groups (from six to twelve). Of the six new species five are recent invaders and one has been "rediscovered". Within the gammaroid amphipods two species have been added to the four already present (*Dikerogammarus bispinosus*, *D. haemobaphes*, *D. villosus*, *Echinogammarus ischnus*); *Obesogammarus obesus* appeared in the early 1990s, while *Echinogammarus trichiatus* was found in 2009. Within corophioid amphipods the presence of *Chelicorophium sowinskyi* (formerly regarded as uncertain) has been proven, and *C. robustum* also appeared recently (2009), which have increased the number of species to three (with *C. curvispinum*). Similar changes have taken place within the mysids; the formerly solitary *Limnomysis benedeni* has been accompanied by two further species, *Hemimysis anomala* and *Katamysis warpachowskyi*. Colonisation patterns, current distributions, and ecological characteristics of the species are discussed.

Importance of the Danube River in spreading the infection of red deer with Fascioloides magna in eastern Croatia

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American giant liver fluke (*Fascioloides magna*) is an important trematode, which mainly occurs in the liver of various wild and domestic ruminants. It was recorded for the first time in eastern Croatia in January 2000, during liver examination of shot red deer from the Danube region. Introduction of the parasite severely damaged the health status of cervids. The survey was carried out during 2001–2004 by qualitative and quantitative faecal examinations of deer living in epizootic areas of the Danube region and in other hunting grounds in eastern Croatia that manage deer game. The highest number of affected deer with a prevalence of 35–60 % was recorded in forested floodplains near the Danube. Mild infections were detected in hunting grounds along the Drava River and in its flooded middle part. Considering the migration paths of red deer along the Danube and epizootic indicators, the spreading of this parasitic disease is expected on left side of the Danube in Serbia, as well as in hunting grounds on the right side of the Drava River in Croatia.

Molecular studies on the phylogeny of immigrated Theodoxus fluviatilis, an alien species in the Upper Danube

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Nowadays biodiversity in surface waters of central Europe is affected by the immigration of alien species. Molecular studies contribute to track the sources of the invaders and give a better understanding of the pathway of colonization.

Theodoxus danubialis (Pfeiffer, 1828) is a small aquatic gastropod mollusc of the family Neritidae. This endemic species is part of the present fauna in the Danube River Basin (DRB). In contrast, the river nerite *Theodoxus fluviatilis* (Linnaeus, 1758) is a fresh- and brackish water snail occurring in the former area of the Mesozoic Tethys Ocean. This river nerite is spread in the Rhine River Basin (RRB) but it was absent in the Upper Danube until first findings of *Th. fluviatilis* were reported in 2001 in Austria and in 2004–2005 in Bavaria (Passau, Regensburg). Immigrations into the Bavarian stretch of the Danube may originate from downstream (DRB) or from upstream (RRB) via Rhine-Main-Danube-Channel.

Molecular studies of the mitochondrial gene of cytochromoxidase are used to identify the affinity between individuals of *Th. fluviatilis* from different sites and sources. Using statistical methods a phylogenetic tree of the individuals can be generated.

Inventory of Macrophytes and Habitats along the River Danube in Croatia

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The stretch of the River Danube through Croatia is 137 km long. The Danube is a bordering river between Croatia and Serbia, and right side belongs to the Croatian territory. During 2003–2004, the inventarisation of aquatic macrophytes and assessment of habitat parameters were carried out along the right riverside of the main channel, in survey units of one river km length. In total 34 plant species were recorded, of which 11 were exclusively found in the Danube main channel. This number indicates a low macrophyte diversity similar to that in the adjacent reaches of the Danube course in Hungary and Serbia. Information on the conservation value of macrophytes is given. In the bank structure, fine inorganic material prevails (63 %), followed by stone blocks used for river regulation (30 %), and concrete embankments (5 %). Among the river sediment types, fine inorganic material is dominant (64 %); sand is present with 29 %, and gravel with 5 %. Average water transparency is 60–70 cm, and medium flow velocity is the most frequent flow class. Broad-leaved forests dominate along the riverside (86 %), agricultural area covers 3 %, and industrial and urban areas were recorded by 4 % each.

Advantage of a Hungarian Rotifer Database System from the aspect of the Danube research

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Our 2008–2009 results showed that rotifers contribute the highest proportion of zooplankton in the River Danube (70–95 % of the abundance and biomass). During this research period we found 92 taxa from the main arm and 83 taxa from the side arm near Göd (rkm 1669). Nowadays the collection of information in well organized databases means an effective tool for easy data access and utility. We constructed a new database system for collecting rotifers data on a country scale, which provides correct information for different water systems (lakes, ponds, canals). There are many taxon lists on the internet, which can provide current, accurate and reliable information about the species. Our database collects recordings of rotifer species in the Hungarian fauna based on scientific papers. Numerous tables facilitate easy access to actual information on valid taxon name, synonym taxon name, paper quotation (name of author(s) and journal, year of publication), date and place of sampling with GPS coordinate or by cities, habitat type, photo of the animal and a habitat map based on recent data. The database operating system functions like Google and Yahoo. The Rotifer database is flexible, expandable and the uploading is continuous.

Can reservoirs compensate oxbow disappearance? The amphibian fauna of the Rétközi reservoir and the Várközi oxbow lake

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The decline of amphibians is a global problem. In Europe it is mainly caused by the disappearance and alteration of habitats. Therefore, it is necessary to counterbalance this negative process with the protection of already existing and the creation of new amphibian habitats. Several large-scale interventions will be realised in the framework of the New Vásárhelyi Plan, a river-regulation oriented programme along the Hungarian stretch of the River Tisza including the construction of new reservoirs. Rétközi reservoir (48º16′30″ N, 22º01′50″ E) was built in 1990 providing a good locality to study the mid-term impacts of such constructions. Várközi oxbow lake is a nearby semi-natural habitat. Our survey started in March, 2008. Two sampling methods, visual encounter survey and sound monitoring according to the MONITOR2000 protocol were applied. *Bombina bombina*, *Bufo bufo*, *Epidale viridis*, *Hyla arborea*, *Pelophylax ridibundus*, *Pelophylax lessonae*, *Pelophylax kl. esculentus* were detected using sound monitoring. In addition, *Rana arvalis* and *Pelobates fuscus* were found during visual encounter surveys. The occurrence of species is different at the two sites. From green frogs *P. lessonae* was only detected at the oxbow, where *H. arborea* and *E. viridis* were also more abundant, while *B. bufo* was heard only at the reservoir.

Diversity of Benthic Macroinvertebrates in Relation to Environmental Parameters in Reservoirs, Danube Basin, North-West Bulgaria

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Twelve reservoirs in the Danube Basin in North-West Bulgaria were sampled in September – October 2009 to study species composition and distribution of benthic macroinvertebrates in relation to selected environmental parameters. The reservoirs, located at altitudes of 110–445 m a.s.l. and with surface areas of 10–360 ha are used for irrigation, drinking water supply, electricity production, aquaculture and recreational fishing.

The benthos fauna consisted of 40 % Oligochaeta, 3 % Gastropoda, 30 % Bivalvia (mostly *Dreissena polymorpha* and *D. bugensis*), 0.1 % Hydracarina, 0.5 % Odonata, 0.5 % Ephemeroptera, 1 % Trichoptera, and 25 % Diptera (16 % Chaoboridae, 7 % Chironomidae, 2 % Ceratopogonidae). Hirudinea, Mysidacea, Decapoda, Heteroptera and Coleoptera were found as well. Highest species diversity was recorded in reservoirs close to the Danube River and in the largest reservoir.

Physico-chemical parameters were analyzed by Principal Component Analysis (PCA). Most of the variance was explained by conductivity, Ca concentration and nutrients. Reservoirs with high values of these parameters were separated from those with low values but high transparency. The diversity of macroinvertebrates is dependent on the environmental parameters and can be used to assess the ecological status. In particular, the role of invasive *D. polymorpha* and *D. bugensis* is discussed.

The study was supported by the Bulgarian Science Fund, Project DO02-283/2008.

Long-term changes of fish fauna in the Hungarian section of the Ipel River

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Setting environmental objectives for rehabilitation of large rivers is hindered by a lack of knowledge of the pre-regulation or reference conditions. Our study was aimed to assess the deviation of the recent fish fauna from its reference state in the regulated lowland section of the Ipel River. Historical habitat analysis and literature study gives a chance for judgement of former fish fauna. Acceptable reports from the fishes of the Ipel River are available mainly from the 19th century and the beginning of the 20th century. The number of observed species increased over time and the occurrence of 57 fish species was reported up to now. The description of recent species composition was based on the results of fish surveys by electrofishing. The comparison of data sets yielded the disappearance of sterlet (*Acipenser ruthenus*) and bullhead (*Cottus gobio*) and increasing abundance of bream (*Abramis brama*), Prussian carp (*Carassius gibelio*) and Ponto-Caspian gobies.

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Topic 7: General limnological themes following the IAD traditions, flora and fauna

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Actual state of biota of the Beregove transboundary polder system as instrument for its ecological status/ potential assessment

SERGIY AFANASYEV, LIUDMYLA GUEIKOVA, OLENA LIETITSKA, OKSANA MANTUROVA, OLEKSANDR SAVYTSKIY, EUGEN SAVCHENKO, OLEKSANDR USOV[1]

Keywords: biological quality elements, ecological status/potential, polder system, the Tisa River

1 Introduction

Catastrophic floods were recorded in the Ukrainian Carpathians in recent years. These perturbations demonstrated the urgent need to bring into play available infrastructure of hydrotechnical constructions, amelioration channels and polders, and further to use them in flood-control measures. The polder systems in the Transcarpathian region have been constructed more than a century ago. They became a unique biodiversity refuge for decades and need therefore to be protected as wetland areas.

The Beregove transboundary polder system (BTPS) is an amelioration system located in the basins of the Tysa and Latoritsa Rivers shared by two countries – Hungary and Ukraine. The total area of BTPS amounts to 880 km^2, where 60% are in Ukraine (Transcarpathian region) (National atlas…, 2007). Hydrotechnical activities have begun in the second half of the 19th century. Up to the mid 1950s BTPS consisted mainly of wetland ecosystems that were almost unsuitable for agricultural use. In the end of the 1950s wide-scale amelioration caused crosscut of almost all areas by a channels net. Hence, the natural features of the floodplain have been lost. However, most agricultural areas are not developed, and many sections of the polder system do not function. Therefore renaturalization dealt with biocoenoses, and existing melioration channels were not cleaned and dredged; they became sites of excessive aquatic and riparian vegetation. Lakes feature minor water exchange and are fed from the limited watershed, during floods and by groundwater infiltration. Washout of the organic fertilizers from the adjacent agricultural areas and high air and water temperatures in summer contribute to an intensive eutrophication of the water bodies.

BTPS comprises the main channel Charonda-Latoritsa (5 km long) and channels of the second (Charonda-Tysa, Sypa-Charonda) and third order (Lower-Sernyanskiy and Upper-Sernyanskiy), constructed in the large-scale amelioration activities. It also includes some rivers and lakes – former riverbeds, which were isolated from the main channels “naturally”, before construction activities have been started. In periods between floods the water from the system flows into the Tysa and Latoritsa Rivers by gravity. During the floods, when water level in the rivers is higher than in the channels, locks in the rivers are closed and excess water from the system is removed by stationary and if needed by mobile pumping stations.

At present the most urgent problem in BTPS is clearance and rehabilitation of the channels in order to provide more effective flood protection of the settlements, industrial objects and agricultural land and water supply during droughts. This often arises a conflict of interests. On the one side it is necessary to ensure good ecological status and ecological potential of the water bodies. On the other side, a mechanical maintenance of the channel system is required but would destroy the habitats of the rare, valuable and protected plant and animal species and therefore not contribute to protect and enhance biological diversity.

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The aim of this work was to study the actual state of biota of different-type water bodies of the BTPS in order to assess their ecological status/potential.

2 Methods

Hydrobiological measurements in the BTPS were carried out during 2009. Further we evaluated literature data from 1999, 2000 and 2005 (Afanasyev 2002, 2006). We analyzed phytoplankton, aquatic plants, zooplankton, bottom invertebrates, and ichthyofauna. The bottom invertebrate fauna was studied in most detail as it is the main indicative group used in water quality and ecological status assessment.

Sampling and sample processing were carried out according to standard hydrobiological methods (Romanenko, 2006). Further, we were taking into account the specific character of mountainous rivers and applied specific methods by Afanasyev (2006) and standard EC methods (AQUEM) (http://www.eugris.info/). Assessment of the River Tisa ecological status was carried out according to the Water Framework Directive 2000/60/EC, on the basis of the RQBA (River Quality Biological Assessment) methods developed in Ukraine (Afanasyev 2002, 2006).

3 Results

The water bodies of BTPS are at different stages of biological successions. It is mirrored by its vegetation character, dependent on their genesis and exploitation, the plankton and benthos development and the occurrence of certain fish species. The main characteristics of biotic communities in the considered water bodies are as follows.

Phytoplankton 126 algae species of 7 departments were found. During the investigation period. The most diverse algal group were Bacillariophyta (53 species). They were followed by Euglenophyta and Chlorophyta (26 species each). Other departments comprised: Cyanophyta and Chrysophyta – 8 each, Cryptophyta – 4, and Dinophyta – 1 species. Maximum number of species comprised genera *Nitzschia* (10), *Euglena* and *Navicula* (9 each), *Trachelomonas* and *Synedra* (6 each). Common forms for periphyton taxa were *Cymbella*, *Gomphonema* etc. Species richness increased from spring (51 species) to summer (70 species) and autumn (79 species). In all seasons Euglenophyta were more diverse and abundant than Chlorophyta. This indicates the presence of easily-accessible dissolved organic matter. The most species rich habitat was channel Charonda-Tysa (92 species), while the lowest species richness was found in the Upper-Sernyanskiy channel (12).

Aquatic plants. By general features of vegetation, BTPS encompasses the European broad-leaved zone, Middle-European province and Pannonia sub-province. The main landscape type is agrocenosis in combination with floodplains, wet and dry meadows, willow beds and poplar thickets. Some limited areas remained primary wetland complexes. According to our observations, 23 species of aquatic macrophytes were found in BTPS. Among them 9 helophytes, 4 – plants with floating leaves, 6 – submerged plants and 1 species of filamentous algae. Some species recorded here are rare and found in the reference list of the Red Book of Ukraine: *Salvinia natans* L. All., *Trapa natans* L., *Nymphoides peltatae* (S.G. Gmel.) O. Kuntzee. Some species need additional protection and are included into the UICN list or protected under the Bern Convention.

Zooplankton. Observed zooplankton communities comprised 71 species, among them Rotatoria – 31, Copepoda – 14 (including nauplial and copepodite stages), and Cladocera – 26 species. In general, the zooplankton was low in abundance. Mass species were those associated with eutrophic and meso-saprobic conditions. Concerning the feeding type they were mainly euryphagous (for instance, rotifer *Asplanchna priodonta* Gosse, juvenile Copepoda) and detritophagous (rotifers of the order Bdelloida, some species of family Chydoridae). The trophic structure of the zooplankton community was quite diverse: both primary consumers (most of rotifers, Copepoda stad. nauplius et stad. copepodit I–III, and Cladocera), and secondary consumers (mature Cyclopidae). Maximum numbers and biomass were observed in autumn in the channels (93,000 specimens/m^3, biomass 1.00 g/m^3). The most abundant species belonged to the family of Cyclopidae. High Crustacean numbers and biomass were also noted in summer in the dead channel Charonda due to favorable conditions. In the channels Rotatoria and Copepoda prevailed, while Copepoda and Cladocera dominated in the former riverbed. Species composition of zooplankton was quite stable throughout seasons.

Macroinvertebrates. Macroinvertebrates comprised 82 species in the bottom sediments. In total 124 species were found, including periphytic forms and species associated with higher aquatic plants (18 taxonomic groups). Chironomidae larvae were the most diverse – 43 species. They were followed by Molluska (Gastropoda – 28 and Bivalvia – 4 species). Other taxonomic groups were significantly less diverse as Oligochaeta – 5, Hirudinea – 3, Isopoda – 3, and Gammaridae – 1 species. Besides Chironomidae larvae, among Insecta were found Trichoptera larvae – 8, Diptera larvae – 7, Odonata larvae – 4, Heteroptera and Coleoptera – 2 each, Culicidae – 1, Ephemeroptera nymphae – 7, and Plecoptera nymphae – 1 species. Maximum species richness was noted in the Charonda-Latoritsa channel (46 species). Somewhat less (about 40 species) richness was found in the Charonda-Tysa and Upper-Sernianskiy channels and former riverbed Charonda. Minimum species richness was noted in the drying channel Charonda-Sypa (only 8 species), which featured also minimum abundance: only Oligochaetes were found (density less than 100 specimen/m^2). In all channels density and biomass of macroinvertebrates varied within wide limits, most likely due to seasonal dynamics of aquatic vegetation. Thus, in the Charonda-Latorytsia channel macroinvertebrates in summer amounted to 1600 specimen/m^2, while in autumn, when plants were bent to the bottom, the number increased to 3800 specimen/m^2.

Ichthyofauna. In the water bodies of BTPS 15 fish species of 6 families were found. Among them Cyprinidae: *Scardinius erythrophthalmus* (Linnaeus, 1758), *Carassius auratus gibelio* (Bloch, 1782), *Rutilus rutilus* (Linnaeus, 1758), *Abramis brama* (Linnaeus,1758), *Leuciscus cephalus* (Linnaeus,1758), *Abramis sapa* (Pallas, 1814), *Leuciscus idus* (Linnaeus, 1758), *Abramis ballerus* (Linnaeus, 1758), *Aspius aspius* (Linnaeus, 1758), *Chondrostoma nasus* (Linnaeus, 1758); Ictaluridae: *Ictalurus nebulosus* (Le Sueur, 1919); Esocidae: *Esox lucius* (Linnaeus, 1758); Percidae: *Perca fluviatilis* (Linnaeus, 1758); Odontobutidae: *Perccottus glenii* (Dybowski,1877); Centrarchidae: *Lepomis gibbosus* (Linnaeus, 1758). In the catches dominated *Rutilus rutilus, Scardinius erythrophthalmus, Ictalurus nebulosus.* In the considered water bodies four invasive fish species were found (*Perccottus glenii*, *Ictalurus nebulosus, Lepomis gibbosus* and *Carassius auratus gibelio*). Not any species of the Red book of Ukraine was noted. In the Charonda-Tysa channel 14 fish species were caught, in the Charonda-Latoritsa channel – 9, in the Charonda former riverbed – 5. Such distribution was driven by the oxygen regime in the water bodies of BTPS. The technical regulation of the channels may be favorable to disperse invasive fish species into other water bodies of the Tysa River Basin.

4 Discussion

In general, the hydrobiological studies of the BTPS water bodies showed a pronounced development of biota and high biological diversity of the aquatic organisms. Primary assessment of the habitats and general features of the biotic communities were used for the further assessment of the ecological status of the water bodies. Such analysis was carried out on the basis of “field protocols” and sample processing (Afanasyev, 2006). Hydrobiological studies were directed to the determination of the actual status of water bodies in BTPS and a general ecological analysis of the region. This enabled to establish type-specific characteristics of the biological quality elements for each water body in terms of water quality, benthos community structure and biodiversity. The biological reference conditions for the water bodies of BTPS were established as shown in Table 1.

Table 1. *Reference biological parameters for different types of natural water objects BTPS*

Characteristics	Rivers		Lakes	
	Small lowland rivers, siliceous geology	Medium sized lowland rivers, siliceous geology	Dead channels with hydraulic connection	Totally isolated dead channels (former riverbeds)
BLOCK 1 – Water quality (bioindication of water quality)				
Trent Biotic Index (TBI)	*7*	*7*	*8*	*6*
Saprobity, phytoplankton,	*1.6*	*1.6*	*1.7*	*1.8*

zooplankton				
Trophic state	mesotrophic	mesotrophic	mesotrophic	eutrophic
BLOCK 2 – Structure of bottom invertebrates communities (*groups indicative and specific for reference conditions*)				
Species number	*Plecoptera >1 Ephemeroptera – 4 Trichoptera – 4 Odonata – 3 Gastropoda – 5*	*Plecoptera – 2 Ephemeroptera – 5; Trichoptera – 5 Odonata – 3 Bivalvia – 1 Gastropoda – 7*	*Plecoptera >1 Ephemeroptera – 4 Trichoptera – 3 Odonata – 3 Bivalvia – 1 Gastropoda – 7*	*Ephemeroptera – 3 Trichoptera – 5 Odonata – 5 Gastropoda – 5*
BLOCK 3 – Biodiversity *(indicative and specific for reference conditions, endemics and protected species)*				
Rare and protected plant and animal species	*8*	*10*	*10*	*12*
Native fish species	*6*	*10*	*3*	*2*
Invasive fish species	*no*	*no*	*no*	*no*

Then, on the basis of the obtained data RQBA tables were completed (Afanasyev, 2001). The assessment was carried out by comparison of characteristics in the columns „actual status" and „target status" (i.e. reference conditions) using the following classification: 0-5% deviation from the reference means "high status", 5–35% deviation means "good status", 35-65% deviation means "moderate status", 65-95% deviation means "poor status", and 95-100% deviation means "bad status" (Afanasyev, 2006). Furthermore, the general assessment includes unpublished data observed by Prof. O. Obodovskiy, Dr. O. Yaroshevich, and Dr. O. Konovalenko on hydromorphological assessment, and by ing. Eduard Osiyskiy on hydrochemical assessment. Table 2 provides the ecological status/potential of the water bodies of BTPS.

Table 2. *Classification of the ecological status/potential of the water bodies of BTPS*

Objects	Integrated hydro-morphology	Hydrochemistry		Hydrobiology, integrated	Ecological status/potential	
		Oxygen, organic matter	Nutrients			
Channel Charonda-Sypa	AWB	3	4	4	4	
Channel Charonda –Latoritsa	AWB	3	3	3	3	
Channel Charonda –Tysa	AWB	2	2	2	2	
Channel Upper-Sernianskiy	AWB	2	3	3	3	
Channel Low-Sernianskiy	AWB	2	2	3	3	
Lake (former riverbed) Charonda	3	3	2	2	2	

Note. According to WFD: AWB – artificial water body; colors: blue- high, green – good, yellow – moderate, orange – poor, and red – bad status. Ecological potential AWB should be indicated by the equal color/grey stripes (WFD, 2006).

Our results showed that the Charonda-Sypa channel needs urgent measures to improve the ecological potential. All considered characteristics of this water body revealed a critical state. The main reason for the low ecological potential can be seen in the periodical absence of water. The necessary improvement of water regulation should be urgently solved at international level. Although it is open whether this water course (at least the section named Sypa in Ukraine and all sections in Hungary) will be identified as heavily modified water body or as natural water body, the rehabilitation of good ecological status/potential has top-priority.

Channels Charonda-Latoritsa, Upper-Sernianskiy and Low-Sernianskiy also need improvement of ecological potential. In periods preceding excessive growth of aquatic plants, phosphorus, nitrogen and organic matter content indicated class 4 (poor). In summer critical low content of dissolved oxygen due to high mineralization and water temperature was registered (class 5 – bad), leading to the suffocation of fish and invertebrates. However, average annual value of ecological potential was “moderate”. Analysis of the biotic community structure and RQBA tables showed that in principle these water courses can be rehabilitated by clearance of their riverbeds from silt deposits and excess growth of the higher aquatic vegetation.

The Charonda-Tysa channel and lake (former riverbed) Charonda revealed a good ecological potential and status. Here Throughout seasons the hydrochemical parameters were similar to those in the above mentioned water bodies, but did not cause a depression of biota. Thus, at present these water bodies do not need expenditures for rehabilitation.

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Leaching losses with special references on nutrient dynamics from five leaf litter species in a side arm of the Danube at Gemenc floodplain, Hungary

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1 Introduction

Large river floodplains are characterised by a high diversity of biogeochemical processes (Junk et al. 1989) and are among the most endangered and diverse ecosystems in the world (Malmqvist & Rundle 2002). An important ecological function of these ecosystems is the exchange of nutrients between the water and its adjacent floodplain. The floodplain vegetation has a remarkable role in this exchange and it was also mentioned as an important element in the flood pulse concept (Junk et al. 1989).

Leaf litter originating from the vegetation of transitional areas constitutes a major part of the total allochthonous organic matter input to rivers (Chauvet 1997). Leaves can immediately enter the aquatic environment by falling straight into it (vertical contribution), or are blown in later by the wind or washed in by floods (lateral contribution) (Chergui & Pattee 1990). Once in the water they loose soluble substances, labile C, N and antimicrobial compounds trough leaching (Gessner & Dobson 1993). Nutrients released from leaves represent a notable energy source for aquatic food webs and play an important role in the metabolism and nutrient cycle of floodplain ecosystems (Gessner & Schwoerbel 1989). The release of nutrients occurs in two main steps: leaching of soluble chemical compounds and microbial mineralization of the structural components (Swift et al. 1979).

The litter breakdown rate is influenced by the intrinsic leaf characteristics (texture, chemical composition) and by the extrinsic factors such as the physico-chemical characteristics of the environment (especially the inorganic nutrients available from the water) (Taylor & Parkinson 1988).

The objective of this study was to quantify and compare the rates of mass loss and the amount of C, N, P, S released during the initial decomposition phase of five different single leaf species: oak (*Quercus robur*), elm (*Ulmus laevis*), willow (*Salix alba*), ash (*Fraxinus excelsior*), poplar (*Populus* hybrids). These trees are characteristic to Gemenc part of the Danube-Drava National Park (46º15'N 018º51'E), which is the largest (178 km^2) forested floodplain of the Danube, unique in Europe, characterised by a variety of hard and soft-wooded tree species and various floodplain habitats (Guti 2001). The hypothesis of this work was that the leaching process varies between the different leaf species and these differences may be related to the quality of leaf litter.

2 Materials and Methods

2.1 Study area and sampling design

The floodplain area of the Danube at Gemenc includes different water body types with different hydrological regime depending on their connectivity with the main arm (Guti 2001). Our study site was located at Rezéti-Holt-Duna (RDU) parapotamal type side arm (Fig. 1) with primarily running water (at 300 cm water level in the main arm, at 1478 rkm) and a current speed of 0.4-0.5 m s^{-1} at MQ. The side arm is 15 km long, 25-40 m wide, 140-400 cm deep (at mean water level) with the junction at 1488 rkm and the mouth at 1485 rkm of the

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main arm. It was originally a bend of the main arm, which was cut off in 1893-1894 in the course of river regulation; as a consequence, due to the deposition of fine suspended matter, it is gradually filling up.

Leaves were collected for decomposition studies in October 2007, immediately after abscission, and transported to the laboratory. 10 g air dried leaves were put in litter bags of 1 mm^2 mesh size and exposed in the water of the Rezéti-Holt-Duna side arm in March 2008 (Fig. 1).

The willow and poplar leaves were exposed at site 1 situated in the depositional part, and the oak, ash and elm leaves at site 2 situated in the erosional part of the side arm; because the depositional bank of the side arm is characterised by softwood (willow, poplar) and the erosional bank mainly by hardwood vegetation (i.e. ash, elm).

2.2 Chemical and statistical analyses

Three bags from each type of leaf litter were retrieved after 48 h exposition for laboratory analyses. Subsamples of decomposing leaf material were dried at 105 ºC to determine the dry mass, then combusted (550^o C, 4 h) for determination of ash content.

Organic matter (OM) content was calculated as ash free dry mass. The C, N, S concentrations were determined by elemental NCS analyser (NA-1500, Fisons Instruments), the P concentrations by spectrophotometric molybdenum blue method, after digestion with concentrated sulphuric acid.

Temperatures, oxygen saturation, electrical conductivity, pH of the water were measured in situ with Hydrolog 2100 field equipment (Grabner). The total (TOC) and dissolved organic carbon (DOC) concentrations were determined in the laboratory by TOC analyser (Elementar-liqui TOC), the NO_3^--N concentrations with DX-120 ionchromatograph (Dionex), the PO_4^{3-}-P, dissolved (DTP) and total phosphorus (TP), NH_4^+-N, suspended matter and chlorophyll-a concentrations by standard chemical methods (Golterman et al. 1978).

Analyses of variance and Pearson product moment correlation analysis of the data was performed according to Hammer et al (2001).

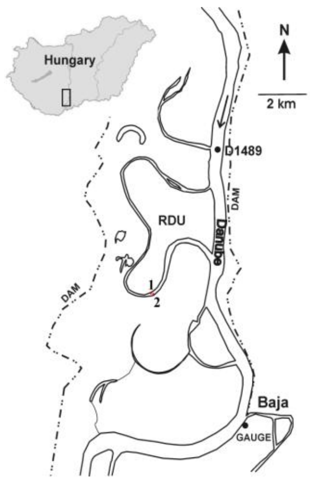

Figure 1: *Sampling sites (1 and 2) at Rezéti-Holt-Duna (RDU) side arm (Gemenc/Hungary)*

3 Results and Discussion

3.1 Environmental background conditions

The water chemistry results are presented in Table 1. During the sampling the water level of the main arm was 332-290 cm. The chemical parameters of the sampling site 1 and 2 were similar. However the NO_3^--N, PO_4-P, DTP and TP concentrations were lower in the side arm than in the main arm; also lower chlorophyll-a and suspended matter (SPM) concentrations were recorded in the side arm as compared to the main arm.

Table 1. *The main physico-chemical parameters of the water in the Rezéti-Holt-Duna side arm (site 1 and 2) and in the main arm (Danube) in March 2008*

Site	T C°	Cond. μScm^{-1}	pH	O_2 %	SPM mgl^{-1}	Chl-a μgl^{-1}	NH_4^+-N μgl^{-1}	NO_3^--N mgl^{-1}	PO_4- μgl^{-1}	DTP μgl^{-1}	TP μgl^{-1}	DOC mgl^{-1}	TOC mgl^{-1}
Danub	9.	334.0	7.5	89.	21.6	21.3	18.7	2.88	38.2	49.1	119.4	5.1	5.6
Site 1	9.	323.0	7.4	87.	10.0	11.5	71.2	2.41	22.5	45.4	79.5	4.9	5.9
Site 2	9.	328.0	7.4	87.	10.0	9.8	81.0	2.37	18.9	34.1	86.6	5.2	5.8

3.2 Mass losses

The mass loss of decomposing leaf litter was rapid: 4-26% of the initial mass was lost during the first 48 h of decomposition (Fig. 2). The loss showed a strong positive correlation with the amount of organic matter leached out (Table 3). Ash leaf litter lost the highest amount of dry mass and oak leaf litter the lowest. The poplar, willow, elm and ash leaf litter decomposed with similar rate during the leaching period: 25%, 21%, 24% and 26% of the initial dry mass was lost, respectively. These losses exceeded significantly ($p<0.05$), i. e. 6-7 times the mass loss of oak leaf litter.

The relative fast loss of dry mass and nutrients in the initial decomposition phase of the different leaf species can be explained by the rapid loss of the soluble organic and inorganic compounds. Berg & Ekbohm (1991) reported a positive relationship between the amount of substances leached out and the overall breakdown rate; this means that the litter types which release higher amounts of soluble compounds decompose faster.

According to our results leaching may account for less than 26% loss of the initial mass (except for oak: 4%), which is similar to the results of Bärlocher (2005) and Nykvist (1963) who reported a loss of about 30-33% or less.

The strong correlation between the amount of dry mass and organic matter lost (Table 3) suggest that the major part of the substances washed out were soluble organic compounds, which also support the results of Nykvist (1963) who found that about 90% of the leached compounds are of organic nature.

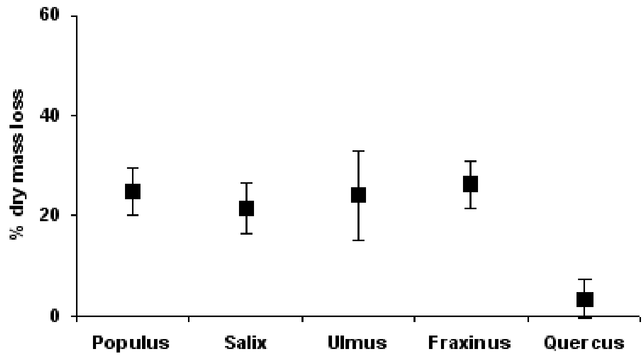

Figure 2. *The amount of mass leached out from decomposing leaf litter within 48 h. Means ± 1SE, n=3.*

3.3 Nutrients leached

The loss of C, N, P and S varied among species and the C loss of different leaf litter types followed patterns similar to the N, dry mass and organic matter losses (Fig. 3).

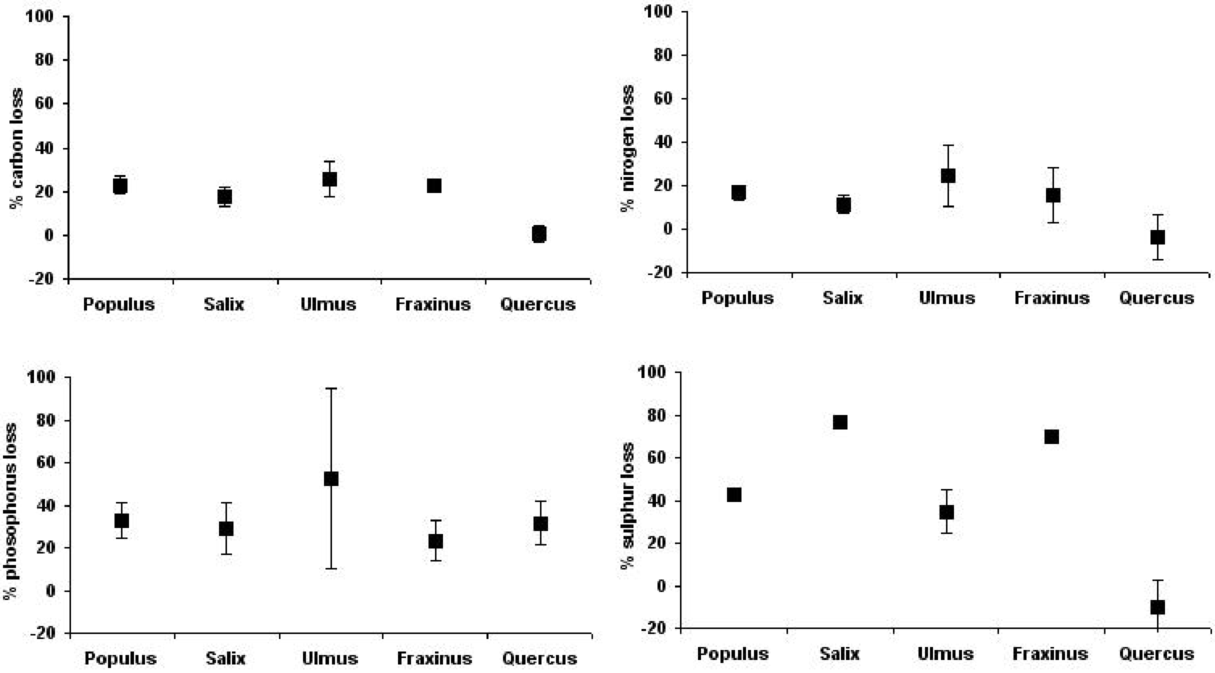

Figure 3. *The amount of C, N, P, S leached out from different leaf litter types within 48 h. Means ± 1SE, n=3.*

Substantial quantities of C, N, P and S were lost from the different leaf litter species during the leaching period (C: 18-26%, N: 11-24%, P: 23-52% and S: 34-77%) (Fig. 3), except of the oak leaf litter, where the C loss (0.8%) was significantly ($p<0.05$) lower as compared to the other leaf species, and on which N and S immobilization occurred. The decreasing order in the amount of nutrient released was: elm>poplar>oak>willow>ash for P and elm>poplar>ash>willow for N.

Accoring to Xiong & Nilsson (1997) the leaching period lasts from one day to a few weeks (regardless of leaf litter type), however several authors suggested that the leaching of soluble substances occurs within the first 24-48 hours of decomposition (Gessner & Schwoerbel 1989, Poppe et al. 1999, Bärlocher 2005); our leaching rates for 48 h are comparable with the results of other studies e.g. the percentage of N released from *Populus* leaf litter (17%) was similar to the results of Andersen & Nelson (2006), who found that *Populus* leaves lost 20% of their N content through leaching (within the first 24 h) and have an important role in the floodplain nitrogen dynamics. The nutrients derived from leaves have the potential to influence the ecosystem processes (Friberg & Winterbourn 1996).

3.4 Influence of the initial litter quality on the leaching

The initial C:N, C:P, N:P ratios of the different leaf litter types varied significantly ($p<0.05$) Table 2. The amount of dry mass lost was interrelated with the initial C:P, N:P ratio and with the amount of organic matter of the initial leaf litter, while the C:N ratio which varied from 22 in *Fraxinus* to 65 in *Populus* did not show any correlation with the amount of dry mass and organic matter washed out (Table 3). The ranges of C:N ratio (22-65) obtained in this study were similar with the ranges (20-60) reported by Chauvet (1997) for deciduous forest tree species.

Table 2. *Chemical characteristics (C, N, S, P concentrations) and quality indices (C:N, C:P, N:P molar ratio) of the initial litter. Means ± 1SE, n=3.*

	***Populus* hybrids**		***Salix alba***		***Ulmus laevis***		***Fraxinus excelsior***		***Quercus robur***	
	mean	*SE*	**mean**	*SE*	**mean**	*SE*	**mean**	*SE*	**mean**	*SE*
C [%]	**47.27**	*0.32*	**47.57**	*1.15*	**46.31**	*0.19*	**49.11**	*2.43*	**47.88**	*0.50*
N [%]	**0.85**	*0.02*	**1.97**	*0.11*	**1.21**	*0.02*	**2.66**	*0.53*	**1.40**	*0.03*
S [%]	**0.17**	*0.10*	**0.54**	*0.08*	**0.12**	*0.00*	**0.56**	*0.01*	**0.09**	*0.02*
P [%]	**0.06**	*0.01*	**0.12**	*0.01*	**0.07**	*0.01*	**0.12**	*0.01*	**0.16**	*0.03*
C:N	**64.77**	*1.09*	**28.13**	*0.85*	**44.56**	*0.51*	**21.95**	*2.99*	**39.97**	*0.56*
C:P	**2168.54**	*303.65*	**997.88**	*111.36*	**1729.00**	*375.83*	**1095.43**	*66.19*	**777.25**	*123.45*
N:P	**33.48**	*4.68*	**35.54**	*4.73*	**38.75**	*7.96*	**50.82**	*10.07*	**19.45**	*3.16*

Table 3. *Pearsons's correlations between the amounts of organic matter (OM), dry mass (DM) leached out and the initial leaf litter quality indices (C:N, C:P, N:P molar ratio) (p<0.05)*

	N:P	**C:N**	**C:P**	**DM**	**OM**
N:P	**1.00**				
C:N	**-0.39**	**1.00**			
C:P	**0.28**	**0.75**	**1.00**		
DM	**0.51**	**0.03**	**0.41**	**1.00**	
OM	**0.39**	**0.18**	**0.50**	**0.96**	**1.00**

Some studies define leaching mainly as an abiotic process (Bärlocher 2005), however biotic processes may also play a role in this initial phase of decomposition. The correlation of dry mass and organic matter with the initial C:P and N:P ratio suggests that the initial leaf litter quality influences the leaching phase of the decomposition and the biological processes in addition to physico-chemical processes. Microbial conditioning of leaf litter could be the reason for N and S immobilization in the oak leaf litter. Another explanation of the accumulation of these elements in the decomposing oak leaves may be that they are bound in complex insoluble molecules such as lignin.

4 Conclusions

In their initial decomposition phase the examined leaf litter species (*Populus, Salix, Ulmus, Fraxinus, Quercus*) contributed in different degree to the allochthonous nutrient input of the Danube side arm. Leaf species affects ecosystem functions such as nutrient cycling through their chemical composition. The differences in the amount of dry mass and nutrients released may be accounted for the differences in the initial leaf litter structure and quality. Our results may contribute to understand the interaction between the river and its floodplain, especially the contribution of the forested floodplain vegetation to the nutrient dynamics of the river and provide data for the management to optimize the maintenance of the river and its floodplains.

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Implementation of the WFD from the perspective of nature conservation: Analysis of the programmes of measures and the River Basin Management Plans of the Danube and the Elbe river basins

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Keywords: Water Framework Directive, nature conservation, river basin management plans, Danube, Elbe

1 Introduction: Links between WFD and nature conservation

Due to its ecological approach, the Water Framework Directive (WFD) interferes with nature conservation in various aspects. First of all, it sets the general target to protect and improve the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems (Article 1a WFD). The WFD considers water bodies as a whole and addresses their function as habitat for plants and animals. A direct relation to the question of nature conservation can be found in three aspects: (1) the biological quality components to determine the good status (cf. Article 4 para. 1 in conjunction with Annexes II and V WFD), (2) the inclusion of groundwater dependent terrestrial ecosystems (cf. Annexes II and V WFD) and (3) the reference to the water dependent protected areas for animals and plants and their habitats (cf. Article 4 para. 1c WFD) (Albrecht 2007, p. 481). However, the WFD does neither provide direct protection of animals and plants abundant in wetlands, such as amphibian, mammal (e.g. beaver or otter) or bird species nor wetlands as such (Petry et al. 2002, p. 12). The overlap between WFD and nature conservation is reflected in the content of the programmes of measures and the river basin management plans (RBM Plans) which had to be finalized and published by the end of 2009. Both types of plans follow the purpose to achieve the good status for surface and ground water as required in Article 4 WFD. They are to be reviewed and updated by the end of 2015 and every 6 years thereafter (Articles 11 and 13 WFD). From the perspective of nature conservation it is of interest, how its targets are connected in practice to the targets of the WFD and which possibilities exist to strengthen the influence on nature conservation. This question is addressed in the ongoing project „WFD and Nature Conservation: Analysis of the River Basin Management Plans“, which is funded by the Federal Agency for Nature Conservation of Germany. The project is carried out by the Leibniz Institute of Ecological and Spatial Development (IOER) in cooperation with the Chair in Landscape Planning at the University of Technology of Dresden. Basis of the analysis are assessment criteria to be derived from a comprehensive study of the plans existing in Germany regarding their contents and level of detail, but also from relevant literature and best practice examples. On this background it will be investigated which recommendations can be given for emphasizing the aspects of nature conservation in the practical implementation of the plans. Moreover, proposals for strengthening the concerns of nature conservation will be made for the scheduled revision of the plans in 2015. The

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present contribution to the IAD-Conference will show first results of the project with special focus on the Danube and the Elbe RBM Plans.

2 Content of the programmes of measures and river basin management plans

The content of the programmes of measures and the RBM Plans is designated in Articles 11 and 13 WFD. Both plans form the basis for a coherent, all-embracing management concept for river basins. While the RBM Plans reflect the whole planning process in the river basin (cf. Annex VII WFD), the programmes of measures set out the actions to be taken during the plan period to attain Directive objectives. Both the programmes of measures as well as the RBM Plans contain a number of connections to nature conservation. There is, firstly, the data collected in the context of the initial characterization designated by the WFD (analysis of the characteristics of the river basins, review of the impact of human activity on the status of surface waters and on groundwater, protected areas according to Article 6 and Annex VI WFD). From the perspective of nature conservation, especially information on terrestrial ecosystems, with which the groundwater body is dynamically linked, is relevant, as well as information on areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor (including relevant Natura 2000 sites). In order to establish a coherent and comprehensive overview of water status within each river basin district, a map of monitoring networks and the results of monitoring programmes are included in the RBM Plans (Art. 8 WFD). In addition, RBM Plans list the specific environmental targets for the individual water bodies as well as exemptions according to Article 4 WFD and summarize the content of the programmes of measures. The setting of the targets, the respective exemptions and the determination of the derived measures provide the largest room for maneuver to optimize management planning from the perspective of nature conservation. Those measures should be selected and prioritized which correspond to both the targets of the WFD and nature conservation, e. g. the creation and restoration of wetlands areas (cf. Article 11 and Annex VI Part B WFD). In contrast to the RBM plan, the programme of measures is subject to strategic environmental assessment (SEA) that has to show which significant impacts on fauna, flora, biodiversity and various other environmental issues have to be expected. Furthermore, the RBM Plans contain a register of more detailed programmes and management plans for the river basin district dealing with particular sub-basins, sectors, issues or water types. Thus, it is easier to harmonize parallel planning documents, for instance special programmes for river meadows or flood risk management plans. Last but not least, a list of competent authorities and a summary of the public information and consultation measures taken are included in the RBM Plan (cf. Article 14 WFD). Here, it is important to consult nature conservation authorities, NGOs and other institutions in the process of planning, as it is their concern to emphasize issues of nature conservation.

3 Implementation of the plans in the international Danube and Elbe River Basin district

Article 3 WFD stipulates transboundary river basin management from headwaters to estuary. The Danube River Basin as well as the Elbe River Basin are international river basin districts, so that cooperation is needed between various domestic and foreign authorities. Whereas the Elbe River Basin district covers the territory of only 4 states, there are 19 states sharing the river basin district of the Danube (8 out of them are non-EU members). In order to secure and facilitate coordination, the WFD requires the administrative authorities of a river basin district to establish appropriate administrative arrangements for such coordination. The responsibility for coordination is by the International Commission for the Protection of the Danube River (ICPDR) and the International Commission for the Protection of the Elbe River (ICPER), respectively. The obligation for coordination applies explicitly to the establishment of RBM Plans (cf. Article 13 para. 3 WFD). The plans are based on three levels of coordination: Part A: the international, basin-wide level (Roof level); Part B: the national level (e.g. German territory of the Elbe River Basin) and/or the internationally coordinated sub-basin level for selected sub-basins (e.g. Tisza, Sava, Prut and Danube Delta); and Part C: the sub-unit level, defined as management units in the national territory (ICPDR 2009, p. 1). The information of the plans increases in detail from Part A to Parts B and C. In the Danube and Elbe River Basins, there has been set up one international RBM Plan each coordinated by the ICPDR and the

ICPER, respectively. Regarding Parts B and C, further management plans for parts of the river basin district or sub-basins have been established which are coordinated by various institutions on the international or national level. For example, there is one common plan of the 10 federal states which share the German part of the Elbe River Basin district, coordinated by the River Basin Community Elbe. In contrast, the German part of the Danube River Basin district is shared only by 2 federal states (Bavaria and Baden-Württemberg), so that there is no common plan for those states. However, they have coordinated their individual planning by a so-called Chapeau-chapter (Baden-Württemberg) or a coordination document (Bavaria), respectively. The comparison of the planning documents of the Danube and Elbe River Basin districts reveal a lot of similarities, but also some differences. Regarding the content, the RBM Plans follow widely the structure given by Annex VII WFD. The A-level-plans contain mainly information on problems and measures of water management, which have to be discussed and coordinated river basin-wide (ICPER 2009, p. 97 et seq., ICPDR 2009, p. 73 et seq.). From the viewpoint of nature conservation is important, that the Danube and the Elbe RBM Plans both discuss the ecological continuum of rivers and the restoration of floodplains as target of basin-wide importance (ICPER 2009, p. 97, ICPDR 2009, p. 73 et seq.). The reconnection of adjacent disconnected wetlands and floodplains is treated with high priority in the Danube RBM Plan. It is emphasized, that those areas should be maintained or offset wherever possible ("no-net-loss-principle") (ICPDR 2009, pp. 21 and 81). Wetlands and floodplains with reconnection potential are listed and located in a map (cf. ICPDR 2009, Map 6). For detailed information, the plans usually refer to the plans of the B- and C-levels.

4 Analysis of the plans and programmes from the perspective of nature conservation

In general, many synergetic effects for nature conservation can be expected by the WFD objective to achieve the good ecological status and to protect water dependent ecosystems. Nevertheless the question remains, how far the potential of the WFD for nature conservation has been realized within the planning process, especially with regard to the selection and prioritization of measures. Furthermore, also conflicts in detail are expected, which are to be solved. To submit proposals for strengthening the concerns of nature conservation regarding the implementation and the revision of the plans, the following research topics are considered:

River basin management planning and the objectives of nature conservation in general: To which extent will the implementation of the measures cause synergies or conflicts to particular objectives of nature conservation given by Section 1 German Federal Nature Conservation Act? To clarify this, the measure types brought out by LAWA (the working group of the federal states on water issues in Germany) have been graded in 20 groups of similar cause and effect relations. Those groups are confronted with the particular objectives for the different environmental goods designated in Section 1 Nature Conservation Act. Whereas about one half of those measure groups exhibit a high degree of conformity or neutral impact on the other environmental goods, the other half requires an adjustment on following planning levels because conflicts with the objectives for the other environmental goods might arise depending on the concrete spatial situation. For instance, by measures for habitat improvement in waters by water course modification, very favorable effects can be expected on enabling the exchange of populations. At the same time, these measures can provoke impairment on areas of historical cultural landscapes. An as early as possible coordination between representatives of water management and nature conservation as well as a raising of awareness for the interdependence of all environment goods are essential for the optimization of the results within the implementation process till 2012.

River basin management planning and Natura 2000: Furthermore, the degree of conformance of WFD management planning with conservation objectives of NATURA 2000 areas has to be investigated. In parts, different directions of objectives can arise, because the ones of the WFD are normally process oriented and the ones of EC Habitats Directive have objectives of literal conservation in addition to process protection (Hübner 2007, p. 9). By a confrontation of water dependent species and habitat types of the Habitats Directive abundant in Germany plus their requirements and the impact factors of the LAWA measure types, the necessity for further coordination in case of certain species presence can be indicated and pointed out. Overlaying the areas concerned by those measures and the Natura 2000 sites with relevant species and habitat types in Germany, this necessity of coordination can be spatially defined. This can particularly give hints for nature conservancy, where conflicts of objectives have to be internally solved, concerning which species/habitat types are to be supported in certain spatial situations. This is relevant for practical implementation as well as for the following revisions of the management plans.

River basin management planning and the ecological network: As another important subject from the point of view of nature conservation, the conformance of WFD management plans with the objectives of the ecological network is to be explored. Rivers themselves, and especially their floodplains, if intact, are important transboundary network elements. Although floodplains are not literally mentioned in the WFD, they are of vital importance for the maintenance or achievement of the good status of the water body (Korn et al. 2005, p. 18). A development implemented for that reason can bring essential contribution for the transposition of the national ecological network. Therefore, it has to be clarified, how the WFD management plans are methodically laid out concerning the delineation of surface water bodies and prioritization of measures. By overlaying maps of relevant measure types such as “Initiation/allowing of a dynamic natural development of surface waters” or “Support of natural retention (including inland moving of dykes and dams)” and maps of current loss of floodplain structures, the synergistic effect for the national ecological network can be estimated. This implies important strategic foundations for politics, water management and nature conservation concerning the next cycle of WFD management planning.

River basin management planning and floodplains: The knowledge developed in this research module helps to clarify, to which degree the present WFD management plans exhaust the potentials for the protection and development of floodplains as hotspots of biodiversity in Central Europe. In fact, floodplains are of greatest importance for the protection of species as well as for the protection and the development of biodiversity, and as mentioned above, they are of vital relevance to achieve the good ecological status of the surface water body, too. Given the problem of space availability, it seems that space encompassing measure types for floodplain development are considered with hesitance within the first cycle of WFD management planning. As an example, in 22 of 61 planning units of the FGG Elbe the measure type “Measures for improvement on habitats in the corridor of river development including floodplain development” is basically not intended (FGG Elbe 2009, Annex A3-1, p.4). For the next cycle of management planning the floodplains should be consistently included in the consideration of water bodies and literally more space should be given to rivers. To that topic the political discourse has to be carried on.

River basin management planning and groundwater dependent surface ecosystems: It is questioned, to which extent the current WFD management planning respects the capabilities for protection of groundwater dependent ecosystems and wetlands. In addition to this protection generally claimed by Article 1a WFD the state of directly groundwater dependent ecosystems is used as a criterion for the quantitative status of the connective groundwater bodies in the WFD. According to Annex II WFD, the groundwater bodies with directly dependent ecosystems had to be designated within the so-called initial characterization. In case of risk of impairment, also the associated surface ecosystems have to get an inventory (cf. Annex II No. 2.2 WFD). These regulations are implemented in different ways by the German states. For instance, Bavaria assumes a minimum size of 50 ha (LfW 2005: p. 52), Baden-Württemberg of 5 ha (LfU 2005, p. 90) and Saxony of 20 ha (SMUL 2005, p. 34), respectively, for assessable groundwater associated ecosystems. Crucial questions of research refer to the delineation practice of regarded groundwater bodies, the definition and identification of considered ecosystems as well as to concepts of monitoring for the assessment of status changes of the affected ecosystems. Appropriate procedures from the nature conservation point of view can be used as good practice examples for the second cycle of WFD management planning.

5 Conclusions and Outlook

It has been shown that the management plans contain a variety of connectors which can be used to take into account the concerns of nature conservation in a proper way. The protection and restoration of floodplains and wetlands is a key factor in this respect. Indeed, the plans contain measures relating to those areas. However, the plans remain vague especially as far as the measures are concerned. Thus, it is difficult to link the statements of the plan to specific areas. Furthermore, the degree of detail varies considerably between the individual plans. This makes it difficult to derive improvement options. A more uniform approach to setting up the plans as well as a higher degree of detail for the contents relating to nature conservation would be beneficial. However, many questions can be addressed only at stage when the plans are actually applied. It is important, therefore, to make the water authorities sensitive to the concerns of nature conservation and to encourage them to consult with the nature conservation authorities in an early stage of putting the plans in action.

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Spatial variability of heavy metal pollution in groyne fields of the middle Elbe – implication for sediment monitoring and risk assessment

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Keywords: Elbe, sediments, transport, heavy metals, monitoring strategies

1 Introduction

Many European rivers like Danube, Elbe and Rhine have been regulated by engineering works for navigation and bank erosion protection. Regulating cross structures along the river banks, so called groynes, concentrate the discharge on the middle part of the river channel and hence, provide higher water level for navigation during low discharge periods. During low water level suspended material is being trapped in the slowly flowing water of the groyne fields and partly deposited whereas sediments can be re-suspended during high water stage (Ockenfeld & Guhr 2003). The German part of the Elbe River has a length of about 730 km, approximately 485 km of this stretch being regulated by about 6900 groynes field elements. Beside groyne fields, floodplains of about 800 km^2 are the main morphological features of the middle part of the Elbe River.

In the past, organic and inorganic pollutants have been discharged into the river system and are still present in deposited sediments due to historical contamination by industrial and municipal activities in the river basin (Heise et al. 2008). However, the water quality of the Elbe River and its tributaries improved considerably within the last two decades (Lehmann & Rode 2001; Zerling et al. 2003; Klemm et al. 2005; Guhr et al. 2006) comparable to other European rivers (Vink et al. 1999). Remobilization of deposited contaminants is a key issue for the river sediment management because of its impact on river ecology. Erosion, dispersion and re-deposition of groyne field sediments are important processes for environmental risk assessment. Hence, pollution sources must be explored and knowledge about erosion stability of fine contaminated sediments must be available to foster a sustainable development of the river system. As shown by Haag et al. (2001) and Gerbersdorf et al. (2007), cohesive sediment stability is characterized by high variability as depending on physico-chemical and biological properties. To assess the spatial variability of the heavy metal pollution of Elbe groyne field sediments, investigations considering horizontal and vertical gradients were performed.

2 Study area and methods

A groyne field, representative for the middle part of the Elbe River, located at rkm 319.5, left bank (nearby Magdeburg), was chosen as study area. The sediments are influenced by polluted discharges of industries located upstream and the input of two major tributaries, Mulde and Saale. The groyne field area is about 1034 m^2.

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Since 2005 several investigations have been performed at this site in order to quantify the sedimentation/erosion dynamics (Prohaska et al. 2008). The results show high spatial heterogeneity of sediment quality and quantity in the observed groyne field, depending on the sampling spot, sediment layer and the sampling season.

In June 2008 an additional sediment sampling campaign took place at mean discharge. Depth profiles of critical erosion shear stress ($\tau_{crit,e}$), heavy metals and arsenic concentrations were investigated. Two parallel undisturbed sediment cores (10 cm diameter) up to 50 cm length were taken at 12 spots in the groyne field (Figure 1).

The critical erosion shear stress was measured in a laboratory channel, so called SETEG system (Kern et al. 1999). Heavy metals and arsenic concentrations were measured in sediment samples sieved < 2mm. After freeze-drying of the sieved samples, the bulk material was ground, pressed to pellets and finally analyzed by means of both energy- and wave length dispersive X-ray fluorescence analysis (EDXRF: XLAB2000, Spectro Instruments and WDXRF: S4 Pioneer, Bruker-axs). Detailed information on the methodology such as sample preparation, matrix influence and correction, precision and recovery are given in Morgenstern et al. (2004, 2005). The capabilities of different analytical techniques for the analysis of heavy metals in solid and liquid samples are discussed in Wennrich et al. 2004. In a former study (Morgenstern et al. 2008) it was shown, that for the analytical method used, most of the variability of the analytical results (97-99% of the total variance) arose due to the location variance resulting from true concentration differences between individual sampling sites. Estimates for the relative measurement uncertainty (caused by both analytical- and sampling variance) on the other hand amount to 2.5 % for As, 12 % for Cd, 2 % for Cu, 4 % for Cr, 12 % for Hg, 4.5 % for Ni, 1.5 % for Zn, 2% for Pb and 15% for U. Each uncertainty was obtained from a 95% prediction interval and analyte concentrations sufficiently beyond of the detection limit.

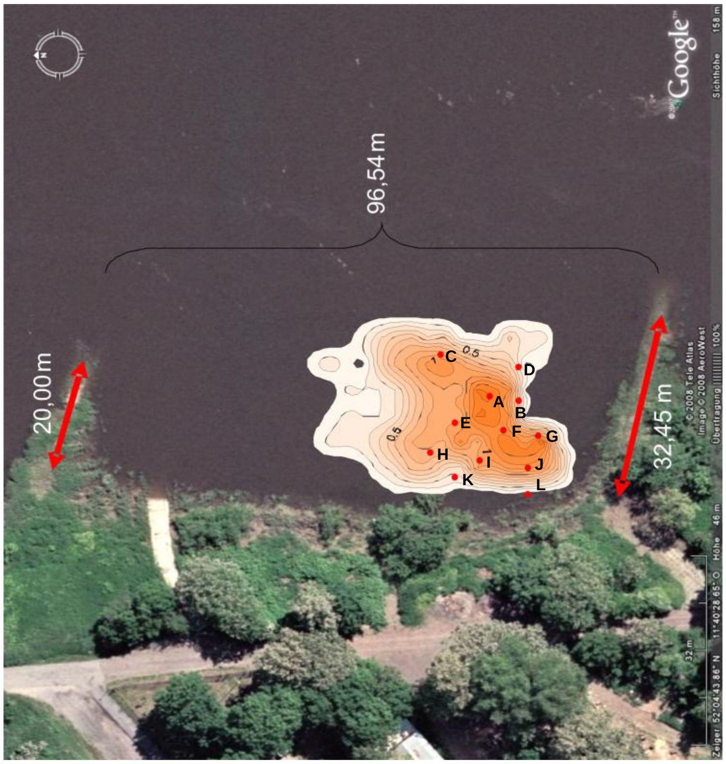

Figure 1. *Topography of the fine sediment deposits within the groyne field (contour lines given in meters) with position of sampling sites*

3 Results and discussion

According to morphological and changing hydrological conditions, the groyne field sediments in the middle part of the Elbe are characterized by varying fine and coarse material layers of different thickness. Expectedly, the critical erosion shear stress $\tau_{crit,e}$ shows a high variability, ranging from 0.3 up to 13.4 Pa. The heavy metal concentrations also show large vertical gradients in each of the cores: the median values of the 12 sediment cores at different depths are displayed in Table 1. The top sediment layer (0-10 cm), representing recently deposited, non-consolidated material, is less polluted compared to deeper and older sediment layers, proving the decreasing trend of the contamination; a more detailed overview of particulate arsenic contamination is shown in Figure 2. Beside the vertical variability, the graphs presented in Figure 2, demonstrate also a high spatial variability of the sediment composition.

Table 1. *Median concentration and range (minimum-maximum) of heavy metals and arsenic of sediment layers in different depth (in mg/kg)*

Depth	As	Cd	Cu	Cr	Hg	Ni	Zn	Pb	U
0-10 cm	33	6	88	101	2	38	999	99	1
	(15-267)	*(1-24)*	*(30-525)*	*(41-350)*	*(1-25)*	*(11-95)*	*(249-2120)*	*(36-476)*	*(1-21)*
0-20 cm	73	13	322	244	18	75	1402	188	8
	(15-269)	*(1-24)*	*(30-553)*	*(41-385)*	*(1-78)*	*(11-102)*	*(249-2228)*	*(36-520)*	(1-45)
0-30 cm	114	18	377	274	19	83	1598	270	13
	(15-343)	*(1-24)*	*(30-553)*	*(41-385)*	*(1-149)*	*(11-102)*	*(249-2407)*	*(36-568)*	(1-69)
Whole core	118	18	400	283	21	84	1658	271	13
	(15-343)	*(1-24)*	*(30-553)*	*(41-385)*	*(1-149)*	*(11-102)*	*(249-2407)*	*(36-568)*	*(1-69)*

Because of the high vertical variability, sediment monitoring must capture not only surface sediments but also deeper layers. As shown in Table 1 and Figure 2, monitoring based on sampling and analyzing surface sediments allows only assessing the environmental impact of discharges causing an erosion depth of less than 10 cm, while the level of uncertainty could be high for discharge events with higher shear stress. Monitoring for environmental risk assessment must be based on data about erosion threshold and contamination up to an anticipated erosion depth. Since environmental risk increases with erosion potential of discharge and contamination level, risk reduction for downstream river stretches, floodplains, coastal area and the sea can be achieved by considering the mobility and bioavailability of deeper contaminated layers of sediments. These are important aspects for the prioritization of sediment management measures targeted to achieve a good ecological status of the water bodies in the river basin.

4 Outlook and conclusions

With respect to remediation projects which are required to achieve the implementation of the EC Water Framework Directive (WFD), appropriate monitoring of sediment and water quality is necessary to assess the efficiency and success of measures. To reduce the uncertainty level, optimization of monitoring strategies is recommended. A first model based approach has been developed to estimate the sediment erosion in groyne fields along the River Elbe in terms of statistical values (Prohaska et al. 2008). Field and laboratory investigations are expensive and model simulations are complex. Therefore, complementary to erosion measurements, tailor-made monitoring of water quality during flood events at river basin scale may be an alternative. Monitoring efficiency can be enhanced by appropriate design of measuring campaigns focusing on erosive discharge events, when remobilization of contaminated sediments is expected (Baborowski et al. 2004); concerted actions together with the Federal State Authorities and the main stakeholders are advisable (Baborowski et al. 2008).

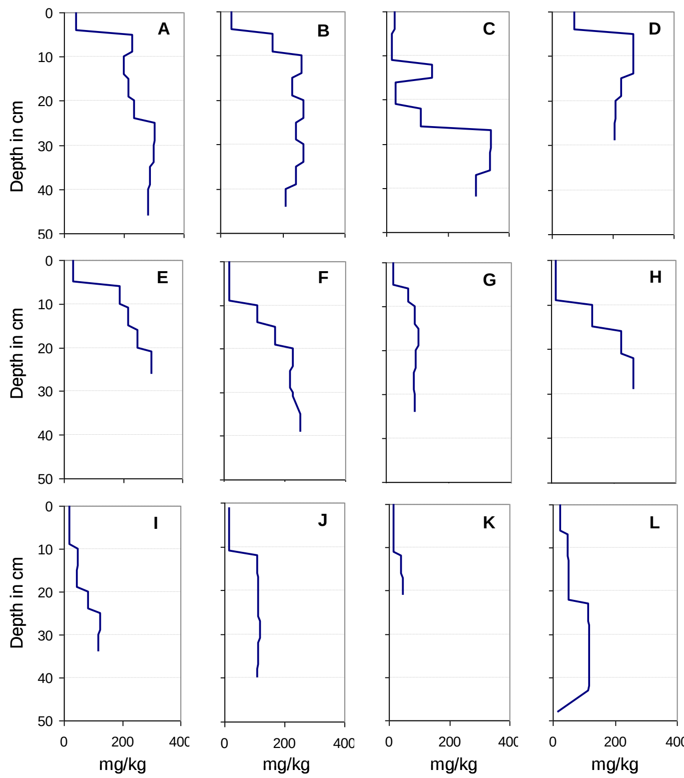

Figure 2. *Horizontal and vertical variability of arsenic concentrations in the cores from the considered groyne field*

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Spatial patchiness and similarity of macrophyte assemblages along a cut-off channel of the river Danube in Linz (Austria)

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Keywords: floodplain, stream, aquatic plants, species richness, Bray-Curtis similarity

1 Introduction

Aquatic macrophyte communities play a key role in aquatic ecosystems, structuring the water column, stabilising the substrate, providing microhabitats for other aquatic biota and contributing to the oxygen and carbon budget of the water body (Haslam 1978, Janauer & Dokulil 2006). They change in a more dynamic way than terrestrial vegetation as their habitats in lakes, rivers and wetlands are highly variable ecosystems. Extensive data collection on macrophyte distribution and floristic composition is indispensable for better understanding the factors mainly causing the variability among these aquatic plant assemblages. Several previous studies worldwide have focused on temporal changes in macrophyte assemblages (Kohler et al. 1994, Champion & Tanner 2000, Veit & Kohler 2003, Otahel'ová et al. 2007 and others). However, few studies exist on exact spatial changes in macrophyte communities and species composition in streams as exemplified by Kohler et al. (2003) and Tremp (2007). Among physical and chemical parameters, varying flow conditions associated with changing substrate types along the watercourse are seen as most influential abiotic factors shaping the structure of macrophyte assemblages (Baattrup-Pedersen & Riis 1999). This study aims to investigate the spatial distribution pattern of macrophyte communities along a lotic cut-off channel of the River Danube in Linz, Mitterwasser (Upper Austria). It represents one of the most precious aquatic habitats in Upper Austria and is part of the 'Natura 2000' protected area 'Traun-Donau-Auen' in Linz, despite the fact that the hydrology of the Traun-Danube floodplain and its watercourses was radically changed in the course of river regulation and power plant construction.

2 Study site, materials and methods

Study site: At the upstream end of the Mitterwasser, the "Weikerlsee" gravel pond feeds groundwater to the system (Fig. 1). Direct inflow of the Danube to the upper end of the floodplain was terminated by Danube river regulation and the construction of the hydroelectric power plant Abwinden Asten and its protective levee in the late 1970s. Thus, the Mitterwasser is mainly fed by groundwater and seepage water from the reservoir, which results in high water transparency. The field survey was conducted in the upper part of the Mitterwasser, which is located far from Danube backflow influence and hardly affected by even extreme flood events (Strausz & Janauer 2007).

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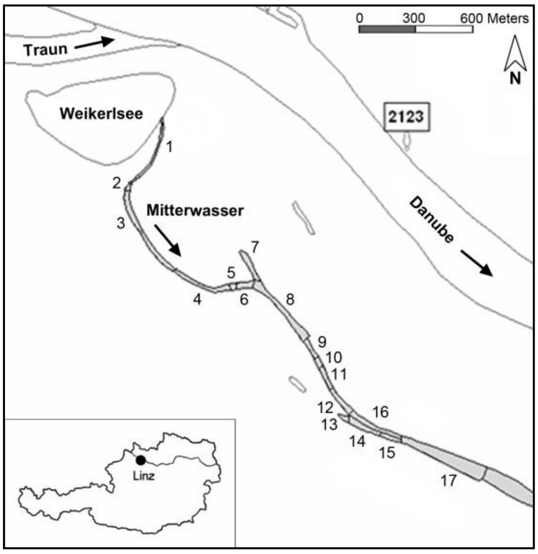

Figure 1. *Study site. The investigated part of the Mitterwasser is subdivided into contiguous survey units (labeled with numbers).*

Field survey: The aquatic plant survey including charophytes, aquatic bryophytes and vascular plants, was conducted four times a year during the vegetation periods of 2001 and 2002 (March to September) and followed the methodology of Kohler & Janauer (1995). This method is commonly applied in Europe for assessing the aquatic vegetation for EU-Water Framework Directive, and complies with the European Standard EN 14184 (European Council 2003). The investigated section of the Mitterwasser was subdivided into 17 contiguous and ecologically homogeneous individual survey units (SU, Fig. 1). For each SU, the abundance of macrophyte species was estimated using the 5-level estimator scale (Kohler Plant Mass Estimate values, PME), which comprises both the area and the vertical development of the plant stands. The ordinal measures of PME range from 1 (rare), 2 (occasional), 3 (frequent), 4 (abundant) to 5 (very abundant). Vegetation samples were taken with the aid of a small anchor and a rake with extendable handle, respectively. Macrophyte identification was based on Casper & Krausch (1980, 1981) and Fischer et al. (2005) for vascular plants, Frahm & Frey (1992) for bryophytes and Krause (1997) for charophytes. Survey unit lengths were derived from a GIS based map; substrate type, flow velocity and water temperature assessment had largely been described elsewhere (Strausz & Janauer 2002, Strausz et al. 2006, Strausz & Janauer 2006).

Data analysis: For statistical use, ordinal scaled PME values were transformed into quantitative data following Janauer & Heindl (1998). Plant species occurring in only one survey unit during the whole investigation period were removed from the data matrix as they produced only negligible biomass. The persistence in the macrophyte species composition and abundance was calculated as Bray-Curtis similarity between each pair of successive survey units using software package PRIMER 5 for Windows. For illustrating floristic changes along the Mitterwasser, species turnover rates were calculated as described for streams in the Rhine floodplain (Tremp 2007): the number of species only occurring in a survey unit was added to the number of species only occurring in the successive downstream survey unit; the sum was divided by total species number of both survey units. The resulting index is scaled between zero and one and indicates from floristic equality (zero) to no species in common (one).

3 Results

During the eight field surveys, altogether 54 aquatic plant species were recorded in the Mitterwasser. Of these, 9 rare species producing only negligible biomass were removed from the data matrix. The majority of the remaining 45 species grew submerged; *Iris pseudacorus* L., *Phalaris arundinacea* L. and *Phragmites australis* (Cav.) Trin. ex Steud. occurred as helophytes.

Highest species numbers were recorded downstream in SU17 with a mean of 24 species, followed by SU8 (15 species) and SU15 (14 species). Lowest species numbers were recorded upstream in SU1 (2 species, Fig. 2).

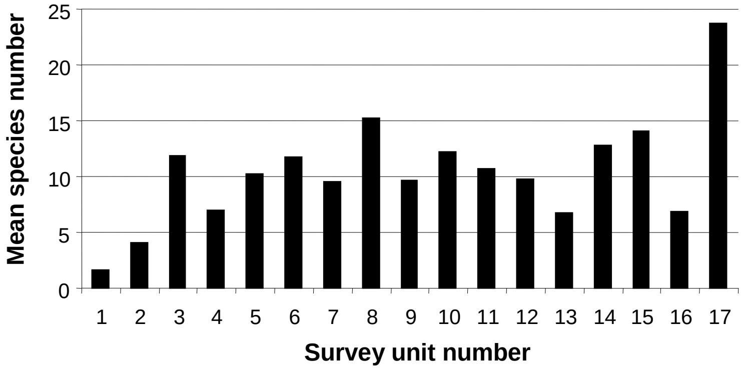

Figure 2. *Mean species numbers per survey unit in the Mitterwasser over the investigation period 2001 and 2002.*

Floristic heterogeneity was highest at the source of Mitterwasser (SU1-2: turnover 0.65), while floristic unification increased over the length of the stream course and slightly decreased downstream again (SU12-16: turnover 0.35, SU16-17: turnover 0.42; Fig. 3).

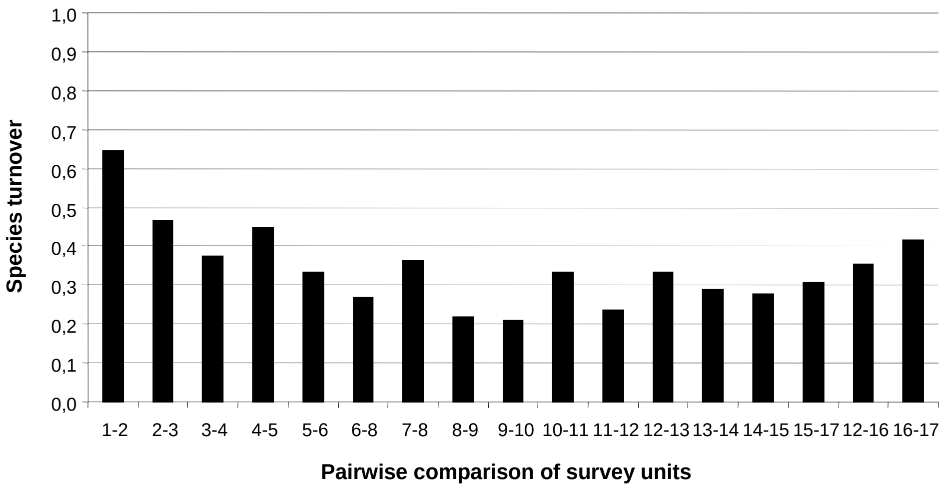

Figure 3. *Turnover rates of macrophyte species assemblages in consecutive survey units in the Mitterwasser over the investigation period 2001 and 2002 (1: the SU have no species in common, 0 = all species are identical).*

Average Bray-Curtis similarity between macrophyte assemblages in consecutive survey units showed four peaks and five minimum values (Fig. 4): Highest similarity values occurred mainly between SU with low flow velocities (<0.10 ms^{-1}) and fine sediment layer, as between SU3-4 (69%), SU6-8 (57%) and SU14-15 (59%) and refer to lower species turnover rates. Maximum similarity (74%) between SU11-12 represents an exception as SU11 was mainly dominated by gravel and mean flow velocities of 0.47 ms^{-1}, while SU12 was mainly dominated by finer sediments and flow velocities around 0.10 ms^{-1}.

The five lowest Bray-Curtis similarity values between SU1-2 (7%), SU4-5 (27%), SU7-8 (25%), SU12-13 (29%) and SU16-17 (36%) correspond well with the higher species turnover rates in these pairs of survey units. Flow velocities and substrate types in successive survey units changed between SU1 (0.31 ms^{-1}, gravel) and SU2 (0.06 ms^{-1}, mud) as well as between SU4 (0.05 ms^{-1}, mud) and SU5 (0.46 ms^{-1}, gravel). The other mentioned survey units (SU7-8, SU12-13 and SU16-17) were all dominated by muddy sediment and very slow flow velocities (<0.10 ms^{-1}). SU7 and SU13 are shallow oxbows with stagnant water and higher mean water temperature. All in all, similarity increases over the whole investigation period (Fig. 4, trend line with R=0.25).

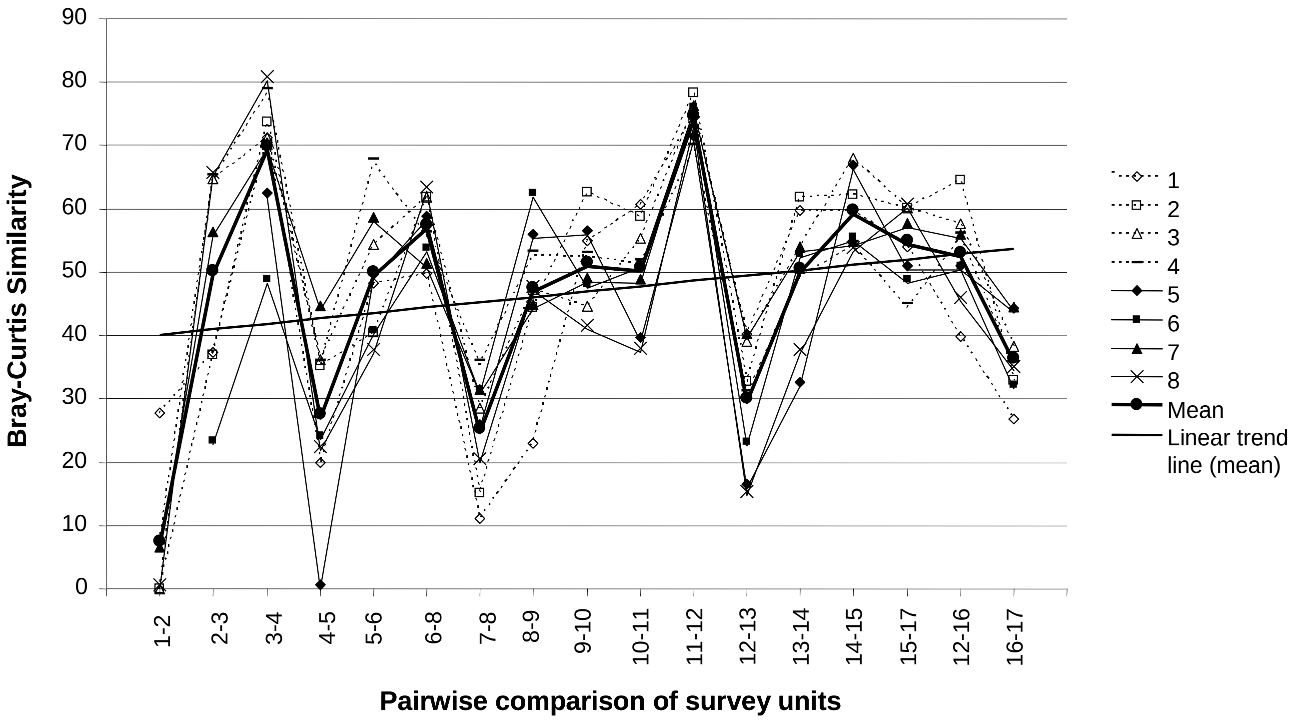

Figure 4. *Bray-Curtis similarity between consecutive survey units along the Mitterwasser over the investigation period 2001 and 2002 (eight surveys). Surveys 1-4 (2001), 5-8 (2002) and the average over the whole period are presented.*

The significant inverse relationship between similarity and species turnover illustrates that a high species turnover rate implies a high dissimilarity among the macrophyte assemblages of two consecutive survey units, while a low species turnover stands for the persistence of macrophyte structure (Fig. 5).

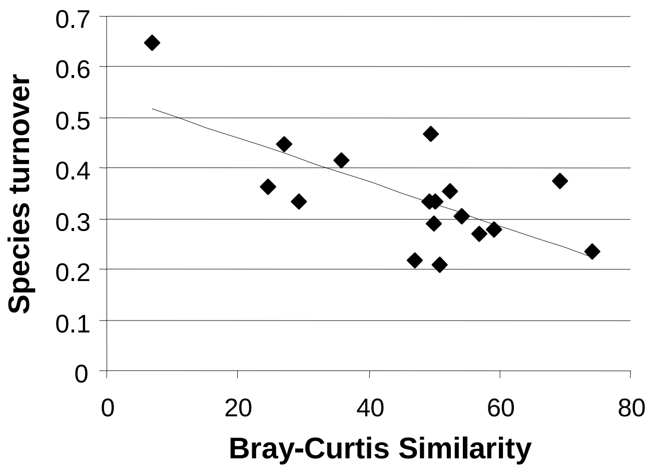

Figure 5. *Regression of Bray-Curtis similarity versus macrophyte species turnover of successive survey units in the Mitterwasser for both survey years 2001 and 2002 (R=-0.68, p<0.01).*

The highest species turnover and lowest similarity was found at the source of the Mitterwasser while inverse values of both measures commonly occurred at the downstream stretches (Figs. 3 and 4).

Similarity values were associated with trends of abiotic parameters. While the increase of persistence of macrophyte community structure was positively related with 'survey unit length' and 'water temperature' we found an inverse relationship for the parameters 'substrate type' and 'flow velocity'. All these trends, however, were statistically not significant and are therefore not illustrated in detail.

4 Discussion

The macrophyte species composition in the Mitterwasser corresponds well with numerous studies conducted in the Danube floodplain in Austria and its neighboring countries (Janauer & Pall 1999, Ráth et al. 2003, Otahel'ova et al. 2007, Barta & al. 2009 and others). Alterations of species within assemblages were studied for various biota groups as phytoplankton (Teubner et al. 2003), zooplankton (Sonntag et al. 2006) and macroinvertebrates (Heino et al. 2007) on temporal and spatial scales. The similarity of plankton assemblages between successive samples, measured by Bray-Curtis index, did not exceed values of 90% for phytoplankton and 85% for ciliate zooplankton although at the same time the total biomass of the respective plankton group was constant (biomass net change rate = 0; Teubner et al. 2003, Sonntag et al. 2006). In the present macrophyte study the similarity index on spatial gradients did not exceed values of 80%. This illustrates the spatial patchiness of macrophyte species distribution along the stream bed. In other words, at least a 20% change occurred between aquatic plant assemblages in consecutive survey units. In contrast to temporal species succession in aquatic plankton, the spatial similarity between macrophyte assemblages was even lower than 10%. This low persistence of macrophyte communities resulting in maximum species turnover rates occurred at the source of Mitterwasser. In this shallow most upstream stretch, the groundwater fed outflow of lake Weikerlsee, environmental factors like high flow velocities and coarse substrate determined species composition. Easily erodable amphiphytes with partly high regenerating abilities from fragments prevailed and produced only a low biomass. These species were likely to be uprooted from litoral habitats of Weikerlsee, transported downstream and rooted again at sheltered sites in the Mitterwasser. Strausz & Janauer (2007) showed a similar effect on amphiphytes in downstream parts of Mitterwasser during the 2002 flood. Subsequently downstream of the above mentioned near-source stretch, successive survey units were characterised by floated-leafed and submerged macrophyte communities related to lower flow velocities and finer substrate due to increased water depth.

This alteration in hydrological and environmental conditions recurred along the Mitterwasser and caused – to a great extent – alterations in aquatic species assemblages. However, endogenous ecological processes like transport of plant fragments and propagules to downstream, structurally different sections, can promote the establishment of floristically similar plant communities in physically different survey units (Tremp 2007, Riis & Sand-Jensen 2006). This is related to low turnover rates between some structurally different successive Mitterwasser sections.

To conclude, Mitterwasser can be considered as a hydrologically stable stream in the sense of Riis & Biggs (2003) as it is protected from natural flooding by damming. Local hydraulic factors such as water velocity, substrate type and depth are likely to primarily determine the establishment of macrophyte assemblages in streams with low disturbance frequencies (Riis & Biggs 2003). Environmental heterogeneity at relatively small scales allows species with differing demands to coexist by niche separation (Santamaria 2002) resulting in spatial patchiness of macrophyte communities along the stream course.

Acknowledgements

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Riparian forests and riverine vegetation - risk factors in case of flooding?

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Keywords: Riparian forests, riverine vegetation, flood risks, mathematical modelling, roughness values

1 Introduction

One of the objectives of the EU Water Framework Directive (WFD) is to achieve a good ecological status of surface water bodies. Ecological status refers to the quality of the structure and functioning of the aquatic ecosystems. In this context the development of riverine vegetation and riparian forests is the most important factor for the ecological improvement of regulated and modified rivers. It is obvious that an uncontrolled development of vegetation might result in higher local water levels in case of flooding and tighten the flood risks there, however, the positive retention effect on flooding further downstream should also be evaluated.

The influence of vegetation on the rising of the water levels during flood events depends, however, predominantly on the local velocity distribution within the cross-section. Cutting down of riparian trees and bushes has often little or no effect on the resulting water levels. Therefore, an adequate consideration of the vegetative flow resistance in a two-dimensional hydro-dynamical model (2D-model) is indispensable for the protection and implementation of new sustainable riverine vegetation.

Only an appropriate analysis of the given boundary conditions enables the proper finding of the balance between flood control and ecological needs. Flow resistance caused by bushes and trees is, at present, in many cases not adequately considered in the commonly used models. Based on the lack of knowledge concerning the realistic flow resistances of vegetation normally constant roughness values are used for the calculation of different discharge events. This might lead to a misinterpretation of the influences of the vegetation resistance on the water level with the result that vegetation and forest stocks are removed although this would not have been necessary.

These questions are discussed with reference to a case study on the River Danube in Bavaria and a research project on the River Elbe. Based on the results of laboratory experiments carried out in the "Theodor-Rehbock-Laboratory" of the Karlsruhe Institute of Technology (KIT) vegetative resistance values for different riparian forest stocks are presented.

2 Motivation: Analysis of the flood event 2002 on the River Danube in Bavaria

During the flood event in August 2002 the water level on the River Danube downstream of the river barrage Straubing (Danube-km 2320) rose to higher levels than expected for the given discharge. The analysis with a 2D-model presumes that the reason for this unexpected rise of the water level was the influence of the riverine vegetation and of maize fields in the flood plains; see photos in Figure 1.

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Figure 1. *Danube at Bogen (Danube-km 2311) with maize fields in summer 2003 and during the flood event in August 2002 with a water level reaching the top of the maize fields (RMD 2006)*

By establishing a 2D-model, which delivers resilient results concerning the influence of vegetation onto the water level, the following questions have to be considered:

- Which vegetative resistance values should be taken to describe the flow resistance caused by riparian forest and especially of such dense vegetation as maize fields taking into consideration emergent or submerged flow conditions?
- Which grid size should be chosen for wetlands to detect the influence of riparian vegetation?

3 Resistance values caused by maize fields and riverine vegetation

Frequently the Strickler-formula is chosen to describe the vegetative resistance since many experienced data are available for determining adequate k_{St}-values. Hartlieb (2006) carried out laboratory experiments to provide k_{St}-values for emergent and submerged maize fields. The flow resistance values for different flow approach directions are given in Figure 2. Hartlieb identified k_{St}-values from one to two as long as the maize fields are emergent. The k_{St}-values rise up to five for submerged flow conditions. Therefore, calculations in a 2D-model with a constant k_{St}-value will not lead to adequate results concerning the rising of the water level. Those low k_{St}-values indicate a very high flow resistance, which is due to the high density of maize fields. It can be observed in situ that maize fields block the flow nearly completely.

Compared to the modelling of such compact structures with little or no flow through the vegetation the modelling of the flow resistances of riverine vegetation is much more sophisticated since flow around the trees and branches occurs even in case of a dense vegetation.

Schneider (2010) carried out laboratory experiments in a 60 m long, 2.0 m wide and 0.7 m high re-circulating glass-walled flume to determine riparian softwood forest resistance values. The vegetation is simulated by using willows with and without leaves as well as hedges. The vegetation arrangement varied during the laboratory experiment between sparse up to dense softwood forest stocks. Recorded data for every setup were: water depth along the flume, flow velocity and pictures of the vegetation density. The chosen discharges created flow conditions with emergent vegetation to submerged vegetation.

The recalculation of the k_{St}-values for the hedges and willows varied from 4 up to 25 in dependence of the vegetation type, emergent or submerged vegetation as well as the stock density. Figure 3 presents the summary of the k_{St}-values for different riparian forest stocks and illustrates the great spectrum that has to be considered. Concerning riverine wetland areas on a macro-scale natural riparian forest stocks are characterised by a huge variety of different vegetation types. Therefore, the results are presented in a decision-making matrix, which enables an easy determination of the appropriate k_{St}-value especially for mixed riparian forest stocks in dependence of the stock density as well as the vegetation type. The figure sorts the k_{St}-values in such a way that the dense, stiff hedges stock is shown at the top left corner and the flexible, sparse stock of softwood-forest vegetation is shown at the bottom right corner.

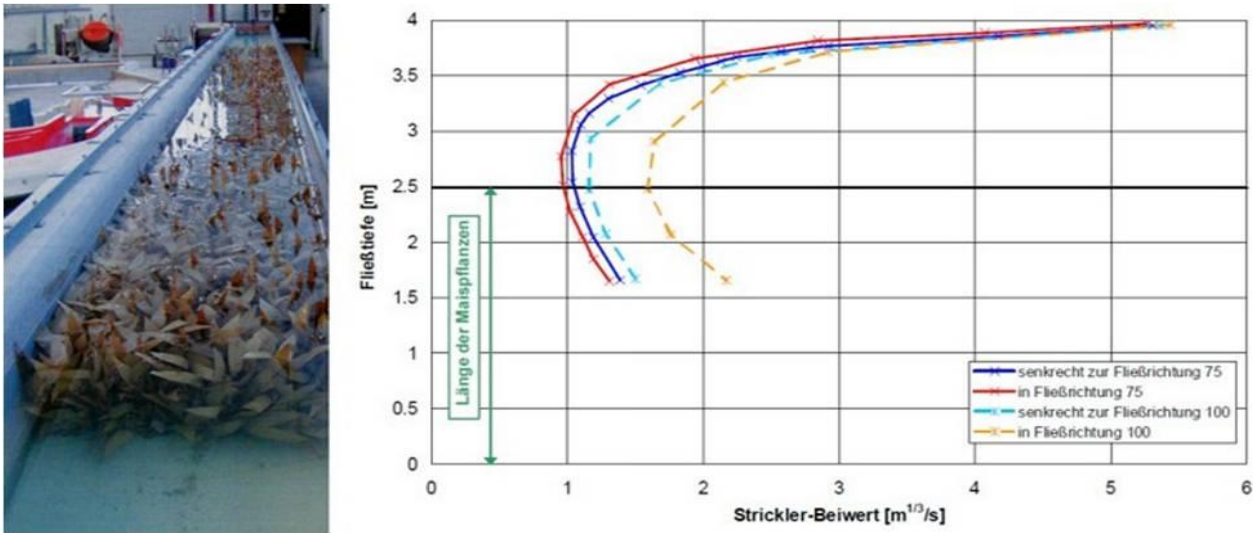

Figure 2. *Strickler-values for maize fields as a function of the water depth in the flood plain; results of hydraulic modelling in the laboratory of the TU München; Fließtiefe = water depth, Strickler-Beiwert = k_{St}-values (Hartlieb 2006).*

	hedges, shrubs k_{st} [$m^{1/3}/s$]	softwoodforest (summer, leafy) k_{st} [$m^{1/3}/s$]	softwoodforest (winter, unleafy) k_{st} [$m^{1/3}/s$]	
dense	4-7	7-10	13-15	emergent
	8 +	11 +	16 +	submerged
transition	8-10	11-13	16-19	emergent
	11 +	14 +	20 +	submerged
sparse	10-13	14-16	20-25	emergent
	14 +	16 +	26 +	submerged

Figure 3. *Strickler-values for different riparian forest stocks as a decision-making matrix (Schneider 2010)*

4 Flow Velocity for emergent and submerged willow stocks

A typical result of the velocity measurements is shown in Figure 4. The picture on the left displays the velocity distribution for the reference conditions without any vegetation in the flume and on the right the velocity distribution for dense submerged willow stocks is shown; the white contours are due to the model vegetation and husks which serve as mounting and bottom roughness. The photos in Figure 5 visualize the great difference between the flow conditions for emergent willows and submerged willows with a rather high flow velocity in the overtopping layer (compare Figure 4).

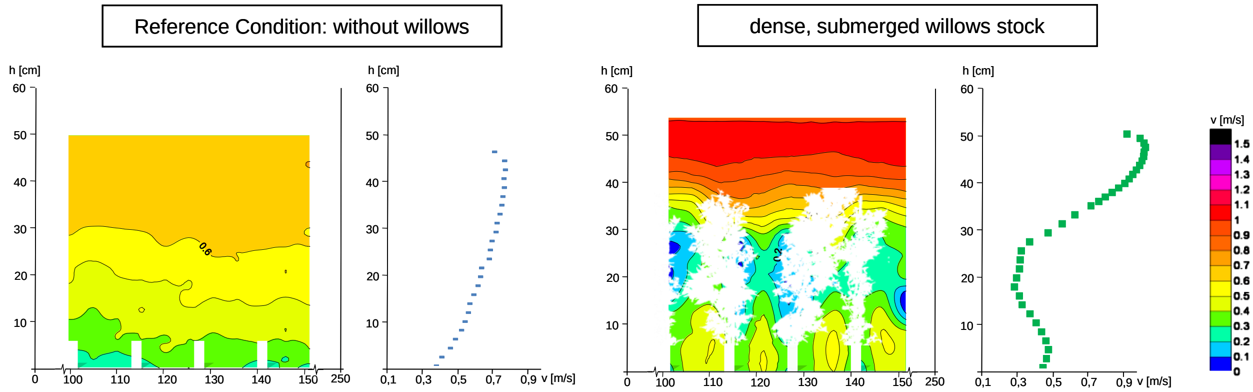

Figure 4. *Velocity distribution with and without vegetation (Schneider 2010)*

Figure 5. *Flow through the model vegetation and flow conditions with overtopping (Schneider 2010)*

5 Grid size for modelling floodplain areas

Concerning the grid size of floodplain areas in a 2D-model it is obvious that rather small elements are necessary for an adequate calculation of the influence of riverine vegetation. Whereas the effect of maize fields might be calculated with a grid size of 20 m x 20 m or even larger this would be absolutely inappropriate for riverine vegetation. With such rough-textured grids it is not possible to identify the influence of small groups of bushes and trees on the rising of the water levels.

6 Study case River Danube

The evaluation of the results given in Figures 2 and 3 illustrates the great variations which could be found and give a good hint which resistance values should be chosen according to the flow conditions for emergent or submerged vegetation. It is obvious that a constant k_{St}-value will not represent the real flow resistance neither for maize fields nor for riparian forest and riverine vegetation. The Strickler-values in the columns on the left and in the middle in Figure 3 are of special interest in comparison to the value of k_{St} = 5 for the riparian vegetation and k_{st} = 10 for riparian forest chosen for the calculation on the River Danube. If additionally the riverine vegetation covers a part of the grid size only, it might be more than questionable that calculations with such model parameters can deliver appropriate results. The cut down activities deduced from those results are shown in the photos in Figure 6. It can be stated that the effect on the water level that is expected due to these measures will not occur.

Figure 6. *Situation before (left) and after cutting of trees (Landschaft + Plan, Passau, 2006)*

7 Study case River Elbe

Possibilities of implementing new riparian forest areas in the floodplain were investigated on the River Elbe. For the calculation of the additional flow resistances to be expected from the vegetation a 2D-model with a grid-size of a few square meters was used. Almost 50 ha of riparian vegetation areas could be identified along a river stretch of 15 km. The implementation of all new riparian stock areas would result in a water level increase of 0.06 m (Schneider 2010).

8 Conclusion

The influence of riverine vegetation on the resulting water level depends on the appropriate consideration of the flow resistance values. A realistic evaluation of the flow conditions can only be verified with 2D-models based on small grid sizes. The choice of constant values for emergent or submerged flow conditions and sparse or dense vegetation is not suitable for calculations. If the influence of vegetation is not adequate the resulting effect might be overestimated.

Acknowledgements

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Phytoplankton composition and abundance in Srebarna Lake and adjacent temporary wetlands (Bulgarian floodplain of the Lower Danube River)

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Keywords: wetland, phytoplankton abundance, functional groups

1 Introduction

Environmental changes taking place in lakes and small ponds located in the floodplains are generally fast and closely related to the hydrological regime of the river. In response to these changes the structure of phytoplankton is also changing rapidly, making phytoplankton a good indicator of the aquatic ecosystem status. The pattern of phytoplankton response of small water bodies to the environmental factors, however, is not as well understood as in large lakes (Padisák et al., 2003; Ortega-Mayagoitia et al., 2003). In these shallow environments the relative importance of abiotic and biotic factors may change dramatically among seasons. Furthermore, such factors like sediment should be taken into consideration when trying to understand the sequence of alterations of phytoplankton structure in wetlands (Ortega-Mayagoitia et al., 2003). Yet another open question is how phytoplankton structure can be used best to indicate the relationship of organisms with their environment. It could be expressed either by the distribution of organisms within major taxonomic groups or on the basis of morpho-functional (m/f) groups (Padisák & Reynolds, 1998, Reynolds et al., 2002). The phytoplankton functional groups have been found to be more precise to indicate environmental conditions (Huszar et al., 1998, Kruk et al., 2002).

In this investigation we are focusing on phytoplankton structure, which will be presented through functional and taxonomical groups. Further, we want to analyse its relationship to a variety of environmental factors, such as the type and density of the sediment (mud), the presence of macrophytes, the water depth and water temperature, the distance from the center and shores of the lake and from the nearby village. Our aim is to compare phytoplankton of the natural permanent shallow Srebarna Lake and different kinds of small ponds (wetlands) located in the area between the lake and the Danube River and to try to explain their differences and similarities.

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2 Materials and Methods

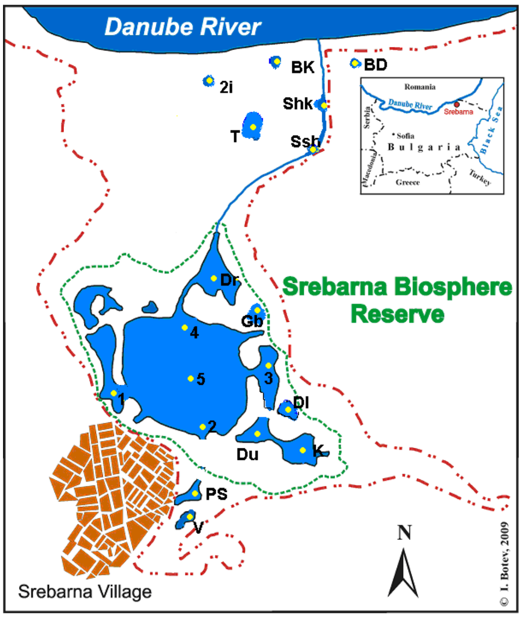

Figure 1. *(modified after Beshkova et al., 2009). Map of Srebarna Lake (M: 1:18000) with location of sampling sites indicated as follows: 1,2,3,4,5 – lake sampling stations, pool 'Kulneza'(K); pudle 'Durvoto' (Du); pool 'Dulboka' (Dl); pools 'Varban Bozun' (V); 'Pod seloto' (PS); pool 'Tanyova' (T); 'Gabritsa' (Gb); 'S shluz' (Ssh); 'S shluz kana' (Shlk), pool 'Dragayka' (Dr); 'Bauz Devnya' (BD); 'Bauz Komluka' (BK); 'Il yama' (2i)*

The location of sampling sites is presented in Fig.1.

Srebarna Lake (SL, 44°07 N, 27° 04 E) has an area of 120 ha, a depth of 1.7 to 4.7 m dependent on Danube water level, and a volume of 2.81-14.35 km^3; lake status is eu-hypertrophic. Characteristics of pools (area/depth): (K): 9.2 ha/2.1 m; (Du): 3.4 ha/2.50 m; (Dl): 2.2 ha/2.60 m; (V) and (PS): 1.2 ha/2.4 m; (T): artificial basin, drying out at low Danube water level; (Gb): 2 ha/3.5 m; (Ssh) and (Shlk) are located in the canal connecting the Danube with Srebarna Lake during high flow; (Dr): 6.8 ha/3 m, located in the south end of the canal, separated by reed beds; (BD), (BK) and (2i) are temporary water bodies, regularly flooded at high water level, around 1 ha/1.5 m.

Sampling frequency: Samples of 0.5 l were taken from 5 permanent lake points and from the pools during the vegetation periods (March-October) during 2004-2006, covering spring, summer and autumn. The number of visits (v) were as follows: SL -12 v.; K and Du -11 v.; Dl -7v.; V -6 v.; Dr -4 v; BD, BK , Ssh and 2i - 2 v.; unmentioned sites got a single visit only. Since lake site no. 3 is separated from the main lake by thick reed belt it was analyzed in the group of the pools.

Methods: The samples were preserved with formalin (4%) to count and calculate phytoplankton numerical abundance as individuals per liter (ind l^{-1}) and biomass (mg l^{-1}). The counting was done on a light microscope (200x) in the hemocytometer type of Bürker's chambers. Biomass was obtained on the base of individual algal volume measured and calculated by the method of geometrical approximations (Rott, 1981). The variables mud density (MudD), degree of macrophyte coverage (DMC) and degree of macrophyte remains (DMR) were evaluated through relative scale: 0 - absent, 1 – low, 2- middle, 3-high. The type of the mud (MudT) was characterized as: brown - 1, black - 2, black-gray – 3. Other variables measured were temperature (T,°C), water depth (m), distance from the center of lake mirror (D_1, m); distance from the closest lake shore (D_2, m), distance from the village (D_3, m).

Statistics: Partial canonical analysis (CCA) (Ter Braak & Šmilauer, 2002) was applied to reveal spatial and temporal variations of phytoplankton taxonomic and functional groups in relation to the environmental factors. Explanatory variables were considered: depth, T, MudD, DMR, DMC, D_1, D_2, D_3. Response variables were biomasses of different taxonomical and functional groups. The taxonomical groups (divisions) Cyanophyta, Chlorophyta, Bacillariophyta, Chrysophyta, Cryptophyta, Pyrrhophyta, Euglenophyta, and Xanthophyta are presented in figures by abbreviation composed from the first three letters. Functional groups are indicated with letters according Reynolds et al. (2002).

3 Results and discussion

During the study period phytoplankton numerical abundance in the ponds showed a far wider range (from 540 to 187668 .10^3 ind./l) than in Srebarna Lake (from 4418 to 201594.10^3 ind./l). Biomass changed from 0.52 mg/l to 51.65 mg/l and from1.99 mg/l to 62.66 mg/l respectively. The main m/f groups prevailing in biomass of phytoplankton were S_1, D, H_1,Y, X_1 and J, available in biomass shares of 35:16:7:7:7:6 respectively. The biomass shares of the main taxonomic groups were as follows: Cyanophyta - 46, Bacillariophyta -22, Chlorophyta -12 and Cryptophyta -7. Other m/f or taxonomical groups include shares smaller than 5 %.

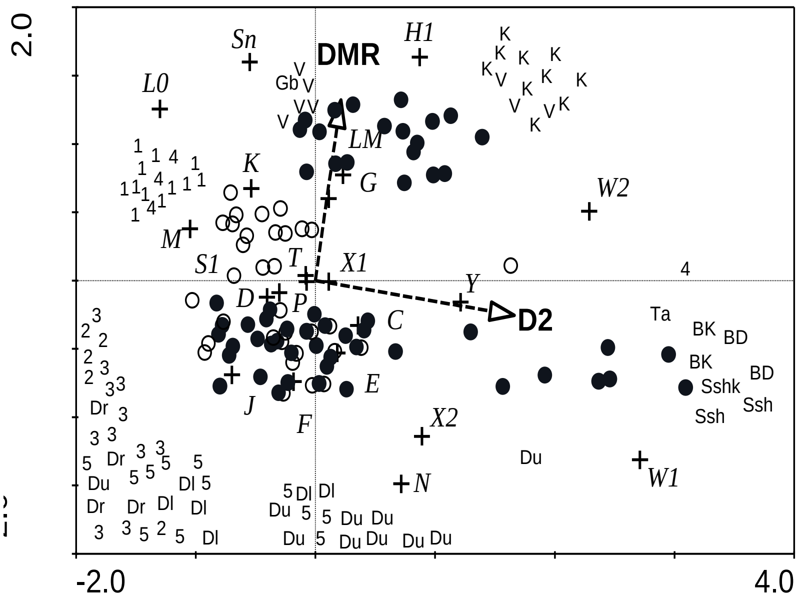

Figure 2. *Partial CCA triplot of sample spatial distribution with phytoplankton functional groups as response variables and D_2 and DMR as explanatory variables after elimination of seasonal and annual influences. + functional groups; ● - pools, ○ - lake sampling stations; DMR - degree of macrophyte remains, D_2 – distance from the neighboring lake shore; Total inertia = 4.840, Sum of all eigenvalues 3.714, Explained EV = 0.393, P = 0.0020*

The distribution of sampling points on the base of m/s groups (partial CCA) shows clear differentiation of pond samples by the first two main axes formed by D_2 and by DMR explanatory variables (Fig.2). Accordingly the pools seem to form three distinct groups. The first group unifies the ponds located far from the lake shore towards the Danube River (BK, BD, T, Ssh, Sshk). They are characterized by higher presence of W_1, W_2 and Y functional groups. All these groups consist of motile organisms, capable to myxothrophic nutrition and often coexisting in small, mixed ponds, rich of organic matter (for example dead vegetation after flooding).

The second group brings together ponds with high DMR - V, K and Gb. They are characterized by predominance of H_1 and S_N m/f groups and to some extent, of L_M and G groups.

The third pool group consists of sites Du, Dl and Dr containing mainly C, E, F, J, P, D functional groups of algae. This group overlaps with half of lake sampling stations (No 2,3 and 5) which contain the same list of functional groups. This overlap between pools and lake stations is explained by their proximity (southeastern part of the lake area). The other part of lake stations (No 1 and 4) does not overlap with pools i.e. their phytoplankton has different composition including functional groups L0, K and M differentiating them from third pool group and lake stations No 2, 3 and 5. The representatives of these functional groups are colonial blue-greens. The phytoplankton in the third pool group has a larger amount of organisms belonging to groups F, J and E.

Figure.3 shows that three factors - the water depth together with D_2 and DMR explain a significant share of temporal (inter annual) and spatial variations of biomass of phytoplankton functional groups.

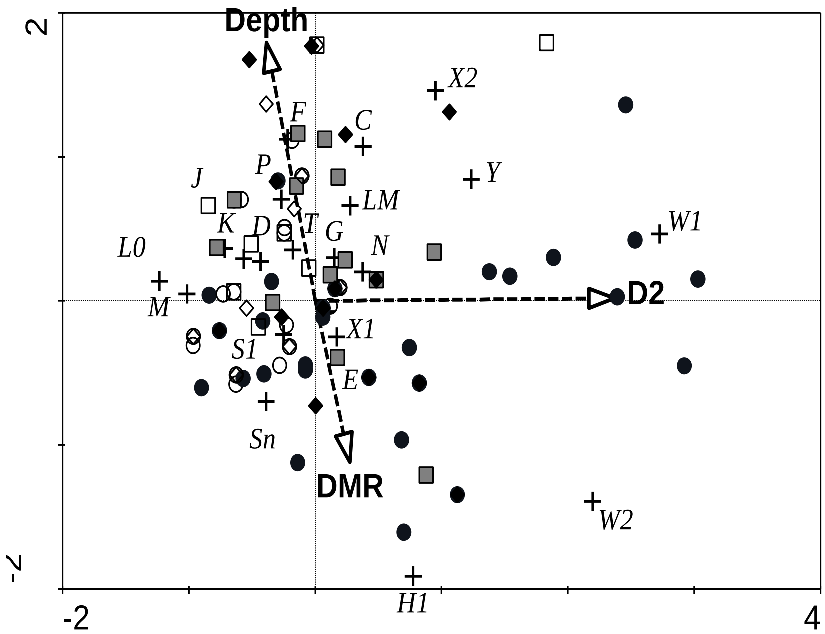

Figure 3. Partial CCA triplot of inter annual and space distribution of samples, phytoplankton functional groups as response variables and depth, DMR and D2 as explanatory variables after elimination of seasonal influences. + functional groups; ● 2004 pools, ○ 2004 lake, ■ 2005 pools, □ 2005 lake, ♦ 2006 pools ◊ 2006 lakes; Total inertia = 4.840, Sum of all eigenvalues 4.126, Explained EV = 0.561, P = 0.0020.

The samples are divided along the second main axis into such with small depth and high DMR (from 2004) and other with high depth and small DMR (from 2005 and 2006). The figure also shows that H_1 (nitrogen fixing cyanobacteria) and S_N, to a certain extend, prevail mainly in the shallower ponds with high DMR. However, these groups are considered as tolerant to low nitrogen and sensitive to mixing (Reynolds et al., 2002), a fact which does not correspond well to their occurrence in shallow ponds. In order to explain this discrepancy we have to refer to some other authors (Padisak & Reynolds, 1998; Huzar et al., 2000), cited after Reynolds et al. (2002), who stated that the solitary forms of H group are recognized to be more closer to S type, and in particular to S_N. Furthermore, groups S_1, H_1 and S_N are often in competition because of their similar requirements to environmental conditions.

The increase of water depth favors the groups F, C, P and L_M. A common feature of these groups is that they are associated with epilimnia in eutrophic lakes, and are considered to be tolerant to carbon deficiencies or low nutrients (Reynolds et al., 2002). The increase of their share probably indicates that depth increase leads to a change in the conditions from polymictic to dimictic (with more stable stratification in the summer). This change immediately affects the structure of phytoplankton not only in the main lake but in the smaller ponds too. The groups X_2 (regarded as tolerant to stratification) and Y (tolerant to low light) are also favored by the increase of the depth, but they are also related to D_2, i.e. they predominate in the small distant ponds rather than in the lake. These groups of C-strategists have been often found in water bodies with low phytoplankton biomass and fish absence, and high zooplankton pressure respectively (Padisák et al. 2003).

As a whole, the functional groups that contribute mostly to the separation of lake and pool phytoplankton samples were S_N, H_1, W_1, W_2, X_2 and Y.

The partial CCA (spatial) of taxonomic group distribution (Fig. 4), shows that the main factors, explaining variations of samples are D_2 and MudD, pointing in similar direction. Cryptophyta, Chrysophyta and Euglenophyta are better represented in the ponds than in the main lake, their relative biomass raises with increase of D2 and MudD.

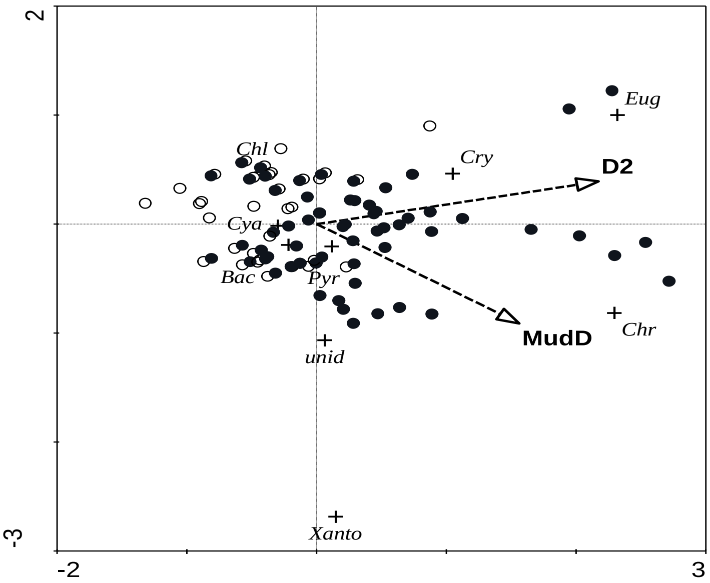

Figure 4. *Partial CCA triplot (spatial variations) with phytoplankton taxonomical groups as response variables and D_2 and MudD as explanatory variables; abbreviation **+** taxonomical groups; ● - pools, ○ - lake stations; MudD – mud density, D_2 – distance from the nearest lake shore; Total inertia = 2.285, Sum of all eigenvalues 1.814, Explained EV = 0.301, P = 0.0020*

D_2 again like in Fig.1 explains a significant share of spatial variations of sample division composition. However, the variation of phytoplankton samples (total inertia) defined by algal divisions is much smaller than that defined by functional groups. Accordingly the separation between different sample groups defined by algal divisions is worse than that by functional groups. The increase of density of the sediment mud in the ponds, remote from the lake (BK, BD) is probably due to their temporary nature. They probably often dry up and have no time to accumulate a thick layer of a loose slime. As regard the ponds Ssh and Sshk, situated in the canal between the Danube River and Srebarna Lake, the loose slime is probably periodically washed by in- and outcoming waters between the river and the lake.

The partial CCA of interannual and spatial variations of the phytoplankton samples presented by higher taxa selected water depth, D2 and MudD as main environmental factors explaining the significance of the structural variations of planktonic biota (Fig.6). In 2004 (distinguished by small depth) the lake and pond samples overlap, and only one group with predominance of Euglenophyta and Chrysophyta is separated. In 2005 and 2006 (with increase of water depth) the divisions of Cryptophyta, Pyrrhophyta and also unidentified species (mainly different small flagellates), become quantitatively more important in the pond samples.

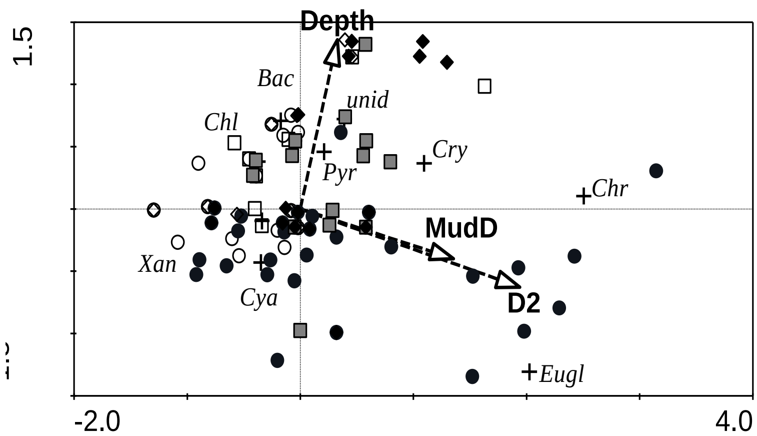

Fig. 6. *Partial CCA triplot of inter annual and spatial variations of samples, with algal divisions as response variables and Depth, MudD and D2 as explanatory variables after elimination of seasonal influences. Meaning of applied signs: + taxonomical groups; black symbols – pools, white symbols - lake sites ● ○ 2004, ■ □ 2005, ♦◊ 2006; MudD - mud density, D_2 – distance from the closest lake shore; Total inertia = 2.285, Sum of all eigenvalues 2.089, Explained EV = 0.419, P = 0.0020.*

The taxonomic groups of Cryptophyta, Euglenophyta and Chrysophyta mostly contribute for the segregation of samples between lake and different small ponds. To a certain extent they coincide with the functional groups W_1, W_2, X_2 and Y. However, with regards to the other major taxonomic groups - Cyanophyta, Chlorophya and Bacillariophyta, they do not contribute to the separation between the investigated ponds.

4 Conclusions

The expression of phytoplankton structure through the functional groups provides a more detailed and informative picture on the similarities and differences between compared water bodies and on the relationship of phytoplankton variables with environmental factors in both spatial and temporal aspects. Nevertheless, the reliability of both classification schemes, by taxonomic and functional algal groups, is in accordance with other studies and they confirm each other with respect of their discriminatory power (K. Teubner, personal communication).

D2 and DMR are the factors significantly contributing for differentiation between lake and pond phytoplankton assemblages regarding their spatial distribution. The same factors, together with water depth explained the combination of interannual and spatial variations together, but MudT replaces DMR as explanatory factor of variations of phytoplankton samples presented by taxonomic groups. The water depth variations are closely connected with lake level changes. As the analyses showed the depth factor appears on interannual basis because these water level variations are stronger than the seasonal ones. These variations are related but are not a direct consequence of the river level changes. Functional groups that contribute most to the separation of samples both in spatial and temporal aspects are nitrogen fixing cyanobacteria ($S_{N,}$ H_1) and motile unicellular species (Y, W_1, W_2 and X_2). These groups are positively related with DMR, water depth and D2 and are better represented in the pools.

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Sediment origin and dispersal dynamics in the Lower Danube Basin

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Keywords: metals, sediments, Pb isotopes, River Danube

1 Introduction

Within mining-affected river systems, identifying the sources of contaminant metals is a prerequisite for developing effective catchment management and remediation strategies. This is of particular importance in large river catchments, where metal inputs are generally received from a variety of different sources (Gelinas & Schmit 1997), and particularly where the catchment includes more than one country. The Danube River Basin represents Europe's second largest international drainage basin, covering an area of 817,000 km^2 and contains a large number of base and precious metal deposits (Heinrich & Neubauer 2002) that have been exploited since pre-Roman Times (Rice et al. 2007). Previous work in the Lower Danube system has identified the environmental impacts associated with historical and contemporary mining activity in Romania (Bird et al. 2005; Bird et al. 2008), Bulgaria (Bird et al. 2010), Serbia (Korac & Kamberovic 2006) and Hungary (Odor et al. 1998); however, there has been little or no attempt to establish and quantify patterns of contaminant-metal dispersal within the wider lower Danube Basin (Figure 1).

It has been noted by a number of studies that total metal concentrations alone are insufficient when attempting to document dispersal and deposition of contaminants (e.g. Ettler et al. 2004). In an attempt to overcome this problem, Pb isotopes have become increasingly used as geochemical tracers in environmental studies (Komárek et al. 2008); however, relatively few have sought to apply their use to the identifying and modelling patterns of contaminant dispersal in fluvial sediments. Four Pb isotopes can be utilized as geochemical tracers: ^{204}Pb, which is a stable, and the long-lived radiogenic isotopes ^{206}Pb, ^{207}Pb and ^{208}Pb, which are the daughter products of the decay of ^{238}U, ^{235}U and ^{132}Th, respectively. This study utilizes Pb isotope and multi-element geochemical data to assess the fluvial dispersal of sediment-associated metals within tributary catchments of the River Danube and within the River Danube itself.

2 Materials and methods

River channel sediment samples were collected from the River Danube and Romanian and Bulgarian tributaries at low river stage from exposed bar surfaces. Samples of mining and smelting waste were also collected from spoil tips, waste dumps and tailings ponds. Sub-samples of the <63 µm fraction were digested in concentrated HNO_3 at 100°C for 1 hour and As, Cd, Cu, Pb and Zn concentrations determined using ICP-MS. Lead isotopes ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb were determined in samples using a Thermo-Finnigan Element2 Magnetic Sector ICP-MS. Analytical accuracy versus the NIST981 standard was 0.28 % ($^{206/204}$Pb), 0.17 % ($^{207/206}$Pb) and 0.44 % ($^{208/206}$Pb).

3 Results and discussion

Metal and As levels in Hungarian, Bulgarian and Romanian tributaries and in the Lower Danube River itself have been reported by Bird et al. (2003; 2010; 2005). It has been found that most significant and spatially-extensive metal enrichment occurs in river sediments, with enrichment patterns mirroring major mineralization types. For example, Cu mineralization in the Timok (Serbia) and Panagyurishte (Bulgaria) ore

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districts is reflected by enrichment of Cu in the Timok (310-500 mg kg^{-1}) and Iskar (17-5500 mg kg^{-1}) catchments and in the River Danube (8-280 mg kg^{-1}).

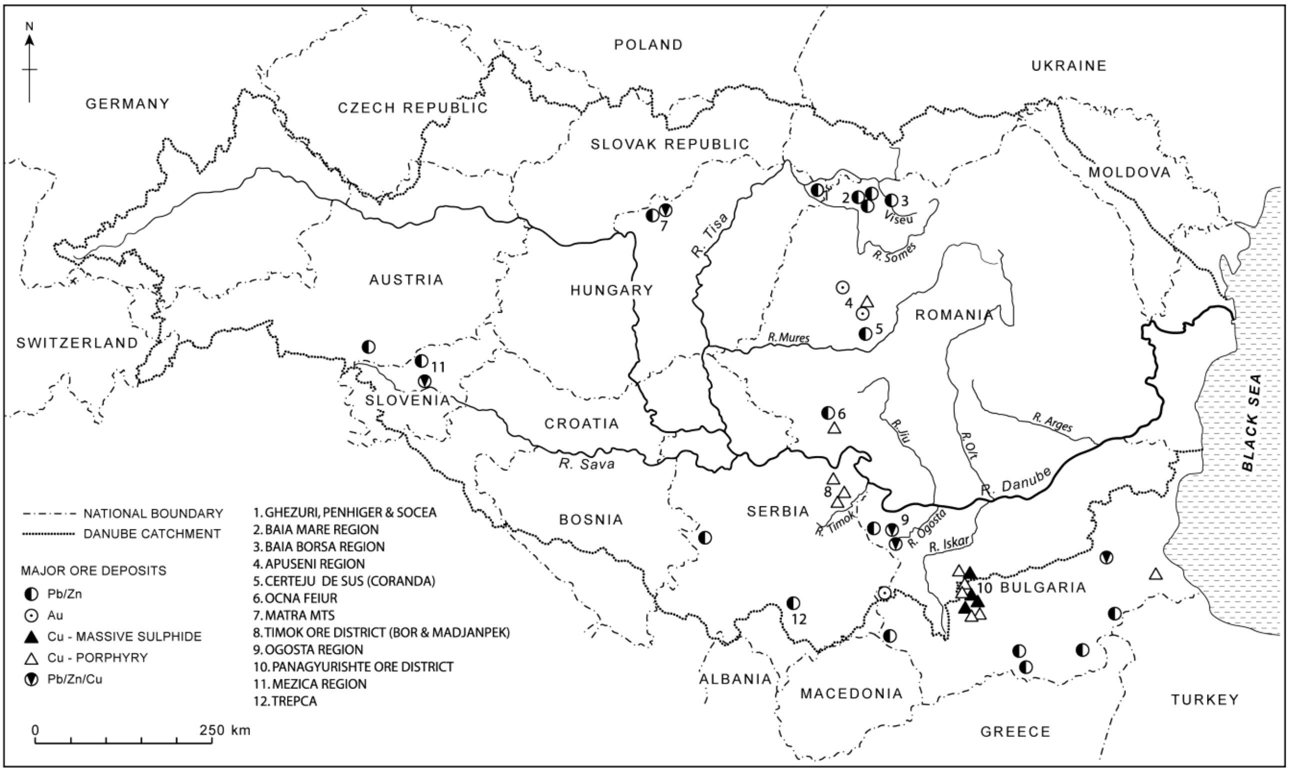

Figure 1. *Map of the Danube drainage basin showing major rivers and locations of metal ore deposits.*

Given that Pb isotopic signatures in mineral deposits will vary spatially due to differing ages of mineralization and geochemical composition, it is possible to differentiate between ore bodies within the Lower Danube Basin based upon bivariate relationships between $^{208/204}$Pb and $^{206/204}$Pb isotope ratios (Figure 2). Furthermore it is possible to differentiate between ore-bodies and potential contaminant sources can be seen within a single country, for example, the isotopic signatures within the West Balkan Metallogenic Zone of NW Bulgaria and the Elatsite deposit within the Panagyurishte ore district, show statistically-significant ($\alpha = 0.05$) isotopic variation, despite being just 60 km apart.

The sediment-metal load of mining-affected river systems will therefore reflect inputs from natural bedrock weathering and key anthropogenic sources such as mined ore deposits, which commonly have a different Pb isotopic signature from the surrounding bedrock. Similar to the Pb isotopic signatures for ore deposits, it is also possible to differentiate between the isotopic signatures determined in river channel sediments of mining-affected river catchments within the Lower Danube catchment (Figure 3). For example, the signatures for isotopes determined in Romanian ore deposits, are mirrored in river channel sediments, with those for the River Someş catchment, which drains the Baia Mare region, exhibiting lower $^{208/206}$Pb (2.0662-2.0740) and $^{207/206}$Pb (0.8323-0.8378) ratios than other Romanian catchments.

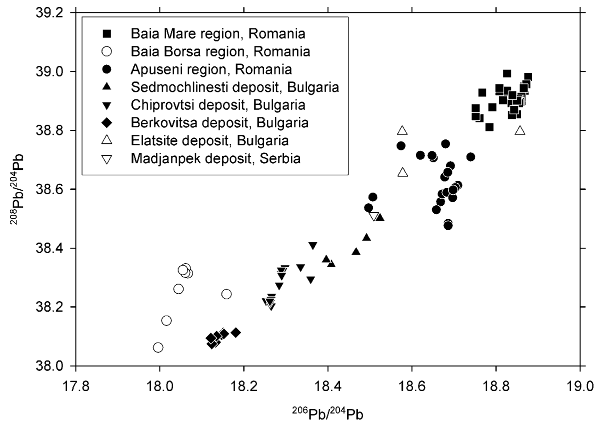

Figure 2. *Pb isotope signatures for ore deposits*

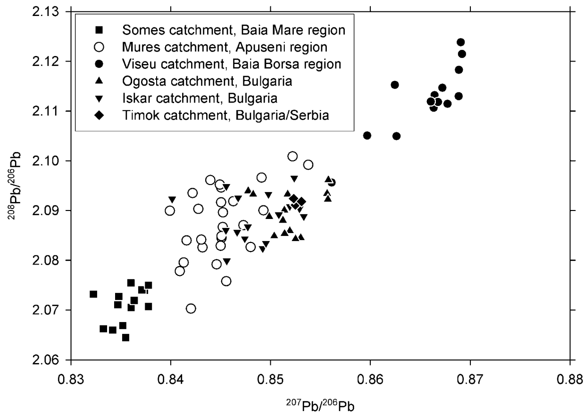

Figure 3. *Pb isotope signatures for river sediments*

In small river catchments (10 – 100 km^2), with a limited number of potential contaminant sources, binary mixing models can be used to quantify Pb contributions to river sediments, based upon Pb isotope signatures in river sediments forming a strong linear trend between two end-members, which are taken to be the primary Pb sources. However, given the greater number of potential Pb sources within larger river systems, such as the Lower Danube Basin, Pb isotopic signatures often do not form strong linear trends. For example r^2 values for bivariate $^{207/206}Pb$ and $^{208/206}Pb$ relationships in river sediments from the Rivers Ogosta, Iskar and Danube are 0.28, 0.49 and 0.54, respectively.

In order to determine sediment provenance in the lower Danube Basin, a composite fingerprinting technique was used to discriminate between sediment sources using multi-element geochemical data and Pb isotopic signatures as diagnostic properties (cf Rowan et al. 2000). Relative sediment contributions from source groups were quantified using a multivariate mixing model (cf Walling et al. 1999). The composite fingerprinting approach and multivariate mixing model was employed in two stages. Firstly within mining-affected tributary catchments of the Lower River Danube (notably the Ogosta and Iskar), to identify key contaminant sources (Figure 4), and secondly using tributary catchments as source groups in order to quantify their relative contributions of contaminant metals to the River Danube (Figure 5).

Within mining-affected catchments, the use of a multivariate mixing model allows key sediment sources to be identified, which may in turn assist in the interpretation of spatial patterns in metal concentrations. For example in the Upper River Ogosta, sediments represent an even mix of material from the Chiprovtsi and Dalgodelska regions, both of which contain a legacy of historic metal mining and are supplying sediment that is particularly enriched in As (Figure 4). With increasing distance downstream the relative importance of mining-affected sediment sources reduces, however at its confluence with the River Danube, approximately 47 % of channel sediment in the River Ogosta is sourced from mining-affected tributaries within the Ogosta catchment. With respect to sediment delivery to the River Danube, data from the mixing model indicate the notable influence of tributary streams upon sediment geochemistry in the River Danube within relatively short distances downstream of Danube/tributary confluences (Figure 5). Whilst a majority of sediment in the Lower Danube is believed to originate from upstream of the Timok/Danube confluence, relative contributions from Romanian and Bulgarian tributaries account for 2-27 % of sediment load, with peak contributions generally occurring within 20 km river confluences; followed by a subsequent downstream reduction due to mixing and physical dilution with inputs from other tributaries (Figure 5). In terms of sediment-bound metal levels in the Lower Danube, the mixing model data provide further evidence of the importance of mining-affected tributaries in Bulgaria.

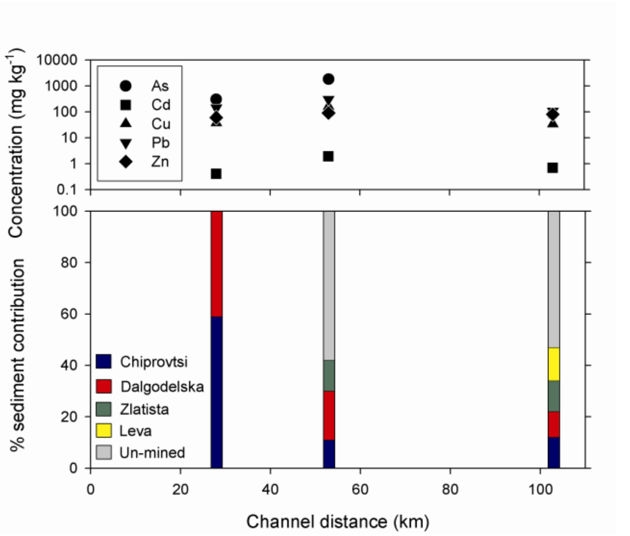

Figure 4. *Sediment-bound metal and As levels in the River Ogosta plotted with percentage sediment contributions from mined and non-mined tributaries. Channel distance is calculated from the source of the River Ogosta.*

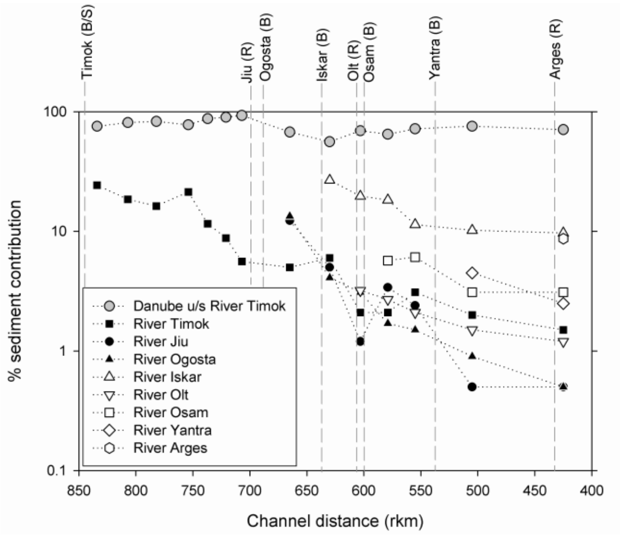

Figure 5. *Relationships between distance in Danube river kilometres (rkm) along the Lower Danube River and percentage sediment contributions from Romanian (R), Bulgarian (B) and Serbian (S) tributary catchments.*

For example, sediment delivered from the River Timok, which accounts for 12-20 % of the sediment supply to the River Danube between 834 and 737 rkm, contemporaneous with the locations of Cu enrichment in Danubian River sediment (250-280 mg kg^{-1}). Sediment delivered by the River Timok is enriched in Cu due to Cu mining and metallurgy at Bor in Eastern Serbia.

4 Floodplain records of contamination

Floodplain sediments represent an important sink for sediment-associated contaminant-metals that are dispersed within fluvial systems. Vertically-accreted sedimentary records provide the opportunity to establish a record of metal dispersal and deposition that can be used to reconstruct a contamination history for the Lower Danube drainage basin. Establishing patterns of contaminant dispersal in a large multi-national drainage basin such as the Danube, which has a long history of mining activity, is key to establishing: 1) the magnitude of contaminant-metal loading to alluvial sediment stores, 2) temporal changes in the origin of sediment-associated metal dispersal, and 3) the potential implications for remobilization of metals within alluvial deposits under changing flood frequency and magnitude.

Floodplain sediment cores collected from the Romanian bank of the Lower Danube River indicate that highest metal levels occur within the upper 1 m of the sediment profile. XRF intensity values determined through ITRAX core scanning of 4-5m long floodplain cores (Figure 6) indicate peak Cu and Zn levels in the upper 70 cm of the Danube floodplain. Concentrations of Cu (63-130 mg kg^{-1}), Pb (30-50 mg kg^{-1}) and Zn (60-115 mg kg^{-1}) in the upper 70 cm, are 2-4 times greater than those at lower depths (Figure 7), but are generally no higher than those measured in contemporary river channel sediments. Preliminary Pb isotope analysis indicates that, in addition to lower metal levels, floodplain sediment at depth may have lower $^{207/206}Pb$ ratios, which are potentially indicative of a different Pb origin to those in more contemporary sediments. Further work is required to establish a chronology for the floodplain sediments and to investigate down-profile variations in Pb isotope signatures.

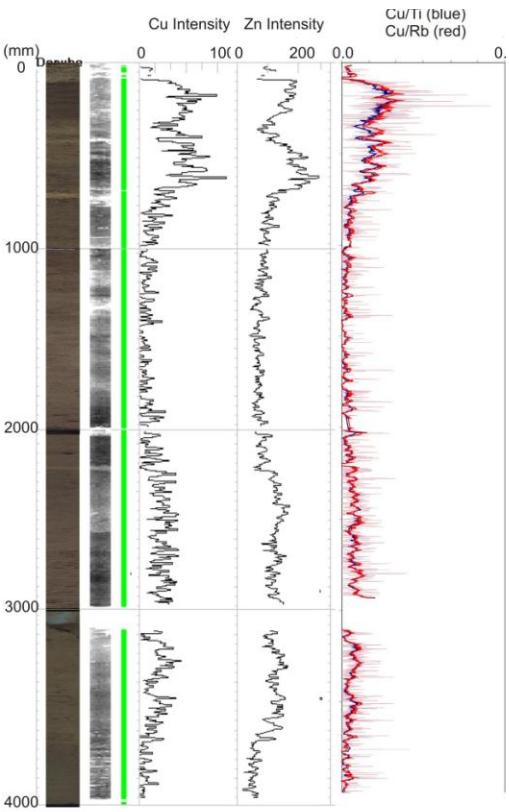

Figure 6. ITRAX XRF profiles for Cu and Zn intensities and Cu/Ti and Cu/Rb ratios in a floodplain core from the Danube floodplain at Giurgui, Romania

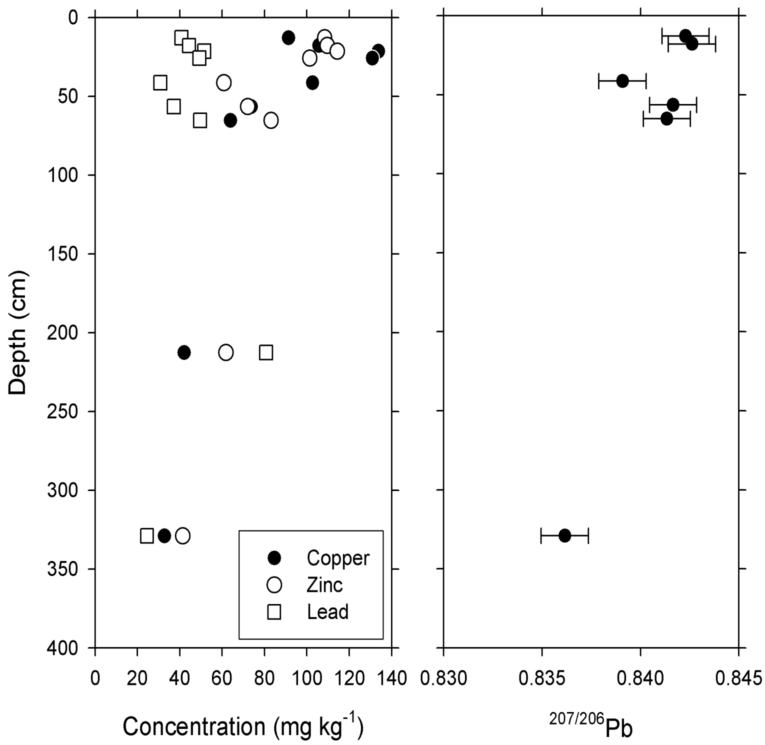

Figure 7. Cu, Pb and Zn concentrations and $^{207/206}$Pb isotope ratios in a floodplain core from the Danube floodplain at Giurgui, Romania.

5 Conclusions and implications for catchment management

Collation of Pb isotope data determined for metal ore deposits in the Lower Danube drainage basin, notably Bulgaria, Romania and Serbia indicate that definable differences in isotopic signatures occur for between a number of mineralised regions, both within and between countries. Furthermore, it has been possible to characterize river catchments within the Lower Danube Basin based upon bivariate relationships between Pb isotope ratios. Within mining-affected river catchments, Pb isotopic data collected for river channel sediments and mine and metallurgical waste have identified tailings, AMD and smelter waste as being key point sources of Pb and other contaminant metals to the metal load of rivers within the Lower Danube Basin.

The use of Pb isotope data in conjunction with a multivariate mixing model allows key contaminant sources within mining-affected river catchments to be identified, which may in turn inform remediation and management practices. The need to develop effective catchment management techniques is increasingly apparent given the implementation of the EU Water Framework Directive (EU WFD), which seeks to take a river basin-scale, ecologically-based approach to safeguarding water quality and protecting and improving aquatic ecosystems.

Acknowledgements

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Modelling hydrological processes to evaluate alternatives for ecologic reconstruction in the Danube floodplain near Braila, Romania

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Keywords: Flooding, reconstruction, hydrological modelling, ROSPA0005, ROSCI0006, Danube floodplain

1 Introduction

The Small Island of Braila Natural Park (ROSPA0005 and ROSCI0006) is a wetland with international importance, declared Ramsar *site* and *Natura* 2000 *site*. The Natural Park preserves on 245 km^2 the last wetland complex of flood-free ecosystems after the impoundment of Braila and Ialomita marshes (i.e. of former Danube Inner Delta 2,413 km^2, Vadineanu et al. 2001). The uniqueness of the area is given by the structure and location of the Park between the Danube branches, which limited the anthropogenic impact. The only anthropogenic changes are produced both by optimizing the use of fisheries resources and by the use of the herbaceous and forests vegetation as food for animals (pig, cattle rearing, etc.) or as timber. The reference state is represented by a characteristic morpho-hydrographic structure which resulted from the long-term sedimentation and erosion processes, which led to the development of a network of banks / natural dams, ponds and canals (Iordache et al. 2005a, Bodescu & Iordache 2008). Most of these banks obstruct the natural channels so that many areas of the basin are in various stages of clogging; the channels are invaded by vegetation, or temporarily or permanently covered by water. The current study of the surface waters in the Fundu Mare Island shows the cumulative effects of the increased sedimentation processes, which clog the ponds, inland lakes and channels connected to the Danube River.

2 Materials and methods

Mathematical models such as numerical modelling of the hydrological processes through automated cells have been used. The models are showing the flooding area and the specific parameters, the velocity and level of flooding waters.

In conjunction with the measured sediment load of the flood water we could assess processes such as sedimentation and erosion (Nicolas 2005). For the hydrologic modelling we used CAESAR and TRACER models proposed by Coulthard (2001) and Coulthard et al. (2005). After developing the digital elevation model (DEM) of Fundu Mare Island and identifying the existing data on the flow dynamics and suspended sediment content of the Danube water, model parameterization was performed for the specific algorithm of CAESAR.

Running the model showed the possibility to simulate both the extreme and normal events. In view of assuring the model quality and to validate the model results we have selected four cases specific for each quartile interval with similar and continuous intervals of simulation, so that their expansion and variability can be compared with LANDSAT-type satellite images (Smith 1997). After hydrological model validation we simulated the specific conditions to show, using the TRACER model, the processes of sedimentation and erosion before and after sediment sampling and assessment for heavy metals load.

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The dynamics of the Danube water flow, as shown by hydrometric measurements conducted at the main regional stations, Harsova and Braila, reveals a high variability. Analyzing the discharge between 1997 and 2002 allowed us to document a variability of the Danube water flow that can be characterized statistically by the values presented in Table 1. Thus, daily discharge in the Danube ranges from <2000 m^3/s to >12,000 m^3/s (quartile limits Q1 to Q3 are presented in Table 1).

A number of 21 available satellite images with an acceptable degree of cloud cover could be identified for the analyzed period, of which 4 were selected for the validation of the numerical model results in terms of extending water flooding at specific values in the lower and upper quartile.

To validate the model we selected CAESAR images for each quartile interval. For each of them a period of 7 days was selected, before the date on which the image was taken and it was parameterized, as in the simulations below to highlight the selected area.

Table 1. *Multiannual water debits statistic indicators (1997-2002) (m^3/s)*

Min	*1431*
Mean	*6870*
Max	*11667*
Q1	*5375*
Q2(me)	*6837*
Q3	*8312*

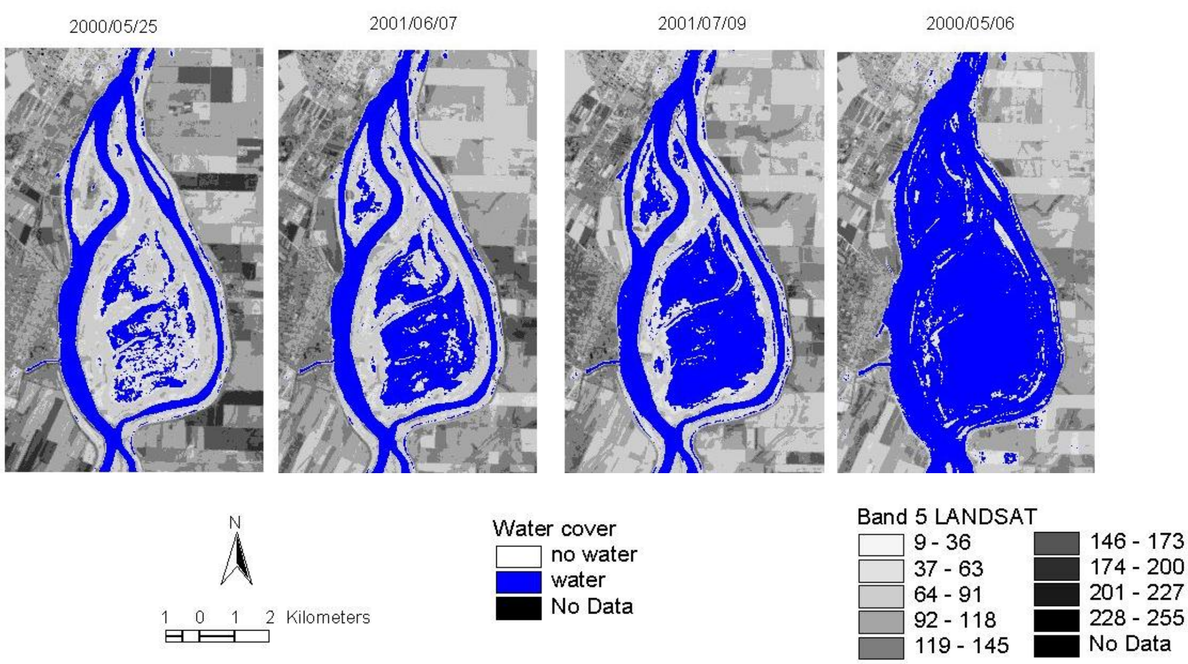


Figure 1. *Flooding water cover of Fundu Mare Island*

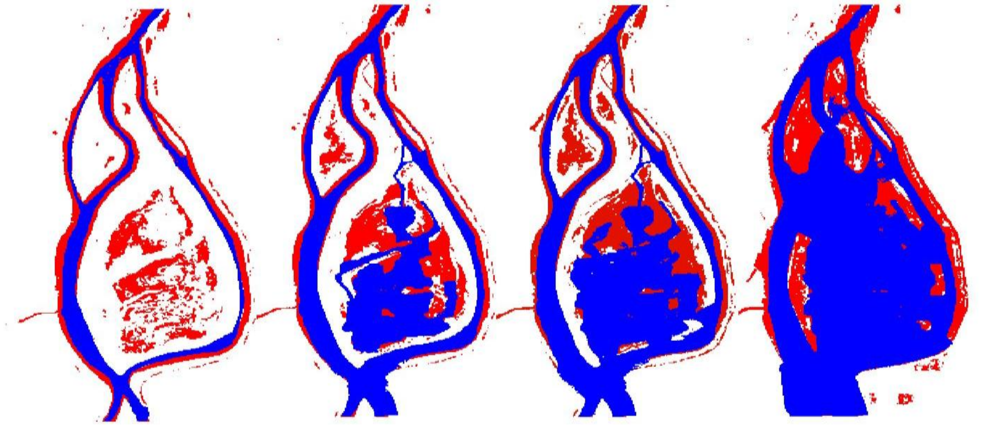


Figure 2. *Comparative analyses of flooding water cover: estimated on LANSAT satellite images classification (red) and by CAESAR model (blue)*

The satellite images were classified using the method of Frazier & Page (2000), which allows the differentiation of the flooding areas using band 5 with up to 96% confidence. Figure 2 shows band 5 for the 4 mentioned images. The method was adapted to the specific conditions, so that using band 5 from the multispectral image good results were observed for interval 8-52 to highlight the flooded areas (see Figure 1).

3 Restoration site: The Fundu Mare Island

Over the past 40 years, especially in the period 1965-1970, national strategies and policies were implemented to increase the area of agricultural land and to enhance the exploitation of available areas. In the Danube Valley this policy resulted in a more than 80% reduction of the natural floodplains (Vadineanu et al. 2001). These measures had major implications both for the agricultural systems and for the systems remaining under natural flooding conditions, as the Small Island of Braila is part of the former wetlands Great Island of Braila. The changes consisted in the alteration (modification) of the hydrologic regime, which narrowed the amplitude of the Danube water level fluctuation. Hence, under natural flooding conditions, fewer areas were inundated, the ponds of the Small Island of Braila became shallow and the load of sediments decreased. These changes are due to dam constructions in the Danube (Iron Gates I and II) and major tributaries. In addition to changes at regional and sub-regional levels, local changes have taken place such as blocking the Păioasa channel from Fundu Mare Island, in the framework of forest and navigation management. In other words, a part of the sediment observed in the lakes of Fundu Mare Island is due to anthropogenic impact.

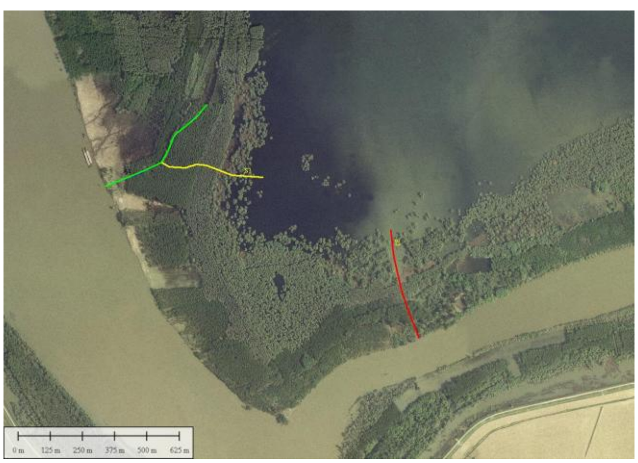


Figure 3. *Alternative scenario of reconstruction (S1 – light green; S2- red; S3 – pink and yellow)*

Restoration of ecological systems is addressing geo-morphological, hydrological and biological factors. For a specific sector of Fundu Mare Island (near Braila, Romania), we tested two hypotheses: the first one implies an increase of erosion near the shallow lakes and channels, achieved by opening connection channels to the upstream Danube arms; the second hypothesis implies that natural erosion and deposition will balance the retention and mobilization of heavy metals.

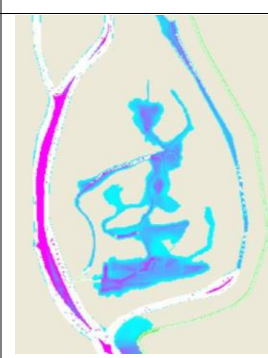
The bottom of floodplain lakes is above the low-water level of the Danube. Therefore, they loose water during the low flow period (from summer until autumn) through surface flow and/or exfiltration. We should also notice that in the state of reference, the islet lakes were usually supplied from the upstream channel and the outflow was located downstream (Antipa 1910, Vadineanu et al. 2001, Iordache et al. 2005b). This ensured a drainage system for the streams, internal canals and lakes and a low sedimentation rate. In fact, the sedimentation processes were much more intense than in the present days, but the hydrological dynamics, intensified by a second channel, washed out the deposits during floods so that the net sedimentation rate was lower than today.

Actually, in Fundu Mare Island there is just one channel for the inflow and the outflow. As a result, the flow velocity decreased drastically and the sediments are trapped in the inner lakes of the island and the canals. Obviously, the high sedimentation rates reduced lake depth, affecting directly the main species of birds *(Nycticorax nycticorax, Ardeolla ralloides* etc.) and fish from the Small Island of Braila. Further, water quality deteriorated since water residence time increased: lower dissolved oxygen concentrations, increased nitrogen and phosphorus concentration, and reduced transparency indicated eutrophication (Vadineanu et al. 2001, Iordache et al. 2005a). This process was supported by poor management – using the dam at the end of Chiriloaia channel and disconnecting the Danube.

4 Simulation results and discussion

Under this context, modelling the hydrological processes is used to test and validate various integrated management solutions both for the control of diffuse pollution with heavy metals and for the exploitation of fisheries and forestry resources. We selected for the analysis three alternative scenarios (figure 3). Scenario 1 is the reactivation of former Paioasa channel; the second scenario is the creation of a new channel following the shortest upstream connection from the lake to the Danube arm; the third scenario is a combination of the first two scenarios, where Paioasa channel is reactivated and connected to a new channel linking the upper inland lake.

After, correction of the digital elevation model to reflect the inconsistencies identified by the testing method, we applied the specific parameterization of each scenario for the proposed channels (figure 4). The effect of scenario 1 is mainly to activate the former channel but at this moment this will have a small beneficiary effect as sedimentation will continue, with a smaller rate. In the second scenario the activation of the proposed channel will strongly enhance erosion in the island lakes and channels. The last scenario is preferred, because it will keep the equilibrium between erosion and deposition.

	S1	*S2*	*S3*
Water depth			
Flow velocity	Lowest	Higher	Medium

Deposition/erosion	 deposition	 erosion	 deposition / erosion

Figure 4. *Comparative analysis of the alternative scenarios*

5 Conclusions

The inconsistencies in the comparative analysis of the flood prone area identified between the numerical model and the interpretation of the satellite images may be attributed primarily to the lack of detail of the digital model and secondly, to the underestimation of the flooded area that was not fully detected by the sensor because of the density and height of the riparian vegetation. The differences in the inter-quartilic intervals 2 and 3 may be due mainly to the anthropogenically maintained (controlled) water from the inland lakes.

Our recommendation is the use of the third scenario that has been completely analyzed in an integrated feasibility study and accepted by the scientific and administrative councils of the Small Island of Braila Natural Park (ROSPA0005 and ROSCI0006). We showed that the proposed methodology is a viable tool for the analysis of flooding processes in a specific river sector and for modelling the processes of erosion and sedimentation (essential hydrological processes with relevance to the mobility of heavy metals).

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Reviewing comments from Jürg Bloesch and Dieter Gutknecht to focus this paper are greatly appreciated.

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Towards risk-based management of European river basins: key-messages of the EC FP6 project RISKBASE

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Keywords: WFD, RBMP, risk, risk-based management, stakeholder participation, adaptive management

1 Introduction

In the EC FP6 Coordination Action project RISKBASE, leading European scientists and representatives of major European stakeholder groups reviewed and synthesised the outcome of EC RTD Framework Program projects, and other major initiatives, in relation to integrated risk-assessment based management of the water-sediment-soil system at the river basin scale. In this paper you will find a brief summary of the resulting key-findings and recommendations. All involved in RISKBASE sincerely hope that these will inspire and thus leave traces in the first update (2015) of the Water Framework Directive river basin management plans.

At the RISKBASE website (www.riskbase.info) a booklet (Brils & Harris, 2009) is available that provides a more detailed summary. Furthermore, in the second part of 2010 you may expect a scientific book (Brils *et al*., in prep.), providing an in depth, state-of-the-art description and review of all main topics addressed by RISKBASE.

2 River basins at risk

The health of river basins throughout the world is under pressure from economic activities and a changing climate. Water is necessary for life, agriculture and many industrial production processes but is also a receptor for our waste products. In Europe, diffuse pollution from agriculture and our industrial legacy, together with hydraulic engineering for navigation, water supply, hydroelectricity or flood control, are seen as the main factors adversely influencing the quality and ecology of European freshwaters and estuaries (Menedez *et al*., 2006). Economic activities affect the chemical and ecological status of our rivers, lakes and groundwater and deplete available soil-sediment-water resources. The wide range of economic activities and the eco-hydrological complexity of river basins, in terms of the functioning of the soil-sediment-water system and the links between water quantity, quality and economic activities, make a more integrated management approach to river basins complex and challenging (Chapman *et al*., 2007).

3 Risk-based management

As the pressures from both anthropogenic and natural causes on environmental systems increase, it is no longer effective or efficient to deal with one issue at a time, since solving a singular problem often causes damaging impacts on other environmental compartments or in other places. We must consider the consequences of our actions on all parts of the environment in an integrated way and configure these

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actions to cope with an uncertain future. These challenges demand a different approach in order to achieve actual improvement of the ecological quality of our river basins, and thus sustain the goods and services they provide for the well-being of society. Risk-based management is this new approach. It involves the integrated application of three key-principles (figure 1): be well informed, manage adaptively and take a participatory approach (Brils & Harris, 2009).

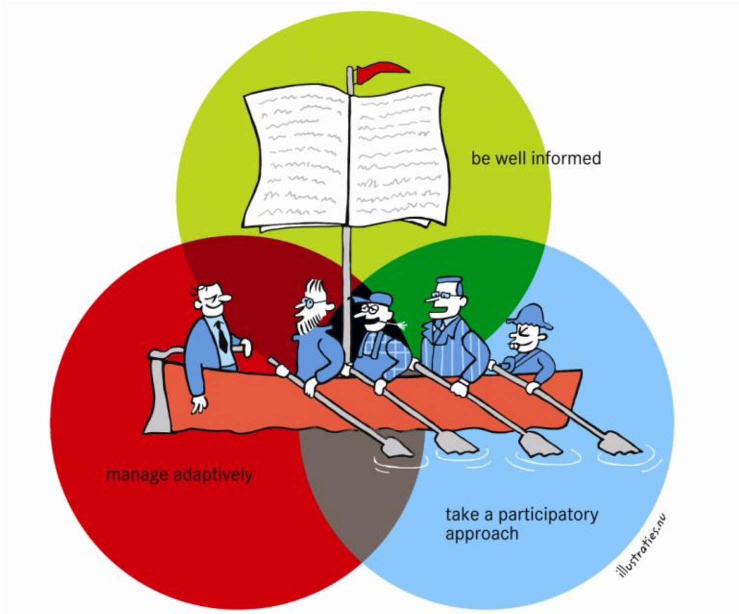

Figure 1. *Risk-based management involves the integrated application of three key-principles: be well informed, manage adaptively and take a participatory approach (Brils & Harris, 2009).*

The 1st key principle to risk-based management: be well informed

This implies that a sound understanding of the functioning of the soil-sediment-water system (ecosystem) and its interaction with the social system (figure 2) is the basis to river basin management.

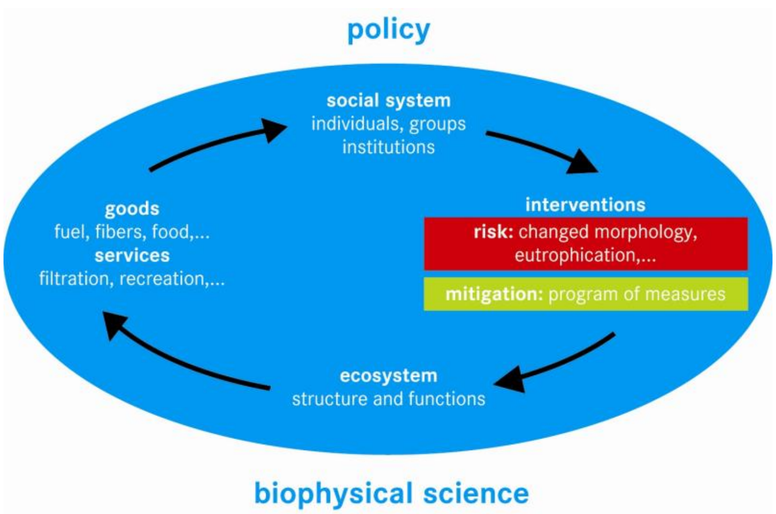

Figure 2. *The understanding of functioning of river soil-sediment-water ecosystems and its interaction with the social system is the basis to river basin management. Starting point in the circle is the ecosystem. Science plays a key-role*

to improve that understanding and improved understanding should lead to improved policymaking or implementation (figure modified after www.resalliance.org).

A range of EC Framework Programme projects, like AQUATERRA (www.eu-aquaterra.de) and MODELKEY (www.MODELKEY.org), have helped deliver, through a range of applied tools, new ecosystem understanding at the site specific, catchment and river basin scales. For instance, they produced evidence that ecosystem functioning is threatened by contaminants, such as pesticides, nutrients and heavy metals, that are propagated via groundwater pathways from the land surface to rivers, lakes and the sea. Furthermore, there is also evidence that this functioning is threatened by historic contamination (e.g. solid waste disposals) mobilised by extreme floods from sediments within rivers, on river banks, or in floodplain soils. The first generation of river basin management plans has only rarely included targeted measures to mitigate these risks. However, the Water Framework Directive (Annex IV) demands that such system understanding should be integrated in the first or subsequent updates of these plans.

The 2nd key principle to risk-based management: manage adaptively

Using our best available understanding on how river ecosystems function, will certainly improve river basin management. However, when using scenarios, models or other tools such as visioning workshops, simulation games and scenario planning (see e.g.: www.psiconnect.eu) to frame plausible trajectories of change, uncertainties will always remain. This is intrinsic to social as well as ecological systems. Systems, especially at larger scales, are extremely complex and dynamic and can respond in non-linear and unexpected ways. We may be able to cope with these uncertainties by applying the concept of adaptive management, characterised as 'learning-by-doing' or "learning to manage by managing to learn" (Pahl-Wostl, 2007). In addressing changes in climate and hydrology, the EC Framework Programme project NEWATER (www.newater.info) delivered guidance to apply the concept in practice.

The 3rd key-principle to risk-based management: take a participatory approach

Participatory processes involve stakeholders in management and aim to enable them to exchange their views and opinions on problems and bring their knowledge to the table. By learning together to understand the land-water system in a better way, better solutions can be found. This process of social learning requires a common language (Slob *et al*., 2007). The developing ecosystem services approach (European Commission, 2006; van der Meulen & Brils, 2008) may provide that language. A common understanding of the value of the goods and services that a healthy ecosystem can provide, and how their present poor status due to our actions can be improved, is the key to a new approach to river basin management (Brils & Harris, 2009).

4 Towards practice

The Water Framework Directive recognises several of these aspects. It is both risk-based and ecologically centred. It also recognises the need to balance improvements to water and ecosystem quality with economic benefits including the need to supply water for human requirements. Increasingly governments also see the need to grow and supply food as part of the balancing act we have to make.

Some examples from practice are already available where integration of these three key-principles is attempted. They show very encouraging results and may inspire others. However, it is our conviction that well-designed, coordinated and monitored 'learning catchments' (i.e. aimed at stepwise improvement of the effectiveness of measures) are needed to transform our general framing and develop best practice. The International Risk Governance Council's (IRGC, 2008) risk governance framework is recommended as a source of inspiration for the design and execution of such learning catchments (figure 3).

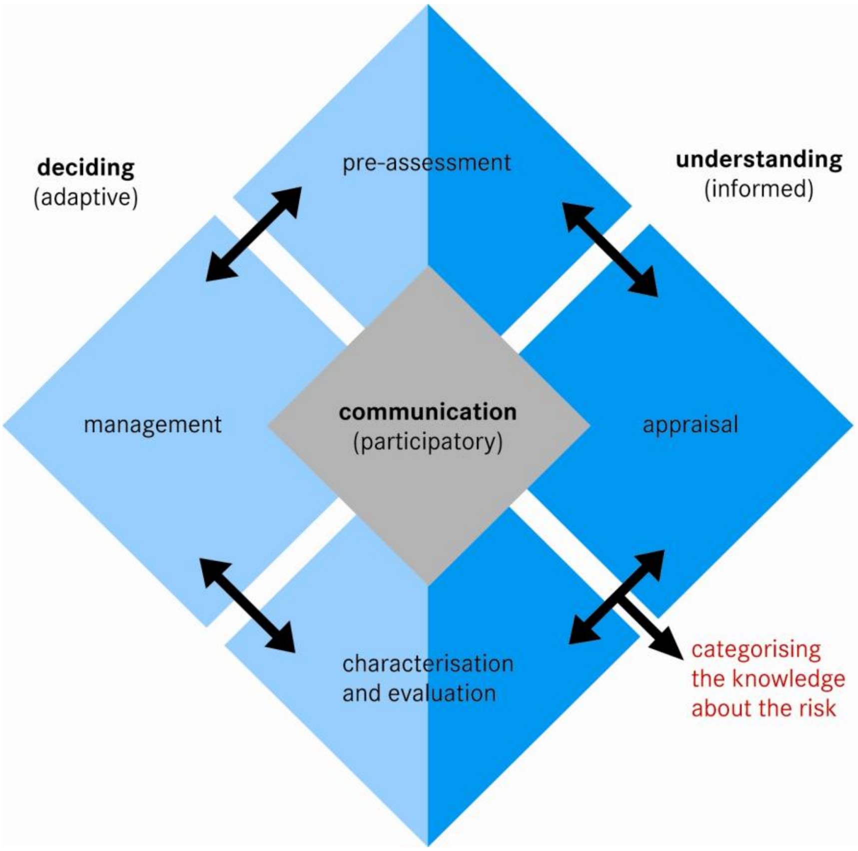

Figure 3. *The IRGC risk governance framework (IRGC, 2008). In between brackets the key-principles to risk-based management are positioned.*

5 Recommendations

Recommendations for river basin managers:

- Develop a network of more well designed, coordinated and monitored 'learning catchments', that are, amongst others, aimed at a stepwise improvement of the effectiveness of measures. Apply in these catchments – following the IRGC's risk governance framework – the three key-principles to risk-based management: be well informed, manage adaptively and take a participatory approach. This is needed to transform our general framing and develop best practice.
- Award incentives (e.g. prizes) for the most effective measure in river-basin management. Creating a prize for the most effective measure or tool used in the implementation of the WFD would increase the visibility of best practices, stimulate managers to innovate and provide positive attention for river basin management.

Recommendation for river basin management related EU policy makers:

- RISKBASE would welcome an EU policy initiative that encourages Member states and river basin managers to consider the ecosystem goods and services provided by river basins in addition to ecological status *per se*. This broadening of the scope opens up possibilities for more stakeholder involvement and more scientific input in decision making. A common understanding of the value of the goods and services that healthy river basin ecosystems can provide, and the diminution of these values by our actions, is the key to a new approach to river basin management.

More recommendations, i.e. recommendations for research funders and scientists are available in the RISKBASE booklet (Brils & Harris, 2009).

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Hydrographical network of the Danube Delta Biosphere Reserve - modelling the morphological dynamics

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Keywords: Danube Delta, hydro-morphologic dynamics modelling

1 Introduction

This paper presents an innovative technology to investigate the natural environment, particularly the water regime, focusing on hydro-morphologic changes (as a result of fluvial processes) and their effects on water quality and biodiversity. This technology is based on field measurements and field data processing by using research equipment and computational techniques of high performance /high accuracy compatible with GIS. They result in geospatial databases for hydrologic regime, hydro-morphological dynamics, water quality, and biodiversity. Numerical /spatial maps are processed in ArcGIS /ArcMap /ArcCatalog program and contain all these databases. Ultimately, these geospatial data have been used to construct the mathematical /hydraulic model for hydro-morphology dynamics, using as workbench the Delft3D software – a product of DELTARES – Delft Hydraulic Institute, The Netherlands.

Since 2008, this technology has been developed in the Danube Delta Biosphere Reserve (DDBR) hydrographical network. Its main objective is to emphasize the zones where fluvial processes (erosion and, especially, alluvial sedimentation) are active. It addresses to end users, especially the Danube Delta Biosphere Reserve Authority, to scientifically justify the management decisions made on the DDBR's protection, preservation and ecological reconstruction of protected aquatic ecosystems.

The DDBR represents one of the main components of the Danube River - Danube Delta - Black Sea geo-ecosystem. In 1990, it was declared as UNESCO World Heritage site and RAMSAR wetland of international importance. Its area of about 5,800 km^2 (on Romanian territory) makes it one of the greatest wetlands in the world. It contains 30 types of terrestrial and aquatic ecosystems, out of which 23 are natural or artificially modified and 7 are man-made ecosystems.

The Danube Delta plays an important role as a chemical and physical filtering system for the Western Black Sea coastal waters, especially when floods pass the various river branches and inner canal systems. In this context, the large and compact surfaces of reed beds play a significant role as sinks of nutrients (Cioaca 2000, 2004).

The DDBR hydrographical network is very complex, formed by the Danube Delta inner network, the Razim-Sinoie lake area, and the Black Sea north-western coastal waters up to the isobaths of 20 m depth. It consists of about 3500 km of channels /canals which connect /supply about 500 lakes (200,000 ha), naturally structured in 7 hydrographic units (Figure 1). The upstream zone of the Sontea-Fortuna hydrographical unit presents a detail of the DDBR landscape complexity (Figure 2). The main canal supplying this area is Mila 36. Being directly connected to the Tulcea Arm, this canal is subject to active fluvial processes, and erosion and sediment accumulation occur in different zones and at various intensity (Cioaca et al. 2009).

2 Material and method

In order to evaluate the morphological changes, zones with active fluvial processes (erosion and /or alluvial sedimentation) have been identified. For these zones, the hydraulic model has been constructed to simulate morphological changes for real scenarios. Hydro-morphologic (bathymetric and topo-hydrographical)

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measurements have been performed in the DDBR since 1998 and resulted in geo-spatial data of channel /lake measured tracks, as follows:

- Channel depth data in cross-section bathymetric profiles;
- Channel depth data in longitudinal bathymetric profile;

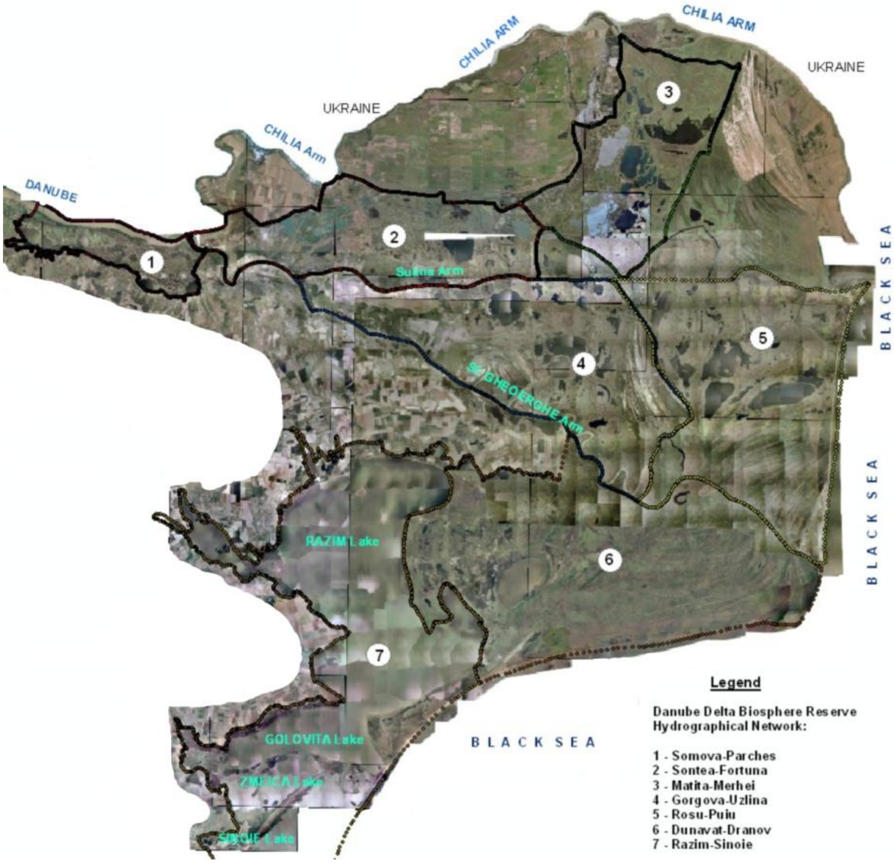

Figure 1. *Danube Delta Biosphere Reserve hydrographic units.*

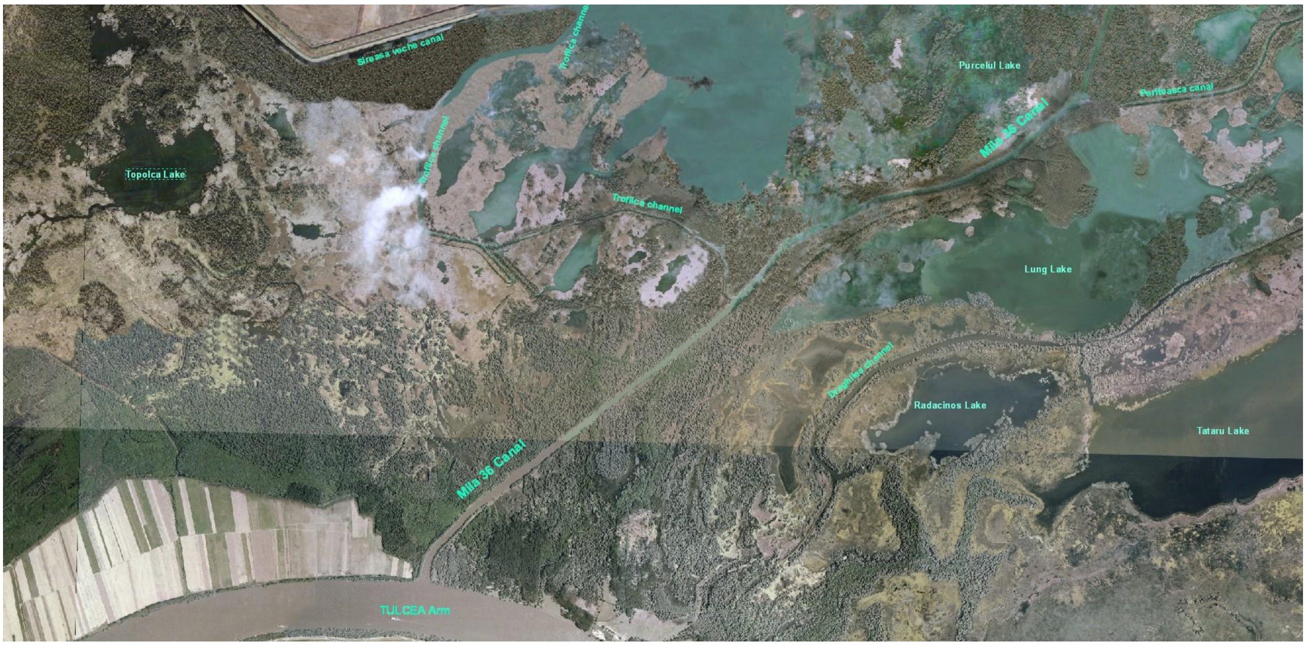

Figure 2. *The upstream zone of the Sontea-Fortuna hydrographic unit detail: Mila 36 canal case study for morphological modeling.*

- Lake depth data in longitudinal bathymetric profiles;
- Land elevation data for the channel sides /banks.

The equipment used for bathymetric measurement (well fitted to a boat) has as component parts:

The transducer: an ultrasonic device fitted to the bottom end of a vertical metallic bar and deployed 15 ÷ 20 cm into water. It “reads” (2 readings per second) the water depth and transmits it to the SonarMite;

SonarMite instrument: the “brain” of the entire bathymetric measurements equipment. It makes all the transducer “readings” corrections and combines the incoming GPS antenna messages with the transducer (echo sounder) messages and sends them to its specialized software, OHMEX;

GPS antenna captures and transmits geospatial position data (1 reading per second) on a target moving on water;

Portable computer with multiple serial interfaces to which both SonarMite and GPS antenna are connected to transmit for measured point its water depth and geographic position, respectively. The specialized software OHMEX is installed in the laptop, to which field data are transmitted at the same time, for each point measured by SonarMite;

The equipment used for hydrologic measurement is an ADCP - Acoustic Doppler Current Profiler, type Workhorse Rio Grande. It measures: water velocity, flow direction, discharge, cross-section bathymetry in geographical coordinates. The specialized software is WinRiver II – Teledyne RD Instruments. It processes the gathered field data in tabular and graphics format, as shown in Figure 3.

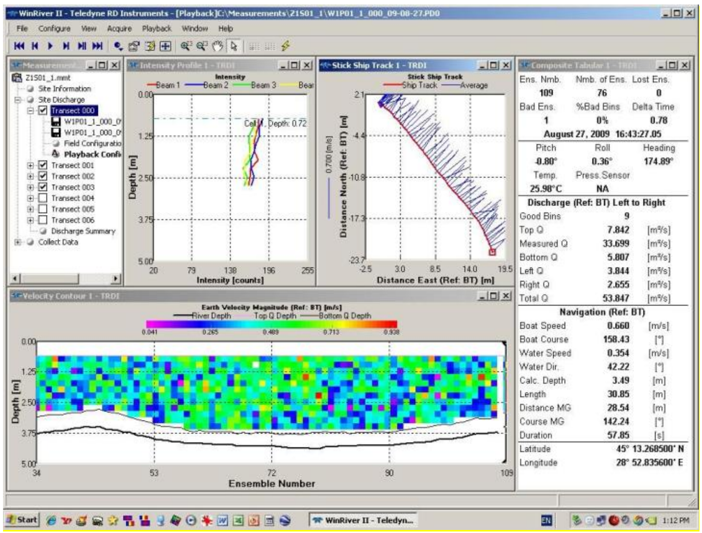

Figure 3. *Hydrologic data gathered by the ADCP equipment for Mila 36 canal upstream end cross-section.*

Digital (numerical) maps are processed in ArcGIS /ArcMap software, in Geographic Coordinate System (either GCS_WGS_1984 or GCS_Dealul_Piscului_1970) and /or Projected Coordinate System (either WGS_1984_UTM_Zone_35N or Stereo_70, respectively). They show the spatial distribution /location of hydrographical network zones where fluvial processes are studied. The maps present data in distinguished thematic layers of information, for each channel /lake studied. Thematic layers of information contain, in most cases, the following data: channel /brook /lake description; X_coordinate; Y_coordinate; Z_Depth of channel /lake bottom or land [m BSL]; Water depth [m]; Water level [m BSL]; Distance [m].

Database is constructed for the entire DDBR, meaning the hydrographic network and the land.

3 Morpho-hydrographical dynamics model

Geospatial data provide input to the mathematical /hydraulic model, Delft3D. The morphological profile of the hydrographic network is constructed in Delft3D-QUICKIN module. Figures 4 and 5 show, as examples, such a morphological profile, for Mila 35 canal (including the banks) and Fortuna Lake, respectively, both of them belonging to Sontea-Fortuna hydrografic unit.

The average depth of Mila 35 canal is about 5m. Compared to this value, due to fluvial processes, the deepest zones (subject to erosion, dark-blue) reach 11m depth, while the shallow zones (subject to alluvial sedimentation, light blue) 1m depth. In Fortuna Lake, alluvial sediments are mainly discharged by the Cranjala channel (from Sulina arm) and deposited in the south-western zone, where the highest deposits reach 1.65m above Black Sea Level (yellow and light blue color).

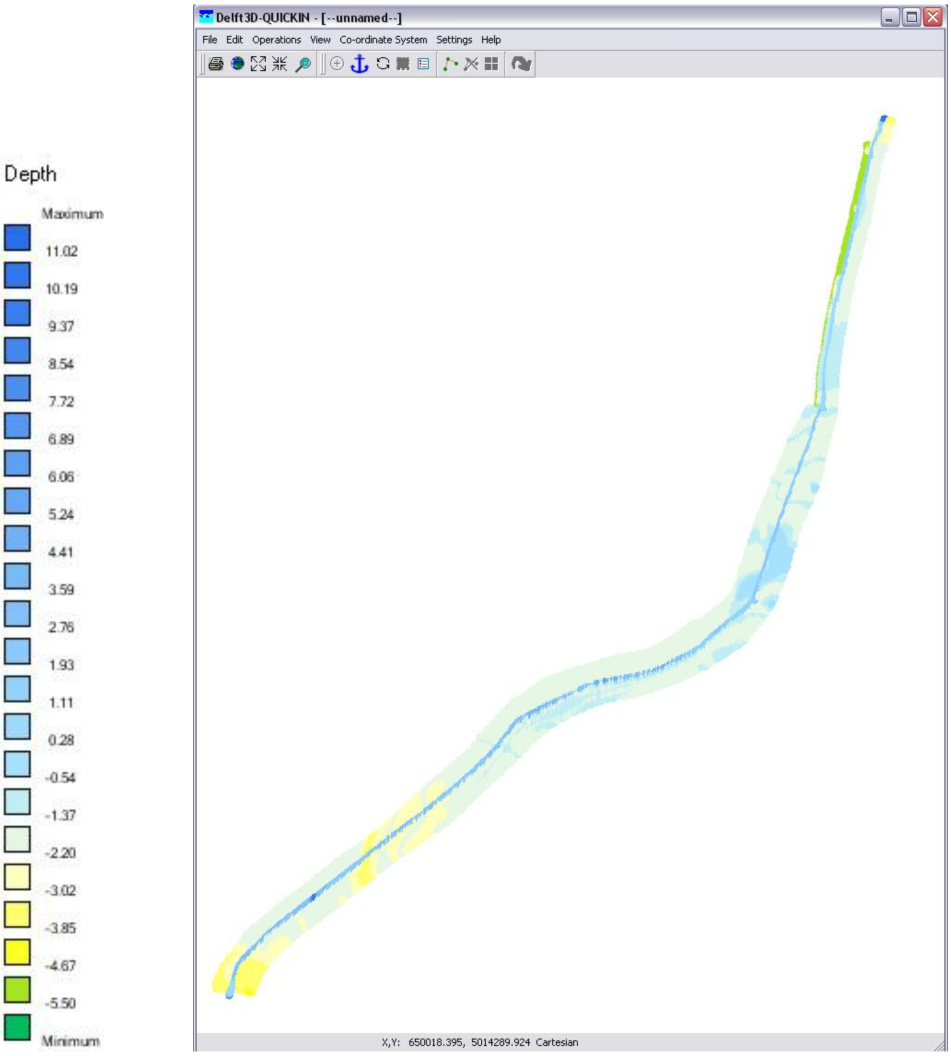

Figure 4. *Morpho-hydrographical profile of Mila 36 canal constructed in Delft3D-QUICKIN module.*

4 Outlook and conclusions

Within the DDBR hydrographical network, alluvial sedimentation zones are of greater interest, compared to erosion zones, as these depositional zones are ”bottlenecks” for navigation during low water level conditions. Alluvial sedimentation occurs when certain hydraulic conditions are fulfilled, such as: the water flow velocity decreases under a critical value, the stream hydraulic slope is flat and sediment load is high. These zones are mostly located at the bifurcation of smaller and larger channels, or at the channel mouth into a lake (delta formation). In the upstream part of a fluvial delta sedimentation intensity is high and can hardly occur in the downstream part of both the fluvial and fluvial-maritime delta, where the water is clear - very clear (Cioaca 2005).

At low water level condition, especially in summer, these “obstacles” may disconnect some channels and lakes from their supplying channels and can even become dry. The result is a significant modification of flora and fauna, reducing biodiversity ((Bondar 1993, 1994; Cioaca & Tudor 1999; Cioaca 2002, 2004).

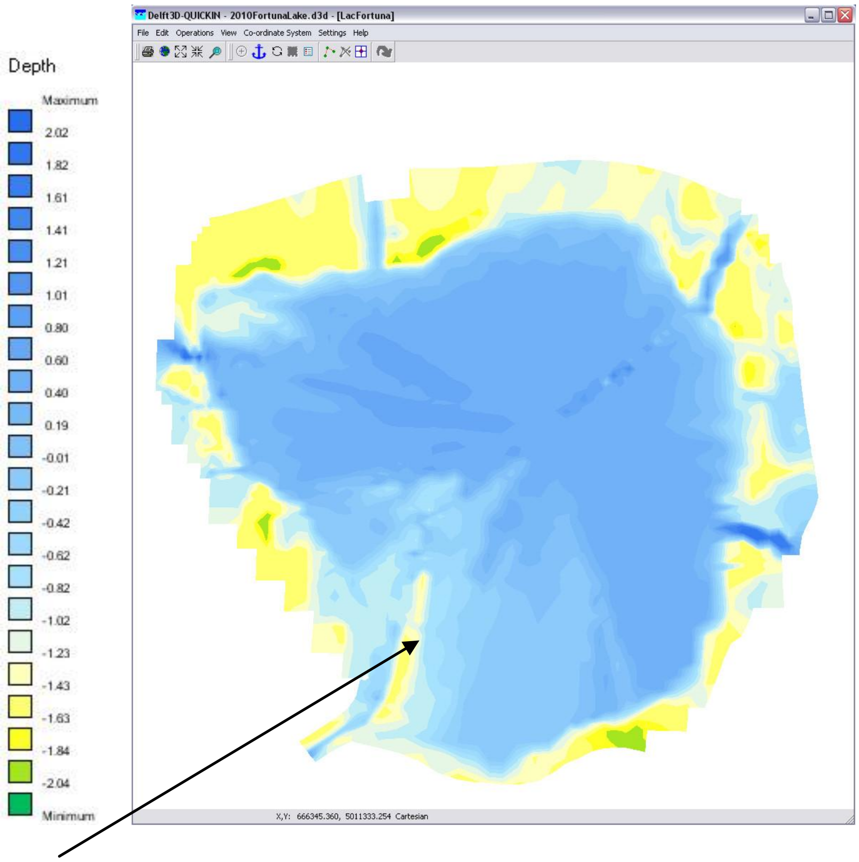

Figure 5. *Sedimentation zone inside Fortuna Lake: The arrow shows alluvial sediment deposits caused by discharges of Cranjala channel from Sulina Arm. These deposits are covered with young vegetation, mostly forests of willow.*

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Gastropoda in the Danube – Carpathian hydrographic space: possible impact of climate change

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Keywords: gastropods, the Danube, the Danube Delta, rivers

1 Introduction

The Danube hydrographical basin including the Danube Delta and all tributaries represents one of the areas with the richest fauna of gastropods.

The distribution of the gastropods between the Carpathians and the Danube, as well as in the Upper Danube, the Middle Danube, the Lower Danube, and the Danube Delta provides a biogeographical unity of gastropods (Cioboiu Codoban 2003, Cioboiu 2008).

2 The distribution of gastropods in the Danube

So far, in the Upper Danube 33 species of gastropods have been identified (Table 1). The species *Viviparus ater, Valvata (Cincinna) studeri, V. (Tropidina) macrostoma, Bythinella austriaca, B. cylindrica, Stagnicola fuscus, Radix lagotis* are characteristic of torrents and mountain streams. They represent 4 percent of the gastropod populations present in the Danube (Frank 1987; Tittizer 1990). Further, more or less ubiquitous species occur, such as *Theodoxus (Th.) danubialis, Th. fluviatilis, Viviparus acerosus, Valvata (V.) cristata, Lithoglyphus naticoides, Bithynia (B.) tentaculata, Physa fontinalis, Stagnicola corvus, St. turricula, Radix ampla, Galba truncatula, Planorbarius corneus* (Jurgen 1988; Grossu 1993).

In the Middle Danube, where relatively uniform biotopes with a mostly sandy-clayish benthic facies prevail, the gastropod populations are represented by the species *Theodoxus (Th.) transversalis, Valvata (C.) piscinalis, Borysthenia naticina, Bythinella hungarica, Lithoglyphus fuscus, Bithynia (B.) mostarensis, Esperiana esperi, Amphimelania holandri, Lymnaea stagnalis, Stagnicola palustris, Ferrissia (P.) clessiniana, Anisus (A.) leucostoma, Gyraulus (Lamorbis) riparius, Planorbarius corneus* (Oertel 2000). Some of these species also appear in the Upper Danube (Table 1). They represent 11 percent of the total species number of this area.

In the Lower Danube, due to the connectivity between the river and its floodplain and to the influence of its numerous tributaries, the species diversity of the gastropods is higher (Cioboiu 2008). In the river, we can find lentic species characteristic of the eutrophic lacustrine ecosystems – *Theodoxus (Th.) danubialis stragulatus, Theodoxus (Th.) pallasi, Viviparus acerosus, Valvata (C.) piscinalis, Lymnaea stagnalis, Stagnicola corvus, Radix auricularia, Planorbis planorbis, Gyraulus (G.) acronicus*, as well as lotic (reophilic) species that are better adapted to the conditions of stream ecosystems – *Lithoglyphus naticoides, L. pygmaeus, Esperiana (M.) daudebardii acicularis, Radix ampla, Segmentina nitida.*

On the other hand, some species prefer the sandy facies – *Theodoxus (Th.) prevostianus, Turricaspia (Oxypyrgula) ismailensis, Radix balthica*, while others prefer the clayish facies – *Lithoglyphus apertus, Galba truncatula.* Within the areas characterized by rocky banks, typically the species *Bythinella austriaca* and *Amphimelania holandri* do occur. Thus, it results that the variable environmental factors of the Danube (the flow velocity, the bed structure, the trophic state) influence this distribution of gastropods (Buşniță & Brezeanu 1970; Negrea 1994; Cioboiu & Brezeanu 2000; Oertel 2000).

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There are no strict limits between these river sectors; therefore an interference of the gastropod species between different Danube sectors can be noticed; the Lower Danube features the majority (86 percent) of gastropod species (Table 1).

3 The distribution of gastropods in the Danube Delta

The Danube Delta (area about 434,000 ha) represents the final segment of the Danube; 70 percent of its surface is covered by a great diversity of aquatic ecosystems: channels, lakes, marshes.

Up to now, 45 species have been identified (Table 1); the most frequent are *Theodoxus (Th.) danubialis, Th. fluviatilis, Viviparus acerosus, Pseudamnicola (P.) dobrogica, P. leontina, P. razelmiana, Potamopyrgus antipodarum, Turricaspia (Laevicaspia) lincta, T. dimidiata, Physella (Costatella) acuta, Anisus (A.) spirorbis, Gyraulus (Torquis) laevis, Planorbarius corneus* (Grossu 1993).

Even if the aquatic ecosystems of the Danube Delta display an unique character, due to the structure of the biotopes and biocoenoses, the areas located near the shore of the Black Sea show a particular character because they are influenced by brackish water. This mixohaline feature reflected also the structure of the gastropod populations, as certain species are tolerant to salt water (*Pseudamnicola razelmiana, Potamopyrgus antipodarum, Turricaspia lincta)* (Table 1).

4 The distribution of gastropods in the river system of Romania

The river system, which includes 16 main rivers, is more than 66,000 kilometers long. Its ecosystem diversity (mountain and hill rivers with rapid flow and torrents, plain rivers with slow flow, and floodplains) determine the structure and the specific distribution of the gastropods.

According to the ecological character of the rivers, the species *Lithoglyphus apertus, Radix ampla, Radix balthica, Stagnicola palustris* appear more often in the mountain and hilly area; *Bythinella austriaca, Amphimelania holandri, Ancylus fluviatilis* mostly populate the mountain torrents and rivulets; *Theodoxus (Th.) fluviatilis, Viviparus viviparus, Lithoglyphus naticoides, Esperiana esperi, E. (Microcolpia) acicularis daudebardii* are characteristic of the rivers from the plains (Table 1).

Table 1. *The gastropods in the Danube, the Danube Delta, and the other rivers in Romania*

No	Species	The Danube			The Danube Delta	The rivers in Romania
		Upper sector	Middle sector	Lower sector		
1.	*Theodoxus (Th.) danubialis* (C. Pfeiffer, 1828)	+	+	+	+	+
2.	*Theodoxus (Th.) d. stragulatus* (C. Pfeiffer, 1828)		+	+		+
3.	*Theodoxus (Th.) euxinus* (Clessin, 1887)			+	+	
4.	*Theodoxus (Th.) fluviatilis* (Linnaeus, 1758)	+	+	+	+	
5.	*Theodoxus (Th.) pallasi* Lindholm, 1924			+	+	
6.	*Theodoxus (Th.) prevostianus* (C. Pfeiffer, 1828)			+		
7.	*Theodoxus (Th.) transversalis* (C. Pfeiffer, 1828)		+	+		+
8.	*Viviparus acerosus* (Bourguignat, 1862)	+	+	+	+	+
9.	*Viviparus ater* (De Cristofori & Jan, 1832)	+				
10.	*Viviparus contectus* (Millet, 1813)		+	+		+
11.	*Viviparus mamillatus* (Kuster, 1852)		+	+		
12.	*Viviparus viviparous* (Linnaeus, 1758)			+	+	+

13.	*Viviparus viviparous penthicus* (Servain, 1884)	+				
14.	*Valvata (Cincinna) piscinalis* (O. F. Muller, 1774)		+	+	+	+
15.	*Valvata Cincinna) studeri* Boeters & Falkner, 1998	+				+
16.	*Valvata (Cincinna) piscinalis antiqua* Morris, 1838			+	+	
17.	*Valvata (Tropidina) macrostoma* Morch, 1864	+				
18.	*Valvata (Valvata) cristata* O. F. Muller, 1774	+	+	+		+
19.	*Borysthenia naticina* (Menke, 1845)		+	+	+	+
20.	*Pseudamnicola (P.) dobrogica* Grossu, 1986			+	+	
21.	*Pseudamnicola (P.) leontina* Grossu, 1986				+	
22.	*Pseudamnicola (P.) penchinati* (Bourguignat, 1870)			+	+	
23.	*Pseudamnicola (P.) razelmiana* Grossu, 1986				+	
24.	*Bythinella austriaca* (Frauenfeld, 1857)	+				
25.	*Bythinella cylindrica* (Frauenfeld, 1857)	+				
26.	*Bythinella hungarica* Hazay, 1880		+			
27.	*Potamopyrgus antipodarum* (J. E. Gray, 1843)			+	+	+
28.	*Lithoglyphus apertus* (Kuster, 1852)			+	+	+
29.	*Lithoglyphus fuscus* (C. Pfeiffer, 1828)		+			
30.	*Lithoglyphus naticoides* (C. Pfeiffer, 1828)	+	+	+	+	+
31.	*Lithoglyphus pygmaeus* Frauenfeld, 1863			+		
32.	*Bithynia (Bithynia) mostarensis* Moellendorff, 1873		+			
33.	*Bithynia (Bithynia) tentaculata* (Linnaeus, 1758)	+	+	+	+	+
34.	*Bithynia (Codiella) troschelii* (Paasch, 1842)	+	+	+		
35.	*Bithynia (Codiella) leachii* (Sheppard, 1823)	+		+	+	+
36.	*Turricaspia (Clessiniola) variabilis* (Eichwald, 1838)			+		
37.	*T. (Laevicaspia) lincta* (Milaschewitch, 1908)				+	
38.	*T. (Oxypyrgula) ismailensis* (Gol. & Starob., 1966)			+	+	
39.	*T. (Turricaspia) dimidiata* (Eichwald, 1841)			+	+	
40.	*Esperiana esperi* (A. Ferussac, 1823)		+	+	+	+
41.	*E. (Microcolpia) daudebardii* (Prevost, 1821)		+	+	+	+
42.	*E. (Microcolpia) daudebardii acicularis* (A. Ferussac, 1823)		+	+	+	+
43.	*Amphimelania holandri* (C. Pfeiffer, 1828)		+	+		+
44.	*Physa fontinalis* (Linnaeus, 1758)	+	+	+		+
45.	*Physella (Costatella) acuta* (Draparnaud, 1805)			+	+	+
46.	*Physella (Costatella) heterostropha* (Say, 1817)		+	+		+
47.	*Aplexa hypnorum* (Linnaeus, 1758)		+	+		+
48.	*Lymnaea stagnalis* (Linnaeus, 1758)		+	+	+	+

49.	*Stagnicola corvus* (Gmelin, 1791)	+	+	+	+	+
50.	*Stagnicola fuscus* (C. Pfeiffer, 1821)	+				
51.	*Stagnicola palustris* (O. F. Muller, 1774)		+	+	+	+
52.	*Stagnicola turricula* Held, 1836	+	+	+		+
53.	*Radix ampla* (W. Hartmann, 1821)	+	+	+		+
54.	*Radix auricularia* (Linnaeus, 1758)		+	+	+	+
55.	*Radix balthica* (Linnaeus, 1758)		+	+	+	+
56.	*Radix labiata* (Rossmassler, 1835)		+	+		+
57.	*Radix lagotis* (Schrank, 1803)	+				
58.	*Galba truncatula* (O. F. Muller, 1774)	+	+	+		+
59.	*Ancylus fluviatilis* O. F. Muller, 1774	+	+	+		+
60.	*Ferrissia (Pettancylus) clessiniana* (Jickeli, 1882)	+	+	+	+	+
61.	*Acroloxus lacustris* (Linnaeus, 1758)		+	+	+	+
62.	*Planorbis (Planorbis) carinatus* O. F. Muller, 1774	+	+	+	+	+
63.	*Planorbis (Planorbis) planorbis* (Linnaeus, 1758)	+	+	+	+	+
64.	*Anisus (Anisus) calculiformis* (Sandberger, 1874)		+	+		+
65.	*Anisus (Anisus) leucostoma* (Millet, 1813)		+			
66.	*Anisus (Anisus) spirorbis* (Linnaeus, 1758)			+	+	+
67.	*Anisus (Disculifer) vortex* (Linnaeus, 1758)		+	+		+
68.	*Anisus (Disculifer) vorticulus* Troschel, 1852		+	+	+	+
69.	*Bathyomphalus contortus* (Linnaeus, 1758)	+	+	+	+	+
70.	*Gyraulus (Armiger) crista* Linnaeus, 1758		+	+	+	+
71.	*Gyraulus (Gyraulus) acronicus* (A. Ferussac, 1807)	+	+	+		+
72.	*Gyraulus (Gyraulus) albus* (O. F. Muller, 1774)	+	+	+	+	+
73.	*Gyraulus (Gyraulus) chinensis* (Dunker, 1848)	+				
74.	*Gyraulus (Lamorbis) riparius* (Westerlund, 1865)	+	+			
75.	*Gyraulus (Lamorbis) rossmaessleri* (Auerswald, 1852)	+				
76.	*Gyraulus (Torquis) laevis* (Alder, 1838)			+	+	+
77.	*Hippeutis complanatus* (Linnaeus, 1758)		+	+	+	+
78.	*Segmentina nitida* (O. F. Muller, 1774)		+	+	+	+
79.	*Planorbarius corneus* (Linnaeus, 1758)	+	+	+	+	+
80.	*Oxyloma (Oxyloma) dunkeri* (L. Pfeiffer, 1865)		+	+	+	+
81.	*Oxyloma (Oxyloma) elegans* (Risso, 1826)		+	+	+	+
82.	*Oxyloma (Oxyloma) pinteri* Grossu, 1987			+		+
83.	*Oxyloma (Oxyloma) sarsii* (Esmark, 1886)	+				

5 Hypothetical modifications of the gastropod populations as an effect of global climate change

The Danubian-Carpathian space, located in the south-east of Europe, is quite close to the arid areas of the Near Orient. This may represent a model of climate evolution in Romania as part of this region.

The models of these changes emphasize that Romania faces a warming tendency, the forecasted temperature increase oscillating between 2.4 and 7.4°C (Bălteanu & Şerban 2005). Thus, the structures of the plant and animal populations will surely undergo significant modifications induced by the environmental factors.

Climatic changes will certainly affect water resources. The spring maximum flows will occur earlier; the water quality will significantly decrease due to high temperatures and the changed discharge. At the same time, due to the general increase of the sea level, salt water will affect the near-shore aquifers (Budyko 1999).

These modifications will obviously influence the life of the aquatic organisms, including the gastropods. A general image of the gastropods populating the Romanian river system emphasizes the individual ecological features (reproduction period, development rhythm, nature of benthic facies, food structure). In case climatic changes occur, these features will modify. Under these circumstances, certain species may disappear, while others may increase in number and frequency, exceeding the present limits (Busuioc 2003; Bălteanu & Şerban 2005).

The ecological requirements of gastropods represent an important parameter for forecasting their tendency of evolution. Thus, cryophilic and aerophilous species such as *Bythinella austriaca, B. cylindrica, Stagnicola palustris* ssp. *flavida* adapted to clean water may be limited in space or may disappear. On the contrary, ubiquitous species, *Lymnaea stagnalis, Radix ampla, Planorbis planorbis, Planorbarius corneus,* adapted to highly eutrophic and poly-saprobic water, may spread and become abundant since an increase in temperature will change hydrological features and water quality. If brackish water extends, the species *Theodoxus (Th.) euxinus, Pseudamnicola razelmiana, Turricaspia (Laevicaspia) lincta, T. dimidiata* tolerant to salt water will be favoured and become more frequent.

6 Conclusion

The global evaluation of the gastropod populations in the Danube – Carpathian hydrographic space represents an important part of the European malacofauna (Fauna Europaea 2005). It is worth mentioning that the highest species diversity (Table 1) is found in the Lower Danube, especially the Romanian part of the river, where the floodplain, the delta and the tributaries represent factors that enrich the biodiversity. The afore-mentioned ecological features of the gastropods can be a realistic criterion to reflect tendencies of evolution of population structures as influenced by realistic or hypothetical climate change scenarios.

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The influence of pH and temperature on the enzymatic activity of acidophilic heterotrophic microorganisms of the genus Acidiphilium

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Keywords: extremophiles, acidophilic bacteria, bioremediation, acid mine drainage

1 Introduction

The study of acidophilic microorganisms has gained increasing importance due to their adaptations to cope with extreme environments (Baker & Banfield 2003, Johnson & Hallberg 2005) but also due to their biotechnological applications in bioremediation of polluted areas or metallic ions recovery from low-grade ores and wastewater mine drainage (Johnson 2003, Johnson & Hallberg 2003). The ability of these microorganisms to adapt to various environmental conditions is extremely useful also for their use in the biosorption of metals from acidic mining effluents (Carlson 1998, Johnson 1998).

The tolerance of acidophilic bacteria to low pH (1-4) is the result of their adaptation, these species being able to maintain their cytoplasm pH near the neutral value (Matzke et al., 1997). Their enzymatic activity is influenced by the acidity and temperature levels (Norris & Johnson 1998, Gupta et al. 2003); on their turn, through their metabolic activity, the acidophilic bacteria modify the oxide-reduction potential of the environment (Cismasiu 2001, 2004, Cismasiu et al. 2004)

Acidiphilium is a genus, belonging to Eubacteria, phylogenetic division α-Proteobacteria, order Acetobacteraceae; its physiology is close to *Acidocella*, the two genera being frequently isolated from the same acidic habitats (Cismasiu 2004). Due to its heterotrophic nutrition, *Acidiphilium* has the possibility to develop in organic media (with different concentrations of proteins or sugars). As carbon source it uses many different carbohydrates such as: fructose, glucose, sucrose, maltose, cellobiose, xylose, starch and glycogen (Cismasiu et al. 2000, 2002, Dopson et al. 2003).

The aim of the study was to identify new organisms able to cope with the extreme environmental conditions from the mining areas and to isolate them in order to study their bioremediation potential. After isolating more strains from the acid effluents of the Ilba mining area (Maramureş, Romania), identified according to the morphological and physiological characteristics as being part of *Acidiphilium* genus (Cismasiu 2008), the study focused on their metabolic activity.

Since *Acidiphilium* is both a mesophilic and acidophilic microorganism, the influence of temperature and pH on its enzymatic activity was investigated. This paper presents the influence of these two parameters on the amylolitic activity of *Acidiphilium*; starch was selected as a substrate, representing both the carbon and the energetic source.

2 Material and Methods

Ilba mining area is located in the Northern part of Romania, near the border with Hungary and Ukraine, in Maramures county (Fig.1); although the mine was closed in 2001, acidic wastewaters still represent an environmental threat, especially due to their low pH and high heavy metals content, leading to the degradation of local terrestrial and aquatic habitats.

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Figure 1. *Location of Ilba mining area (white rectangle) (modified from www.google.earth.com)*

The samples were collected in spring 2005 from several effluents and the *Acidiphilium* strains presenting the highest metabolic activity were isolated for future studies (Cismasiu, 2008). The strains (Fig.2), were cultivated in GYE (glucose yeast extract) medium with 0.1% starch, pH 3.0, and incubation at 28^0C for 21 days.

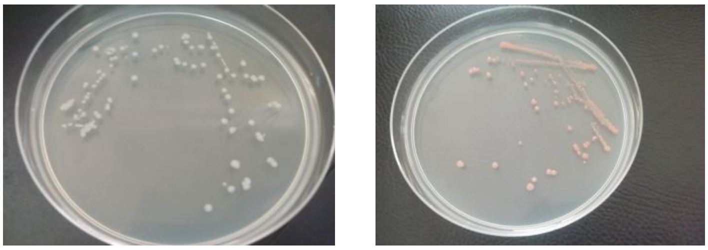


Figure 2. *Acidiphilium sp. (white and red colonies) isolated from mining effluents of Ilba area*

In order to establish the best conditions for the amylolitic activity of the *Acidiphilium* strains, several growth temperatures (15°C, 28°C, 37°C and 42°C) and pH - values (1.5, 2.0, 2.5, 3.0 and 3.5) were tested at different concentrations of starch substrate (1, 2, 3 g/l). These experiments were realized in 100 ml Erlenmeyer flasks, with 30 ml GYE medium and 10% inoculum. The microbial cultures were incubated for 7, 14 and 21 days under continuous agitation.

Starch hydrolysis was assessed by Wohlgemuth method (Gupta et al., 2003): the amylase hydrolyzes starch to simpler sugars which do not give the same color reaction with iodine. 3.5 ml starch solution was added to 0.25 ml triplicate samples and incubated 30 minutes at 37 °C; the reaction was stopped with HCl 1N. After adding a solution of iodine – potassium iodide 0.1 N, the hydrolysis intensity was assessed through spectrophotometer determination at 580 nm of the blue compounds formed between starch and iodine.

3 Results and Discussion

The coal and metal ore mines, and the neighboring areas, are known as extreme habitats (Kozlov & Zvereva, 2007); in the mine galleries, with the increase in depth, the temperature of the surrounding rocks keep rising: for instance, by 2000, in the Chinese coal mines the average depth was about 650 m and the temperature ranged between 35.9 – 36.8 °C (He, 2009). A similar situation is in Europe, where many mine galleries are now considered as geothermal heat exchangers, with the potential of being used as a renewable source of energy (Rodriguez & Diaz, 2009). Besides the high temperatures, the mining areas present usually high concentrations of heavy metals and very low pH (Johnson & Hallberg 2005).

Due to their adaptations, extremophile bacteria are able to cope with such environmental conditions. In our study, the investigations focused on the heterotrophic *Acidiphilium* sp. due to its ability to develop in such polluted areas and the potential bioremediation application. Strains isolated in previous studies (Cismasiu, 2008) were used to investigate its metabolic activity, this being the first attempt of its kind in Romania.

The comparative study of the amylolitic activity of *Acidiphilium* sp. at different growth temperatures and pH conditions revealed the highest activity at 28 and 37 °C, confirming the mesophilic characteristics of this genus. Even at these temperatures, their activity was high only in the first two weeks, decreasing in the third week, possibly due to the released metabolites; however, this hypothesis should be further corroborated.

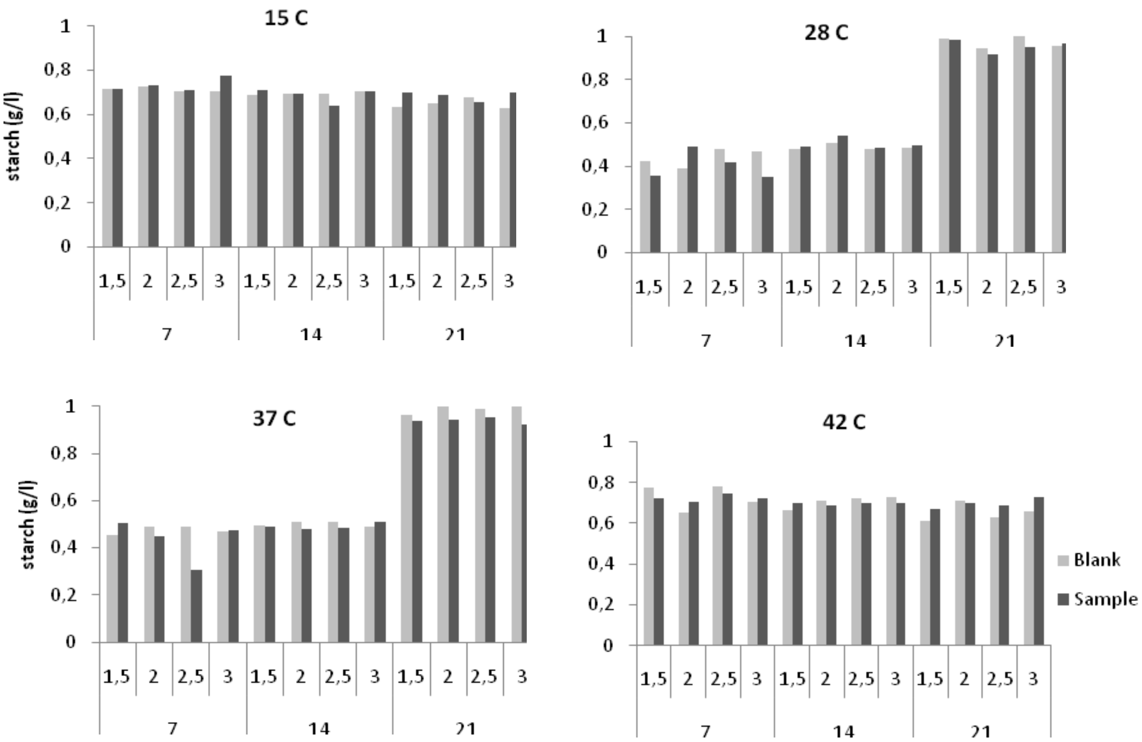
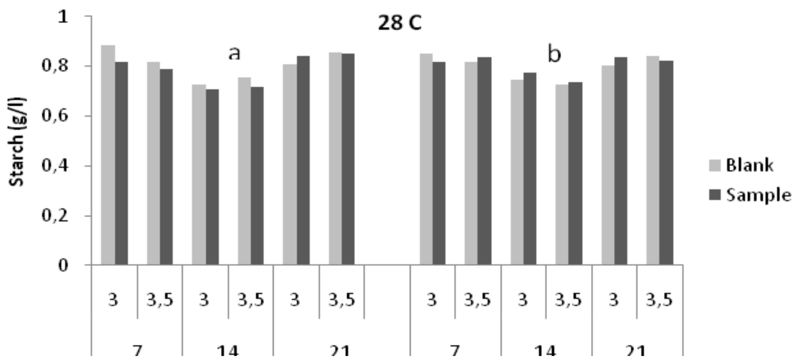


Figure 3. *Starch hydrolysing activity of Acidiphilium at different temperatures (15, 28, 37, 42 °C) and pH (1,5; 2; 2,5; 3), for several incubation periods (7, 14, 21 days). The highest activity was noticed between 28 and 37 °C. Substrate concentration: 1 g/l starch.*

As 28 and 37 °C were proven to be the best temperatures for the amylolitic activity of *Acidiphilium*, they were selected for further experiments, aiming to find the optimum substrate concentration; starch concentration was raised to 2 and 3 g/l, while pH was kept at 3 and 3.5 (Fig.4).

Although the substrate concentration increased, and an increased amount of hydrolyzed products was expected, the results indicated 1g/l as the optimum starch concentration (Fig. 3, 4), confirming previous studies (Popea 2002).

Previous studies of the *Acidiphilium* sp. isolated from different samples have shown that the bacteria isolated from the mine wastewater are more active than the lab cultures probably as a consequence of their adaptations to the high acidic conditions from the mine (Cismasiu, 2004).



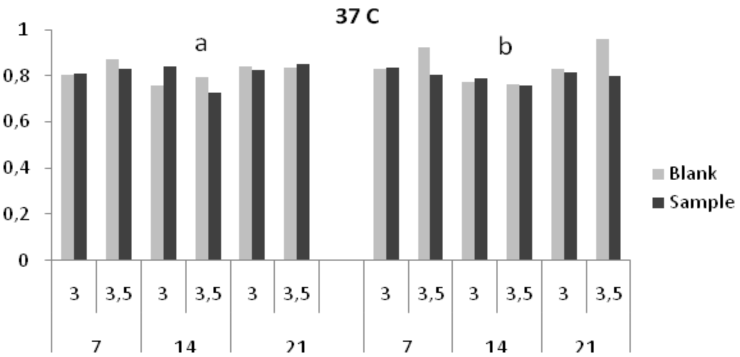


Figure 4. *Starch hydrolyzing activity of Acidiphilium sp. at 28 and 37°C, pH 3 and 3,5 with different substrate amount (a = 2 g starch, b = 3 g starch) and different incubation periods (7, 14, 21 days)*

4 Conclusions

The *Acidiphilium* strains isolated from the acid mine drainage of Ilba mining area exhibited the highest amylolitic activity at 28^0C and 37^0C, at pH 2,5 and 3. At 15^0C and 42^0C the microbial hydrolysis was not significant, proving the mesophilic character of this genus; these values are similar with those recorded at the sampling site (water temperature: 28 ^{0}C, pH = 2.5). The optimum substrate concentration was 0.1 % starch, while values higher than 0.2 % inhibited the metabolic activity.

Unlike other extremophiles, whose maximum metabolic activity occurs at higher temperatures and bigger depths, *Acidiphilium* sp. are able to cope with low pH even at 28 – 30 ^{0}C, the surface temperature of the acid mine drainage in Ilba area; their potential for bioremediation (e.g. retention of heavy metals) seems high and could be further investigated in a local pilot study. For instance, the mine wastewater could be passed through a column with absorbent material synthesized from yeasts and *Acidiphilium* cultures; the biomass could be further separated by filtration or centrifugation and used to recover the retained heavy metals.

Future studies will focus on identifying a narrower range of the optimum temperature where *Acidiphilium* presents its highest enzymatic activity, as well on the implementation of these results in the ecological reconstruction of Ilba mining area.

Acknowledgements

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Morphological evolution of riverbeds - case study: inferior sector of CIBIN RIVER upstream OF Sibiu (olt basin – Romania)

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Keywords: floodplain, meandering, morphometrical parameters, Cibin River, Romania.

1 Introduction

Fluvial geomorphology and riverbeds are subject of worldwide research (e.g., Blench, 1958; Leopold, Wolman, 1964; Schumm, 1977; Lewin, 1978, Thorne, 1982). Important studies have also been conducted on riverbeds in Romania (Diaconu, 1971; Ujvari, 1972; Ichim et al., 1989; Diaconu, Şerban, 1994), in particular the Danube (Panin, 1976) and rivers such as Moldova, Bistrița, Siret, Prut, Mureşul Superior, Trotuş (Bătucă, 1978; Ichim et al. 1980; Duma, 1988; Rădoane et al. 2003). Yet the riverbed of Cibin River has not been investigated in a systematic geomoprhological study. However, some qualitative and quantitative information and maps on the major streambed of Cibin River and the geomorphology of the Sibiu Depression (Sandu, 1998; Giuşcă, 2006) are available. For the development of the fluvial geomorphology database for the Cibin riverbed upstream of Sibiu we combined field work and complex bibliography including hydrological year-books and current or historical maps to compare and analyse the riverbed and morphometric variability dynamics.

2 Regional Conditions of the Genesis and Evolution of the Cibin Riverbed

The inferior sector of Cibin Valley completely overlaps with the Sibiu Depression situated near the geographical center of Romania. The hydrographical network shaped the relief to the present configuration: in the Miocene-Pliocene formations of the depression, the Cibin River formed in an erosive-accumulative manner with different intensities (differential erosion) a monoclinal structure (Geografia României, vol. III, 1987).

The rocks carved by the Cibin riverbed are friable. The variable thickness of the deposits, but especially their different erosion resistance influenced the Cibin riverbed typology and dynamics. The petrographic structure is represented through clays, marls, sands, gravels, in addition to plasters beds, polygenic conglomerates as well as sandstones. In the sector studied, the oldest formations are those of the Medium Miocene (Badenian) represented by thick deposits of white-grey marls, quartz gravels, and ferruginous sands identified in the south of the Cibin riverbed, in Poplaca. However, the Pannonian is the best represented period, through marl-loamy, loam-arenaceous, sandy deposits and gravels on the superior side. The quaternary formations are represented through weakly consolidated terrace deposits (sands, gravels) and recent alluvial deposits with fine granulometry and different thickness (Ciupagea *et.al*., 1970).

At the level of the entire Sibiu depression we notice a clear asymmetry of the relief which was imposed by the tendency of the Cibin riverbed to move towards the north and north-east. This resulted, on the right bank of the

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river, in an incision and the appearance of several successive forms of relief (submontaneous hills, piedmonts, terraces and floodplain). The Cibin meadow as the lowest level is permanently subject to seasonal flows, but also to the accidental influence of tributaries, floods and droughts. In the Sibiu depression, the Cibin meadow has two clearly differentiated sectors: the sector upstream of Sibiu (Gura Râului – Sibiu) in the west-east direction and the sector downstream of Sibiu (Sibiu – Tălmaciu) with a north-west–south-east orientation (Sandu, 1998). Our paper deals with the first sector.

Cibin is an allochthonous river originating in the Cindrel mountains at altitudes of over 1900m a.s.l. with a nival to pluvial-nival flow regime. The river was impacted by technical constructions upstream of Gura Râului (1973-1980), i.e. a concrete dam with abutments. The main purpose of this reservoir is to ensure the water supply of the city of Sibiu and adjacent towns. In consequence, the flow regime of the Cibin River has changed significantly as dependent on storage/release dam operation and on downstream hydrographical network. Hence, the multi-annual medium flow in Sibiu was reduced from 4.72 m^3/s, to 2.8 m^3/s. The sediments are retained by the dam (Ichim, Radoane, 1986) and only downstream tributaries as well as bank and riverbed erosion contribute to fluvial sediments. Water flow and sediment discharge were monitored during 1975 – 2005 at two hydrometric stations (Tab. 1).

Table 1. *Morphometric elements of the Cibin River basin and Cibin River flow rates.*

Point section	Distance from source (km)	Point altitude (m)	Basin surface F (km^2)	Average altitude Hmed (m)	Average slope of basin Imed (m/km)	Medium multiannual flow Q (mc/s) / q ($l/s/km^2$)	Average volume W_R (to/year)
p.h.Sibiu	51.6	403.0	506	943	35.7	4.72 / 9.4	34084.8
p.h. Talmaciu	76.4	364	2210	714	24.6	14.3 / 6.5	100992.0

3 Methodology

The present research was based on the analytical methods frequently used in fluvial geomorphology, on field mappings and on the quantitative methods used to obtain morphometric parameters; all these methods were adapted to the specific conditions of the Cibin River and the Sibiu depression. The dynamics of the major and minor bed of Cibin River was studied on the basis of several topographic maps: the *Hermannstadt mit seinem Umgebungen* military map – 1838, 1:28,800 scale; General-Karte von Mitteleuropa, the Hermannstadt-Sibiu sheet – 1898, 1:200,000 scale; the Nagy-Szeben (Hermannstadt) Austrian map – 1907, 1:75,000 scale; the topographic map 1:25,000 for the Sibiu Depression 1982 edition; and orthophotoplans produced during 2005. In order to update the information on older maps we made use of similar information on the topographic map of 1982 and the orthophotoplan. For geo-references and accurate morphometric measurements we used GIS software. The field research and the detailed morphometric analysis enabled us to identify the morphological changes of the Cibin meadow between Orlat and Sibiu. The data obtained through calculations and measurements was not fully introduced in this material. The emphasis was on changes in the major riverbed in the sector upstream of Sibiur where the meandering is more significant as well as in the minor riverbed.

4 Results and data interpretation

The quantitative analysis of the relief and the morphometric indexes illustrate the spatial distribution of the forms of relief and the intensity of current geomorphologic processes and the different stages of evolution of the sector. The morphometric measurements were performed in the alluvial plain of Cibin, respectively in the active strip

(Ichim et.*al*., 1989) located on both sides of the minor riverbed with elevations from 10 to 15 m; this strip includes the major riverbed and the first terrace – with a relative height of 5 – 10 m. At the edge of the major riverbed several human settlements, i.e. Gura Râului, Orlat, Cristian, Sibiu, and communication networks (DN1-E81, railway) are located. Morphometric measurements have been performed in this perimeter, on the major riverbed through cross sections perpendicular to the minor riverbed, drawn at distances of 1 km (fig.1; Tab.2). The meanders of Cibin River were numbered from upstream to downstream (fig.2) and bend radius, wave amplitude and length were measured (Tab.3). In order to determine the riverbed type we calculated sinuosity coefficients on representative sectors by comparing the minor riverbed length to the wave length of the meander (Tabs.2, 3); values below 1.5 indicate a sinuous riverbed, values equal or greater than 1.5 indicate a meandering riverbed (Leopold, Wolman 1957, qtd by Ichim et al., 1989). The data obtained was statistically processed on classes of values, frequencies of distribution in order to highlight the morphometric variability of riverbed and to study river behavior on the sector. Finally we resorted to the mapping of riverbed sectors and identified evolution phases and tendencies.

4.1 The Major Riverbed

The Cibin meadow between Gura Râului and Sibiu is wide, with bilateral development depending on the fluctuations in time of the water flow and sediment discharge of Cibin River. The width of the meadow varies between 1,300 – 2,500 m, with a maximum value in Orlat.

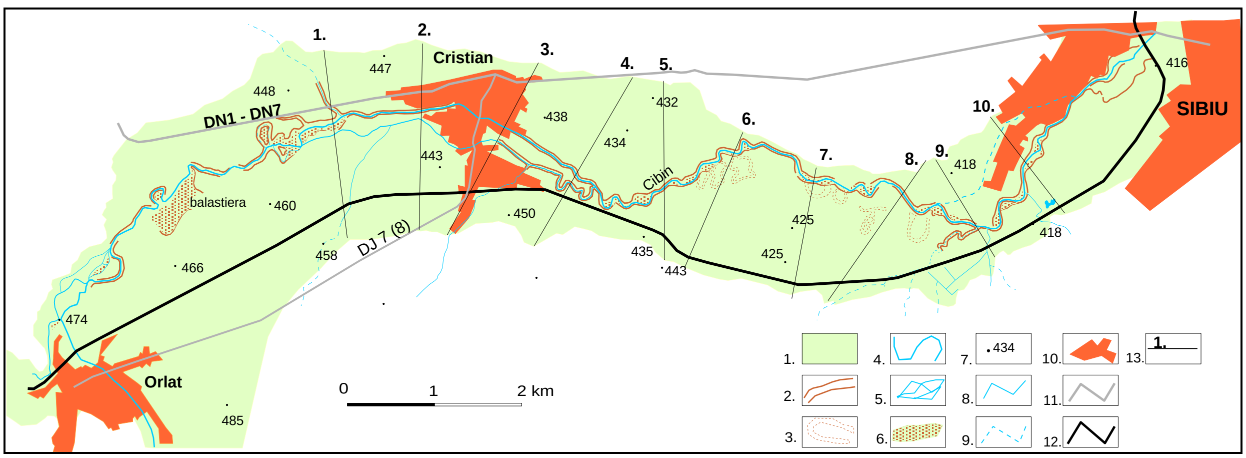

Figure 1. *The major Cibin riverbed upstream of Sibiu: 1. major riverbed; 2. steep banks; 3.abandoned meanders – ancient riverbed ; 4. current meanders; 5. scatterings; 6. sands and gravels accumulations in the minor riverbed; 7. heights; 8. permanent water flow; 9.temporary water flow; 10. settlements; 11. road; 12. railway; 13. sections*

Table 2. *Morphometric characteristics of the Cibin riverbed (for selected cross-sections)*

Nr. Sect.	Actual floodplain width (m)			Riverbed length Lr (m)					Distance (m) from	
	total	left	right	L dr.	Actual L sin.	Actual K sin.	1838 L sin	1838 K sin	Railway Left/right	Road DN1-E81
1.	2200	750	1450	1000	1050	1.05	1123	1.12	-/1025	125/1700
2.	2250	800	1450	1000	1075	1.08	1267	1.27	-/1000	200/1300
3.	2250	900	1350	1000	1050	1.05	1785.6	1.79	-/775	675/-

4.	2300	1425	875	100 0	1738	1.74	1324.8	1.33	-/275	1425/-
5.	2550	1175	1375	100 0	1400	1.4	1238.4	1.24	-/750	675/-
6.	1775	175	1600	100 0	1175	1.18	1526.4	1.55	-/1475	-
7.	1600	150	1450	100 0	1300	1.3	2282.0	2.82	-/1275	-
8.	2075	875	1200	100 0	1050	1.05	1872	1.87	-/1050	-
9.	1375	975	400	100 0	1300	1.3	1584	1.58	-/175	-

To the west of Turnişor and in the Ștrand district (districts of Sibiu), the meadow is 0.5 – 1 km wide. The slope is very low (0 – 2°) and the altitude of the meadow decreases in the flowing direction of Cibin River, the last one being developed along the river at altitudes of 485 – 470 – 460 m a.s.l. between Gura Râului and Orlat, at 410 - 418 m a.s.l. on the west side upstream of Turnişor and gradually descending to 396 m – 405 m a.s.l. on the south-eastern side of Sibiu city. Between Cristian and Sibiu, the major riverbed of Cibin River displays a clear asymmetry between sections 5 and 8 and morphometric variability on the two sides of the river due to the migration of the Cibin River flow and to the deflecting gravel cones discharged by tributaries. In this sense, Ichim et al. (1980) considered that the meandering of the minor riverbed entailed the meandering of the major riverbed as well, and this is quite apparent in this sector of Cibin River.

On the right side, the alluvial plain gradually and subtly makes the transition towards the superior terraces of the Cibin River, while on the left side it is clearly delimitated from the terrace front-side of the river's second terrace. Between Cristian and Sibiu the major riverbed records the lowest width on the left side (150 – 175 m). The main cause is the migration of the Cibin River flow towards north as a result of the meandering processes, which determined the evolution on the right side of some cut-off meanders, loops and hillocks. The large quantity of clay, from the alluvial deposits of Cibin River and of its tributaries and their impermeability determines in this sector the rising of the groundwater level in the meadow and some permanent or temporary plashes which maintain the phytocenoses of wetlands. The human settlements of Gura Râului, Orlat, Cristian and Sibiu are crossed by the minor riverbed of Cibin River which is channellized in the incorporated area**.** Nevertheless, the risk of being affected by floods is quite high.

4.2 The Minor Riverbed

Upstream of Sibiu, Cibin River presents a sequence of types of riverbeds: unitary, right, sinuous, meandering and anabranching (Schumm, 1985; Leopold et.al,1964, qtd by Ichim et. al., 1989). The differentiation between these sectors was made on the basis of the morphometric parameters of the minor riverbed: length, width, sinuosity coefficient, scattering coefficient (Tab.2, 3; fig.2). The type of meandering-interlaced riverbed with islets and lateral banks can be seen downstream of Orlat, given the existence of an alluvial bed mainly built up of blocks (40 x 20 x 30 cm), coarse gravels (2 – 5 cm) and coarse sands. This type is conditioned also by the significant contribution of the Sălişte creek, left tributary of Cibin River downstream of Orlat at an altitude of 474 m a.s.l. The interlaced riverbed can be seen near Cristian village on a length of about 3 km, out of which 1 km is channellized. The scattering coefficient is 1.91. In the scattered area, the minor riverbed has a width of 11 m, a depth of 0.6 m and the bottom is made up of sands. Predominant are lateral accumulations in the form of sandy banks with a width of 50 – 100 m. In the interlacing area, at about 1.250 km downstream of Cristian the sinuosity of the minor riverbeds of the two running channels increases, and the inferior one becomes even more meandered (Ks - 2.35).

Between Cristian and Sibiu, Cibin River has a sinuous riverbed with lateral bar (Thorne, 1982). The alluvial flow influences the mobility of the riverbed in this sector; the annual average sediment discharge is 34084.8 to/year, and the multi-annual average silt charge is 240 g/m^3. Of great significance for the formation of sediment discharge is the composition of the lithologic substrate mainly consisting of marls and clays. Because of the decrease in coarse sediment transport (due to the upstream dam) and the predominance of suspended material, the banks resistance increases and the river erodes in depth. Thus, the banks of the minor riverbed have heights ranging from 1.5 to 3 m, mostly fixed. In this situation, the discharged alluvia are mainly the result of instream erosion rather than basin-wide processes.

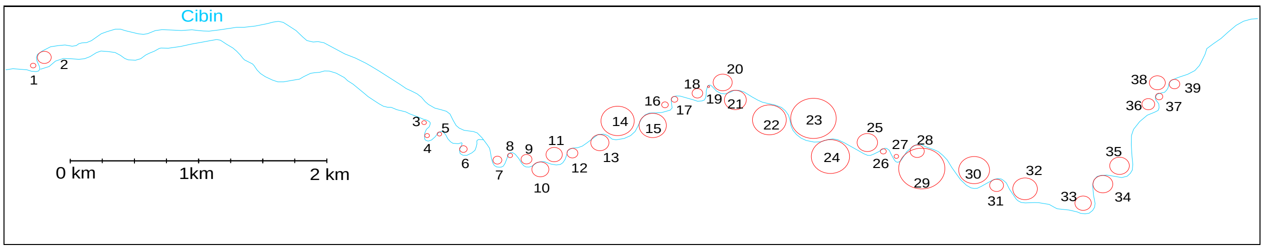

Figure 2. *Meandering sectors upstream Sibiu – model for calculating the morphometric parameters*

Table 3. *Morphometric parameters of the meanders of the Cibin River upstream of Sibiu (centralized data model)*

No. Meand.	Rc (m)	A (m)	L(m)	No. Meand.	Rc (m)	A (m)	L (m)	No. Meand.	Rc (m)	A (m)	L (m)
1.	35.95	125	500	14.	150.62	125	450	27.	32.14	150	212.5
2.	70.27	125		15.	185.65	75		28.	71.31	-	525
3.	32.55	150	250	16.	40.86	75	275	29.	202.81	375	
4.	32.00	150		17.	40.57	150		30.	139.88	375	

The sinuosity of the Cibin riverbed significantly increases (Tab.3) because the sediment load is mainly composed of fine alluvia (mud, sands) and fine stratified and well-compacted gravels, becoming even **a highly-meandered riverbed** between sections 4-5, 5-6, 7-8, 9-10 (fig.1). The meandering is free because of the low resistance of the alluvial bed. The meanders have amplitudes ranging from 25 to 375 m, a wave length of 200 – 575 m and a bend radius (Rc) ranging from 22 to 202 m. The most frequent are the free meanders with a bend radius of 50 – 100 m (fig.3, Tab.3). Riverbed mobility in this sector is proved on the basis of cartographic materials dating from 1838, 1898, 1907, 1982, and 2005 which show the position of the minor riverbed in those respective years (fig.1, Tab.2). In the last century, the migration of the Cibin River towards north is obvious; meanders shifted downstream and formed oxbows. The comparison of maps reveals a meandering running channel with numerous oxbows featuring marshes in the meadow landscape. They have eroded deep banks (-2; - 3 m) in the concave loops and accumulated banks in the convex loops. In the minor riverbed, there is a new meadow level, as a result of sediment accumulation and bank stabilization by hydrophilic grassy vegetation.

5 Conclusion

In conclusion, the changes in the Cibin riverbed in the Gura Râului - Sibiu sector are the result of a complex interaction of natural morphodynamics and anthropogenic impacts. The most significant lateral expansion was recorded after 1900. Downstream of Gura Râului the hydraulic power transmission reduces and the river meanders to achieve balance profile. The river energy remains quite high because of the slope between Gura Râului and Sibiu which is around 4.7 m/km. The change in the horizontal plane of the riverbed is an expression of water energy in the conditions of small-size alluvial constitutes of riverbed. The time range 1950 - 1975 was characterized by an unevenness of the hydrological regime due to the variability of the rainfall regime which surpluses during 1970 to 1975. The instability in the horizontal plane can be explained by the amount of silt carried by the river, which was higher during this period. The gravel pave of Orlat has maintained the meandering tendency of the river.The riverbed becomes clogged downstream, increasing the opportunities of flooding and mobility because of the deepening of thalweg in the exploitation perimeter. This is obvious for the secondary channel in Cristian as well as for the secondary channel of 1898, upstream of Turnisor which has gradually become the running channel with tendency to meander. The evolution of the riverbed has also an environmental significance by changing the aquatic habitats and the riparian habitats or the meadow by creating wetlands habitats of a great societal and scientific interest. Moreover, agriculture and human settlements are affected through changes in channels and hydraulic parameters after the dam construction (1980). Within this framework, the study of the dynamics of riverbeds is given an interdisciplinary character.

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Water chemical characteristics and the spatio-temporal patterns of zooplankton assemblages in a side arm of the Danube (rkm 1437-1440, Hungary)

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Keywords: Danube, floodplain, chemical characteristics, zooplankton

1 Introduction

Natural river-floodplain systems are characterised by a large variety of aquatic habitats (Junk et al. 1989). The physico-chemical characteristics and zooplankton dynamics of these habitats are highly dependent on the hydrological regime (Baranyi et al. 2002, Mitsch & Gosselink 2007). Changes in the river discharge, patterns of expansion and contraction are the main determining factors of the biological diversity and the habitat heterogeneity in the floodplain water bodies (Tockner et al. 2000).

The features of these water bodies can vary from lotic to lentic depending on the degree of connectivity and the hydrological fluctuations in the main arm. The hydrological linkage between the side arms and the main arm is essential with regard to the nutrient cycle. Side arms isolated from the main channel for most of the year have a lentic character and a longer water residence time; hence, internal processes (i.e. internal nutrient cycle) are promoted and there is a higher nutrient retention potential (Glińska-Lewczuk 2009).

Nutrient retention of the wetlands situated along the Danube has been elucidated in many previous works (Cristofor et al. 1993, Garnier et al. 2002, Hein et al. 2004 etc.), while there are only a few respective data of the Gemenc and Béda-Karapancsa floodplains.

The aim of this study was to examine the habitat conditions based on the physico-chemical features of the water and the zooplankton dynamics in the Külső-Béda plesiopotamal side arm in function of changes in water discharge of the main arm. The Külső-Béda is a side arm, with high natural value situated in the Béda-Karapancsa Landscape Protection Area of the Danube-Dráva National Park. It came into existence in the 19th century during river regulation and flood control works on the Danube, which induced drainage and alterations of the ecological conditions in the side arm.

2 Materials and Methods

Study site and sampling time

The Külső-Béda is a plesiopotamal type side arm, i.e. having limited connectivity with the main channel, with junctions with the Danube at rkm 1440.5 (upstream) and rkm 1437.5 (mouth). Its open water area is 4 km long, 90 m wide on average and about 2.5 m deep (Fig. 1). The threshold water level of its mouth is 120 cm at Mohács and only at high water levels (630 cm at Mohács, rkm 1447) water is flowing from the junction.

The physico-chemical characteristics and the zooplankton assemblages (Rotifera, Cladocera, Copepoda) were examined in the Külső-Béda (BDU) at six sampling sites: BDU1, BDU2, BDU22, BDU3, BDU4, BDU5, situated at 450-750 m distance from each other (Fig. 1) and at four sampling times (Fig. 2). Reference samples were taken simultaneously from Danube at rkm 1447.

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Water chemistry

The temperature, pH, electrical conductivity and oxygen concentration of the water were determined in situ with Multi 340i meter (WTW). The sodium, potassium, calcium, magnesium, ammonium, chloride, nitrite, nitrate and sulphate concentrations were determined by DX-120 ionchromatograph (Dionex); the dissolved organic (DOC), inorganic (DIC), total (DTC) carbon and the dissolved total nitrogen (DTN) concentrations by TOC analyser (Elementar-liqui-TOC); the CO_3^{2-}, HCO_3^{-}, chlorophyll-a, suspended matter, soluble reactive (SRP) and the dissolved total phosphorus (DTP) concentrations of the water were determined in the laboratory by standard analytical methods (Golterman et al. 1978).

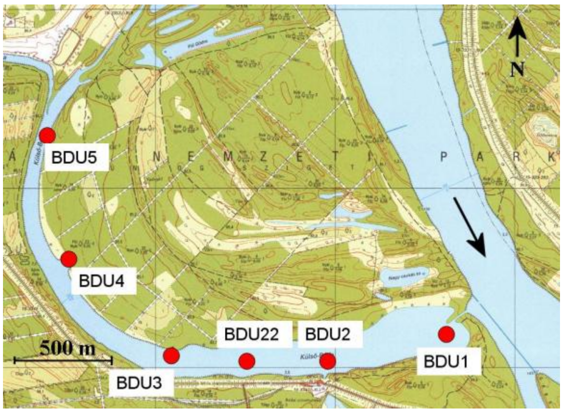

Figure 1. *Sampling sites at Külső-Béda (BDU) and at Danube (rkm D 1447)*

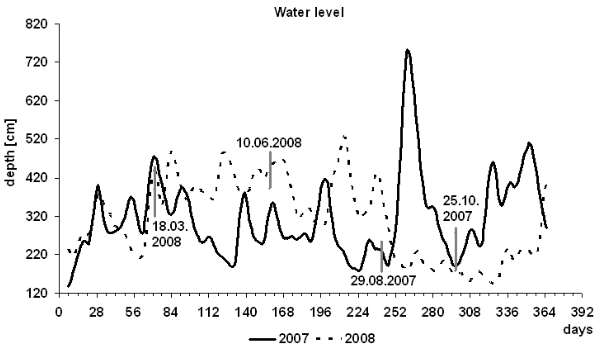

Figure 2. *Water level fluctuations at Mohács (Danube rkm 1447) and sampling dates*

Zooplankton

Planktonic rotifer and microcrustacean species (Cladocera, Ostracoda, Copepoda) were sampled separately: 10 l of water were filtered through a mesh of 40 µm for the rotifer and 50 l through a mesh of 70 µm for the microcrustacean species. Samples were preserved in 4% formaldehyde solution. Nikon SMZ stereo microscope and Olympus light microscope were used for identification and counting individuals. Juvenile stages of copepods (copepodids) were incorporated in the total number of copepods.

Data were analysed by hierarchical cluster (HC) and principal component (PCA) analyses by using the Past (Hammer et al. 2001) and Statistica program packages.

3 Results and Discussion

The changes in water level of the Danube (rkm 1447) during the investigated periods of two consecutive years: 2007 and 2008 is presented in Figure 2.

Water chemistry

Remarkable differences were found between chemical parameters of the main and side arms (BDU) and among the sampling sites of the side arm, which were caused by the water regime of the main arm inducing seasonal changes in the biotic and abiotic parameters.

The pH, conductivity, sodium, magnesium, calcium and sulphate concentrations in most of the cases were higher in the side than in the main arm (Tab. 1).

Table 1. *The main physico-chemical parameters in the Külső-Béda (BDU) and in the Danube at rkm 1447*

Site		pH	T	Cond.	O_2	Na^+	K^+	Mg^{2+}	Ca^{2+}	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}
			C°	μScm^{-1}	%	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}
BDU	**min.**	**7.6**	**8.4**	**300.0**	**83.0**	**9.4**	**2.4**	**11.6**	**26.1**	**78.6**	**0.0**	**13.9**	**25.7**
	max.	**8.8**	**26.8**	**752.0**	**169.5**	**34.3**	**3.5**	**24.0**	**100.7**	**347.3**	**49.3**	**31.7**	**59.2**
Danube	**min.**	**7.3**	**9.7**	**340.0**	**96.6**	**9.8**	**2.1**	**8.5**	**38.8**	**135.5**	**0.0**	**21.6**	**22.2**
	max.	**8.3**	**24.8**	**454.0**	**129.0**	**17.0**	**5.9**	**15.1**	**61.9**	**203.3**	**38.8**	**24.6**	**36.5**

The N concentrations were lower in BDU than in the main channel (D rkm 1447) (Tab. 2), the nitrate concentrations by 2-100%, the ammonium by 23-96% (except from 25.10.2007) and the TDN by 12-81%. Also lower P concentrations (SRP and DTP) were measured in the side arm. The lower nutrient concentrations in the BDU demonstrate the role of floodplain waters in nutrient retention e.g. denitrification and sedimentation, which are higher in the floodplain than in the main channel (Venterink et al. 2003). The nitrate concentration decreased with distance from the main arm and this was associated by an increase in the concentration of HCO_3^-, which suggests that the intensity of denitrification processes, mediated by the microbial oxidation of organic carbon (Kim et al. 2009) also increase with distance from the main arm. This process is essential for N removal and water purification.

Contrary to the N and P concentrations, the C concentrations at BDU in most of the cases exceeded those in the main arm (the DTC by 3-37%, the DOC by 0.4-47% and the DIC by 2-39%) and increased with distance from the main arm. From among the measured C forms the DOC is one of the most important components of the aquatic food webs (Guéguen et al. 2006).

The chlorophyll-a concentrations varied between 8.0-129.9 µg l^{-1} (Tab. 2); higher chlorophyll-a concentrations were measured in the side arm. The high chlorophyll-a values might have been the reason for an algal bloom and suggest the contribution of phytoplankton to the DOC of autochthon origin (Guéguen et al. 2006). The chlorophyll-a concentrations in most of the cases positively correlated with the examined nutrient concentrations.

Table 2. *The nutrient, chlorophyll-a and suspended matter concentrations of the water in the Külső-Béda*

Site		Susp.m	Chl-a	NO_2^-N	NO_3^-N	NH_4^+N	DTN	SRP	DTP	DIC	DOC	DTC
		mgl^{-1}	μgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	μgl^{-1}	μgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}
BDU	**min.**	**2.0**	**8.0**	**0.00**	**0.00**	**0.00**	**0.86**	**0.07**	**14.07**	**22.05**	**4.67**	**31.12**
	max.	**50.8**	**129.9**	**0.12**	**2.83**	**0.49**	**2.02**	**32.22**	**42.62**	**63.40**	**26.08**	**81.48**
Danube	**min.**	**10.4**	**4.9**	**0.00**	**0.90**	**0.00**	**1.76**	**0.16**	**47.04**	**26.77**	**5.09**	**31.86**
	max.	**24.4**	**36.4**	**0.03**	**2.88**	**0.14**	**2.59**	**61.79**	**50.89**	**38.80**	**12.23**	**51.03**

Classification of the sampling sites based on the chemical parameters of the water

The relationship between the sampling sites and the chemical parameters of the water were determined by hierarchical cluster and principal component analyses on each sampling time (Fig. 3).

The farthest sampling site from the main arm, BDU5 represented the first similarity group on 29.8.2007 and 18.3.2008 and its separation was mainly determined by the electrical conductivity, DTC, DIC at both sampling times. The second similarity group involved two further sub-groups: when the water level was low (239 cm at Mohács, on 29.8.2007) BDU1, BDU2, BDU4 and BDU22, BDU3 were separated from the main arm (DU), but when the water level was high (453 cm on 18.3.2008) the sampling sites situated close to the main arm (BDU1, BDU2, BDU22) were in the same group with the main arm (DU) and were separated from the sampling sites distant from the main arm (BDU3, BDU4). On 25.10.2007 and 10.6.2008 the first similarity group was represented by the sampling sites situated in the side arm and the second group by the main arm (DU). At low water level (207 cm on 25.10.2007, after a flood event) the sampling site BDU5 was separated from the other sites of the side arm, while at high water level (487 cm on 10.6.2008) it was in the same group with the sampling sites close to the main arm: BDU22, BDU2, BDU1 (Fig. 3).

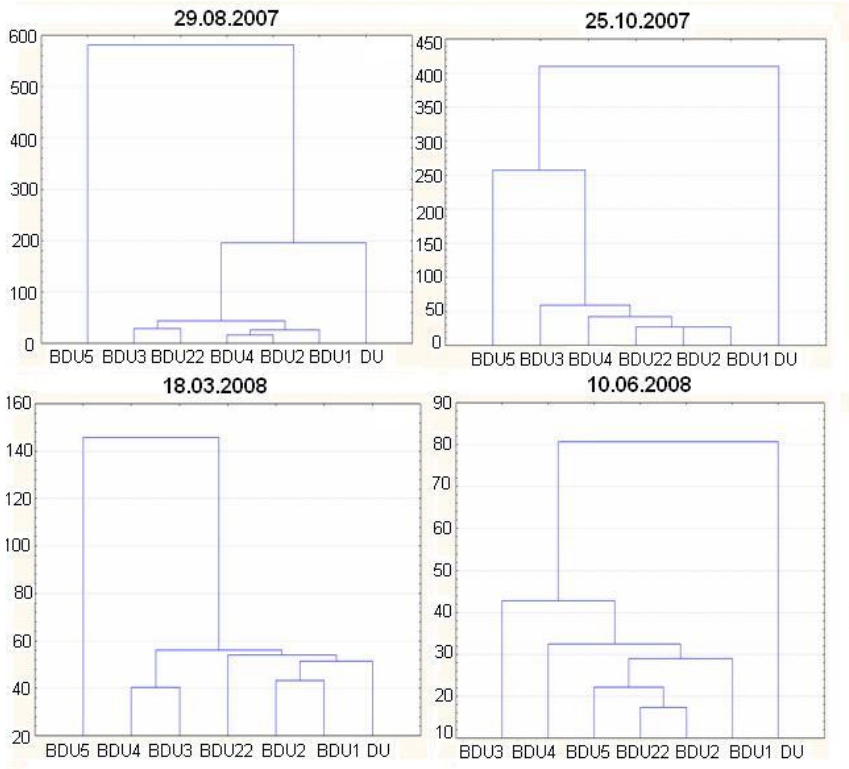

Figure 3. *Comparison of sampling sites based on the chemical characteristics of the water*

Zooplankton

24 Rotifer and 21 Crustacea taxa were found in the BDU during the investigation period. The rotifer abundance ranged from 160 to 560 ind. l^{-1} and the microcrustacean abundance from 0.04 to 450.2 ind. l^{-1}, while in the main arm the average number of rotifers and of the microcrustaceans was 38.5 ind l^{-1} and 1.7 ind l^{-1}, respectively.

Among the rotifer taxa Brachionus homoceros and B. forficula are rare in Hungary and in the last years have been reported only from the floodplain water of Gemenc by Schöll (2009). 13 Cladocera, 7 Copepoda and 1 Ostracoda taxa were identified and Copepoda (especially Thermocyclops oithonoides) clearly dominated by 82% in the main arm and 88% in the side arm. The zooplankton densities negatively correlated with the water level of the main arm.

Classification of the sampling based on rotifer densities

Remarkable differences were observed between the rotifer samples of the main and side arms except from 29.8.2007. Lower rotifer species number, diversity and density occurred in the main arm, caused by the characteristic high flow velocity, which inhibits rotifer reproduction and due to lower temperatures phytoplankton productivity, serving as a food source for rotifers. The temperature and hydrological regime play a major role in structuring the habitat conditions and biotic communities in the floodplain ecosystems (Tockner et al. 2000). The sampling sites of the side arm (BDU1-5) differed corresponding to their proximity; neighbouring sites were more similar (e.g. BDU4-5, BDU2-3, Fig. 4), independent of water levels of the main arm (18.3.2008: 453 cm, 10.6.2008: 487 cm). Site BDU1 situated close to the mouth of the side arm made an exception, as it was most likely affected by the main arm (backflow). On 29.8.2007 the similarity of sampling sites differed from the above described pattern, this was not significant as species and individual numbers were too small for HC and PCA analysis. The cause of the low species number and abundance is unknown; similar fluctuations in density and diversity occur from time to times most likely triggered by short generation time (7-9 days) of rotifers. Hydrological influence could be excluded as the water level of the main arm was low (201 cm) at this sampling time and in the previous week.

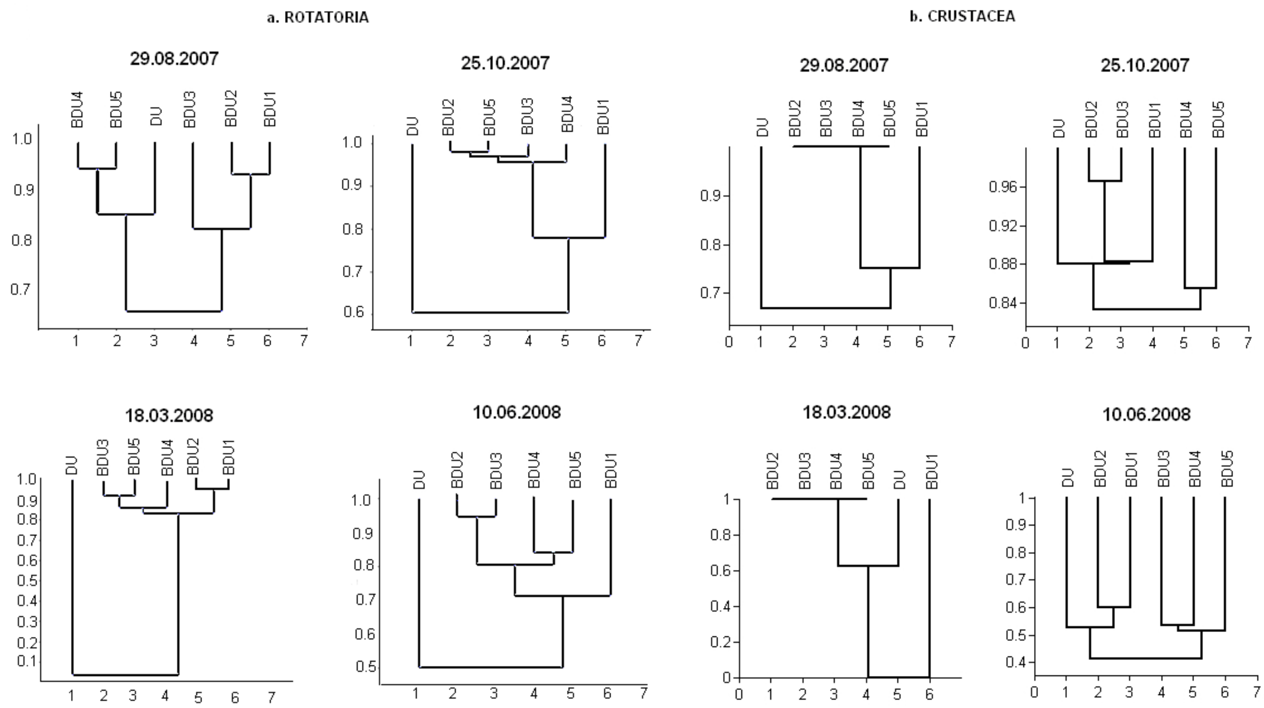

Figure 4. *Comparison of sampling sites based on rotifer and micro-crustacean densities*

Classification of the sampling sites based on microcrustacean densities

Similar to rotifers microcrustaceans showed different abundance in the main and side arm, especially in 2007 at low water period (Fig. 4). The crustacean assemblages of the side arm on 29.8.2007 and 18.3.2008 were very similar. In March 2008 the abundance was very low at all sites (especially in BDU1); because of the inhibitory effect of low temperature values (8.4-9.9 °C) mostly copepodids were present. In August 2007 (water level: 239 cm) the composition of assemblages were similar in the side arm, but copepod abundance increased significantly with distance from the main arm. On 25.10.2007 and 10.6.2008 the taxon number and diversity of assemblages were maximum at the farthest sites of the side arm (BDU4-5), presumably because of the slower water flow at the end of the side arm. These results showed that the temperature and the hydrological regime were the most important variables affecting the microcrustacean assemblages of the side arm.

4 Conclusions

The nutrient concentrations (N and P forms) were lower, while the concentrations of the C forms were higher in the side arm as compared to the main arm, which demonstrated the nutrient retention function of the Külső–Béda plesiopotamal side arm. The zooplankton densities and diversities were higher in the side arm than in the main arm (these differences increased with the distance from the mouth of the side arm) and beside the seasonal variation, interacted with the changes in the water regime and habitat heterogeneity of the side arm. The monitoring of zooplankton groups provides quick information about the ecological changes of waters, because of their short life-cycle, high mobility and complex species composition.

Our results reflected that the habitat diversity based on the chemical heterogeneity of the water was interrelated with the hydrology and increased the zooplankton densities and diversities in the Külső-Béda side arm, which belongs to the active floodplain zone of the Béda-Karapancsa Landscape Protection Area of the Danube-Dráva National Park.

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Importance of the Danube River in spreading the infection of red deer with *Fascioloides magna* in eastern Croatia

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Keywords: Danube, Fascioloides magna, eastern Croatia, red deer

1 Introduction

Large American liver fluke (*Fascioloides magna*) is a trematode which lives in the liver parenchyma of various wild and domestic ruminants, causing a disease - fascioloidosis. This parasite, native to North America (Mulvey 1991), has been introduced to Europe with wapiti deer (*Cervus elaphus canadensis*) through Italy in 1865. It was sporadically found in Cuba (Lorenzo et al. 1989), South Africa and Australia. From Italy it spread in the 1930s to Germany and Poland, and further to the Czech Republic (in 1960), Austria, Slovakia and Hungary (Erhardova-Kotrla 1971; Rajsky et al. 1994; Majoros & Sztojkov 1994; Ursprung et al. 2006). This specific distribution route mainly follows the Danube River course. It was suggested that *Fascioloides magna* was introduced from Slovakia to Hungary during the seasonal migration of red deer. The occurrence is also confined to the Danube inundation area due to presence of an intermediate host, freshwater snail *Lymnaea truncatula* (Špakulová et al. 1997).

Based on the migration routes of red deer, it is anticipated that fluke will reach the Croatian territory. It was recorded for the first time in January 2000, during liver examination of shot red deer from the Danube region (Marinculić et al. 2002). The aim of this study was to indicate the importance of the Danube River in distribution of *Fascioloides magna* in Croatia, and to foresee its further expansion.

Although many species are susceptible to infection, the common definitive hosts of the fluke in North America are wapiti (*Cervus elaphus canadensis*), white-tailed deer (*Odocoileus virginianus*) and caribou (*Rangifer tarandus*), while in Europe it occurs commonly in red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*). Among domestic animals, cattle are parasitized commonly, but usually are aberrant dead-end hosts, while infection is usually fatal in sheep and goat (Foreyt 1990). First case of *Fascioloides magna* infection in horse was reported by McClanahan et al. (2005) from a horse grazing in a marshy area of Central Minnesota (USA). Infection of the final host occurs via ingestion of metacercariae from herbage. Juvenile flukes emerge from the metacercariae in the stomach and intestine and migrate through the abdominal cavity into the liver. Mature flukes are enclosed in fibrous capsules within the liver parenchyma. The capsule contains a great mass of eggs and is connected to bile-ducts. The eggs are passed together with bile into the bile collecting system, enter the small intestine, and leave the definitive host along with the faeces. Some of the clinical signs are lethargy, weight loss and decreased quality of antlers in cervids.

2 Materials and methods

Faecal samples of red deer (*Cervus elaphus* L.) were collected from 2001 to 2004 in six hunting grounds in Baranja region in eastern Croatia (Figure 1). Along the Danube course are situated: “Šarkanj-Vrblje” (rkm 1433-1426) and “Podunavlje-Podravlje” (rkm 1425-1382), in which *Fascioloides magna* was recorded for the first time

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in Croatia. Two hunting grounds: “Haljevo” and “Koha-Kozarac” are situated in the middle part of Baranja, on higher level outside the reach of floods. The remaining two: “Podravlje” and “Munjoroš” are situated along the left bank of the Drava River, upstream of the City of Osijek.

Sedimentation technique and modified McMaster method (Thienpont et al. 1979) were used for the diagnosis and estimating *Fascioloides magna* eggs in the faecal samples Eggs were detected and counted in Petri dishes using a dissecting microscope (magnification 100-200 x). Arithmetical mean of eggs per gram of faeces, and prevalence as relative amount of positive samples were calculated for each locality. The statistical analysis was carried out by the computer program STATISTICA (StatSoft 2005).

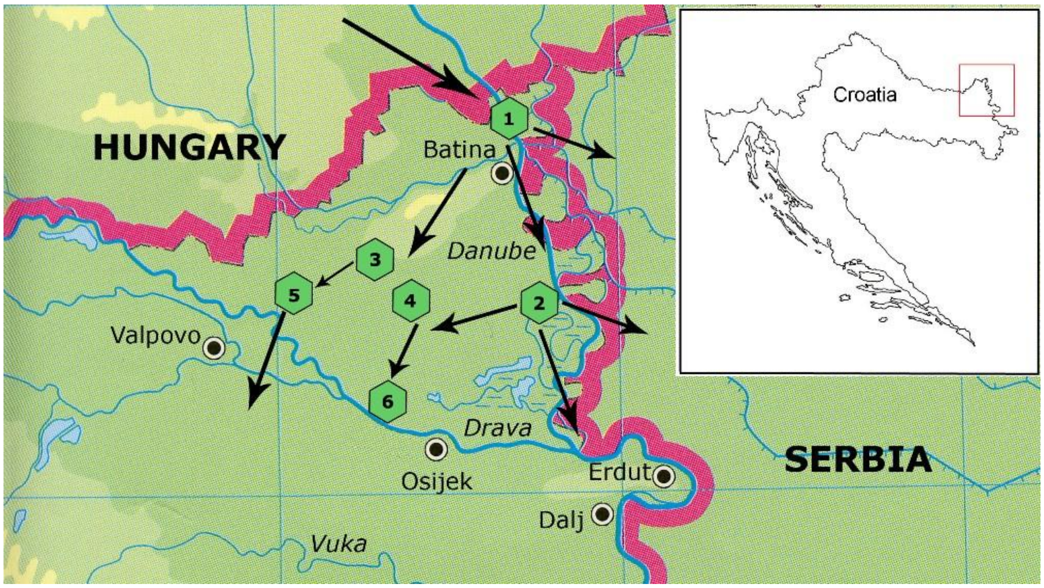

Figure 1. *Map of the study area. Numbers indicate the location of the investigated hunting grounds: 1-“Šarkanj-Vrblje”; 2-“Podunavlje-Podravlje”; 3-“Haljevo”; 4-“Koha-Kozarac”; 5-“Podravlje”; 6-“Munjoroš”. Arrows indicate routes of Fascioloides magna spreading.*

3 Results and discussion

First evidence of fascioloidosis in Croatia arose in winter 1999, when an unusual weaker constitution was observed in individuals of the red deer (*Cervus elaphus* L.) free ranging population in Baranja region (Marinculić et al. 2002). Liver from individuals shot in January 2000 was examined at Faculty of Veterinary Medicine in Zagreb, and 22 adult parasite *Fascioloides magna* were found. In order to estimate the degree of invasion in red deer, a systematic monitoring was carried out in the period 2001-2004. The chosen priority area was Croatian Danube region, in particular hunting grounds in the flooded area.

High prevalence of fascioloidosis in red deer population was recorded in hunting grounds located along the Danube course (Table 1). In „Podunavlje-Podravlje“, the prevalence was 44-52% (mean 48%), and in „Šarkanj-Vrblje“ 35-60% (mean 46%). In comparison, Špakulova et al. (1996) reported a prevalence of 70% in Slovakia during winter season 1995-1996. Gradual reduction of prevalence from 2001 to 2004 is a consequence of intensive treatment of red deer with mixture of triclabendazole and standard deer salt brick components, at a dose of 60 mg/kg body weight per deer, twice in seven days.

Fascioloidosis was not detected in hunting grounds along the Drava River during monitoring in 2001-2002, but it was confirmed in 2003 and 2004 with low prevalence of 13% in „Podravlje” and 7% in „Munjoroš”. This proves that in Baranja well-established migration routes of red deer lead from the Danube floodplains to the Drava River inundation, and across the Drava to Slavonia.

No *Fascioloides magna* eggs were found in faeces of red deer in "Haljevo" and "Koha-Kozarac" with the exception of two samples from „Koha-Kozarac" in 2004, with a prevalence of 7%.

This part of Baranja is located at higher terrain which is outside of the reach of floods and not hydrologically connected to the Danube floodplain. These hunting grounds provide an intermediate stop on the red deer migration route, mainly during the winter period. Thus, the only possible way of spreading fascioloidosis is by seasonal migration of red deer.

Table 1. *General data and prevalence of fascioloidosis in red deer population in selected hunting grounds of eastern Croatia*

Hunting ground	Total surface (ha)	Altitude range (m a.s.l.)	Year	Number of samples		Mean number of eggs per gram ± SD	Prevalence of fascioloidosis	
				Collected	Positive		(%)	Mean (%)
XIV/11 Šarkanj-Vrblje	1,337	85-86	2001	15	7	47.43±27.39	47	46
			2002	60	36	46.08±33.93	60	
			2003	60	26	20.88±11.68	43	
			2004	60	21	10.87±6.03	35	
XIV/9 Podunavlje-Podravlje	25,333	82-86	2001	247	129	51.01±51.84	52	48
			2002	300	151	32.97±23.64	50	
			2003	300	139	23.91±14.11	46	
			2004	300	133	25.69±13.35	44	
XIV/5 Koha-Kozarac	1,293	89-90	2001	4	0	0	0	7
			2002	30	0	0	0	
			2003	30	0	0	0	
			2004	30	2	2±0	7	
XIV/3 Haljevo	1,681	90-101	2001	0	0	0	0	0
			2002	30	0	0	0	
			2003	30	0	0	0	
			2004	30	0	0	0	
XIV/10A Podravlje	8,410	86-90	2001	0	0	0	0	13
			2002	30	0	0	0	
			2003	30	4	5.50±2.88	13	
			2004	30	4	3.25±1.50	13	
XIV/10 Munjoroš	2,400	85-88	2001	5	0	0	0	3
			2002	45	0	0	0	
			2003	45	1	1±0	2	
			2004	45	2	2±0	4	

Relatively high prevalence of fascioloidosis in hunting grounds located along the Danube River can be explained by their terrestrial and hydrological connection. These hunting grounds have similar ecological and habitat characteristics, with optimal conditions for the same red deer population (Florijančić & Ozimec 2004). The frequency of disease depends on population density, which is important for the estimation of epizootiological situation. In „Podunavlje-Podravlje“, the largest hunting ground by its surface, density is 8 individuals per 100 ha of hunting surface, and 2 individuals per 100 ha in „Šarkanj-Vrblje“, reflecting prevalence differences.

The Danube hydrologically connects the upstream Hungarian hunting grounds and Croatian hunting grounds in which fascioloidosis occurred. It can be confirmed that developmental stages of *Fascioloides magna* were introduced in Croatia by migration of red deer, and by intermediate host – freshwater snails deposited with floods during the high water-level episodes.

This corresponds to the description of introduction from Slovakia into Hungary (Mayoros & Sztojkov 1994). Aquatic and wetland habitats favour the growth of the freshwater snail *Lymnaea truncatula*; its high presence is noticable in the flooded area of the hunting grounds.

The risk of spreading fascioloidosis in red deer populations in eastern Croatia is still present, when considering that eggs of the parasite may lie dormant in the environment, and may be carried away at distant sites by flooding. The hunting grounds in the middle part of Baranja and along the Drava River can be treated as endangered areas regarding fascioloidosis. Metacercariae can survive in snails for a long time, and can survive the cold winter period, keeping vitality up to one year (Griffiths & Christensen 1972). Although the fertility of the liverfluke decreases with maturity, deer which are invaded only once can excrete eggs until the end of life (Foreyt et al. 1977).

4 Conclusions

Distribution of American giant liver fluke (*Fascioloides magna*) in red deer, with rather strong invasion, is limited on the Danube flooded area in eastern part of Croatia. The ways of spreading are by seasonal migration of infested red deer through the area, and by transport of an intermediate host, the freshwater snail *Lymnea truncatula*, by high flow. Low prevalence of fascioloidosis was found in flooded areas along the Drava River, while the lowest was at higher terrain outside of the floodplain. Considering the migration routes of red deer and epizootic indicators, the spreading of this parasitic disease is expected across the Danube to the left riverside in Serbia, as well as in hunting grounds across the Drava River in Croatia.

Regular parasitological monitoring (sampling, analyses of faeces and liver) are needed in the epizootic areas of the Danube region, but also in the endangered areas where a disease was confirmed. Proper application of zoo-hygienic measures in hunting grounds, combined with antiparasitic treatment of free ranging red deer population and captive deer is important to restrain the further spread of fascioloidosis.

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The status report on German floodplains

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Keywords: biodiversity, ecological network, floodplain restoration, waterways

1 Introduction

Near-natural inland waters, littoral zones and floodplains as well as connected aquifers are among the most valuable, but also most endangered ecosystems in Europe. They are hotspots of biodiversity and central elements of an ecological network. For instance, about 80% of the Swiss fauna species occur in floodplains and many of the riparian species (47%) are listed as endangered (Tockner & Stanford 2002). Considering the limited taxonomic knowledge on many species groups of fresh waters it can be assumed that the biodiversity of fresh waters as well as its decline is significantly underestimated (Balian et al. 2008). There is almost no other ecosystem type that offers such a remarkable variety of goods and services to humans like rivers, their floodplains, aquifers and wetlands (e.g. Constanza et al. 1997, Antrobus & Law 2005, Turner et al. 2008, Maltby 2009). Freshwaters can provide these ecosystem services only, if their ecological integrity is sustained. However, the ambitious objective of the European governments to stop biodiversity loss until 2010 most probably was not achieved for freshwater ecosystems and floodplains.

In particular, the main reason for the loss of biodiversity in floodplains is the continued decline in floodplain area due to competing land uses. The floodplains of the larger rivers in Germany have lost on average two-thirds of their former area and in many sections even 80 to 90% of its original extent (Brunotte et al. 2009). Even the remaining active floodplains, which maintained more or less their typical flooding dynamics, are partly under agricultural use or are developed areas and have lost their habitat function. Thus, conservation of biodiversity in floodplains mainly depends on conservation and restoration of active floodplains. However, for Germany a nationwide inventory of the loss and status of floodplains was lacking until now. The Federal Agency for Nature Conservation (BfN) funded several projects, which compiled an inventory of the former floodplain area for the larger rivers in Germany, the remaining active floodplains and their status (BMU & BfN 2009, Brunotte et al. 2009). The methods and results of this nationwide survey of active and former floodplains are presented in this paper.

2 Methods of assessing floodplains

The survey of the floodplain area was conducted for sections of the rivers with a catchment area of at least 1,000 km^2. Tidal waters were not included. Remaining active floodplains and former floodplains were assessed. Together they form the geomorphologic floodplain which is defined in this case as the area which could be inundated, if there were no man-made dikes. For each 1-km section of the rivers, separately for the left and the right side, the active and former floodplain areas were assessed and land use, nature conservation value, and protection status were documented. The data base of the floodplain assessment consists of several digitally available georeferenced information (GIS) provided by German federal/state administrations. This way, for 10,000 km of river course of 79 German rivers a consistent data base exists about the floodplains (Figure 1), which can serve as a spatial background for a sustainable development of rivers and their floodplains (compare also Fig 3a and 3b).

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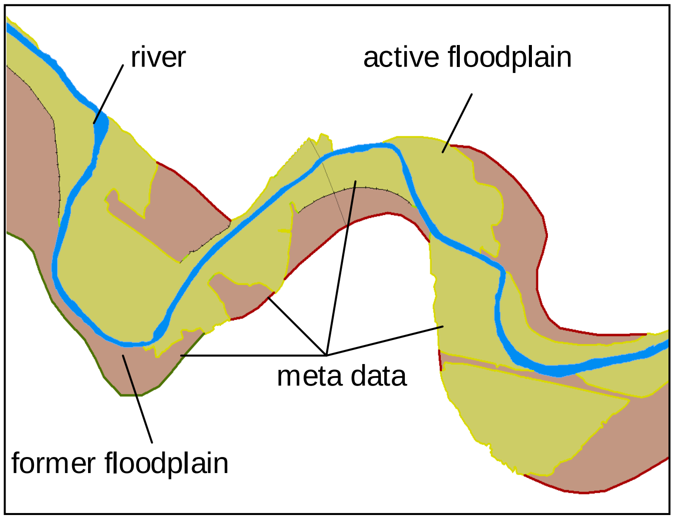

Figure 1. *Exemplary detail of the basic GIS-map of floodplain delineation indicating river, active floodplain, former floodplain and metadata like data origin.*

Koenzen (2005) developed an approach to define reference conditions for riverine landscapes (potentially natural status) which were further used to assess the status of active as well as former floodplains based on the floodplain data suggested above (Brunotte et al. 2009). Main input data for the status assessment of floodplains comprises the main factors of habitat quality for all species, including the geomorphologic and hydrologic habitat conditions, vegetation and land use. Thus, just like the WFD (EC 2000) this methodology refers to a reference status, which is mostly unaffected by human intervention. The more the status of a floodplain section differs from this potentially natural status the more modified it is assessed. The assessment is presented in five classes of the degree of modification compared to the potentially natural status (Table 1). The classification of the status of each assessed floodplain section is based on a number of clearly defined factors and is, hence, completely transparent. This assessment provides a nationwide overview of the degree of the modification of floodplain habitats.

Table 1. *The five classes of floodplain status with a condensed specification*

class		specification
1	nearly natural	Floodplains not or to a very small degree disconnected from floods by river regulation and/or flood protection measures Rivers only slightly regulated, with high flooding possibility Mainly no or very low intensity land use, mostly forest, wetlands, and rarely grassland
2	slightly modified	Floodplains to a small degree disconnected from floods by river development and/or flood protection measures Rivers variably regulated, but usually with high flooding possibility Mainly low intensity land use, mostly forest, wetlands and grassland
3	moderately modified	Floodplains partly disconnected from floods by river development and/or flood protection measures Rivers generally regulated, but usually with flooding possibility Variable intensity of land use
4	severely modified	Floodplains widely disconnected from floods by river development and/or flood protection measures Rivers generally regulated, partly dammed High intensity land use, mainly intensive agriculture and urban areas
5	totally modified	Floodplains completely disconnected from floods by river development and/or flood protection measures Rivers generally regulated heavily, frequently dammed High intensity land use, mostly with high percentage of urban areas

In order to validate the presented assessment of floodplain status an additional detailed methodology was developed and applied to 21 selected sections of different floodplain types and degrees of river modification. It is based on additional locally available information and can be used to meet on-site needs of planners.

3 The status report on German floodplains

This first nationwide consistent and updatable inventory of the loss and status of German floodplains provides an efficient overview of the position, dimension and status of floodplains at larger rivers in Germany. Moreover, because of the unique data basis, the results are comparable between federal states and river catchments.

Floodplains of larger rivers (except small rivers and tidal waters) in the past covered about 15,000 km², which corresponds to 4.4% of the German territory, of which two-thirds were lost by embanking. At large parts of rivers like Rhine, Elbe, Danube and Odra only 10-20% of the former floodplains can be inundated nowadays.

More than one-third of the remaining active floodplains are intensively used as agricultural (28%) or urban (6%) areas. Less than 10% of the active floodplains fully provide their ecological functions. The remaining near-natural hardwood forests of floodplains cover only about 1% of the active floodplain area. Compared to the potentially natural status, less than 1% of the assessed active floodplain sections are rated as "nearly natural" (compare Table 1), 9% as "slightly modified", and 36% as "moderately modified", while 54% of the floodplain sections are rated the worse status classes as "severely modified" or "totally modified". On the one hand, this situation resulted from the intense agricultural use on fertile soils of floodplains and on the other hand from the former importance of rivers as routes for transport and trade as well as the arising settlements and infrastructure.

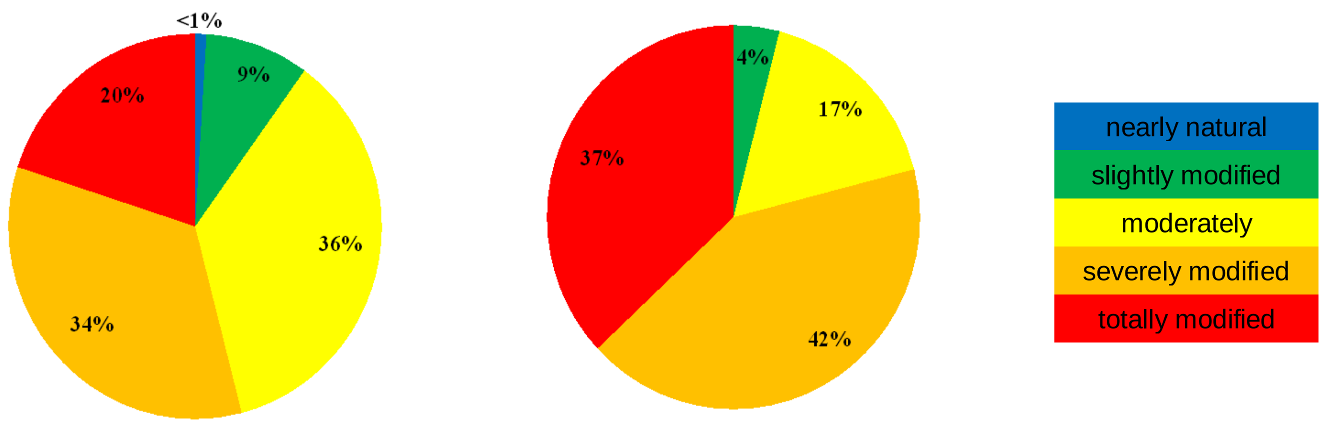

Figure 2. *Comparison of the distribution of the floodplain status classes for all assessed sections of active floodplains (left) with former floodplain areas (right)*

A comparison of the status of the active floodplains with the former floodplain areas showed that the classes 4 and 5 are clearly more abundant (79%) in the former floodplains (Figure 2). However, there is a small percentage (4%) of "slightly modified" floodplain sections, which apparently still maintained a "floodplain-like" environment without being inundated for a longer period. Hence, these areas should be targeted for a potential restoration (activation) of former floodplains.

The assessment of the active floodplains shows clear regional differences. Larger "slightly modified" sections of nationwide importance are to be found for example at the Peene and the Tollense, at the Spree between Cottbus and Berlin, at the lower Havel, at the middle and lower Mulde, at the middle Elbe near the Saale confluence, at the Danube near the Isar confluence (Figure 3a) and at the upper Rhine near the "Kühkopf" (Figure 3b). Several of these floodplains have been admitted to the federal program that supports nationally representative nature conservation areas.

In contrast, rivers, which are German federal waterways, especially when they are additionally used to produce hydro power, are massively regulated and their discharges as well as their groundwater conditions are heavily modified. Together with the intense agricultural and urban use of the floodplains at these rivers, these are the reasons for the rating of such floodplain sections as "severely modified" or even "totally modified".

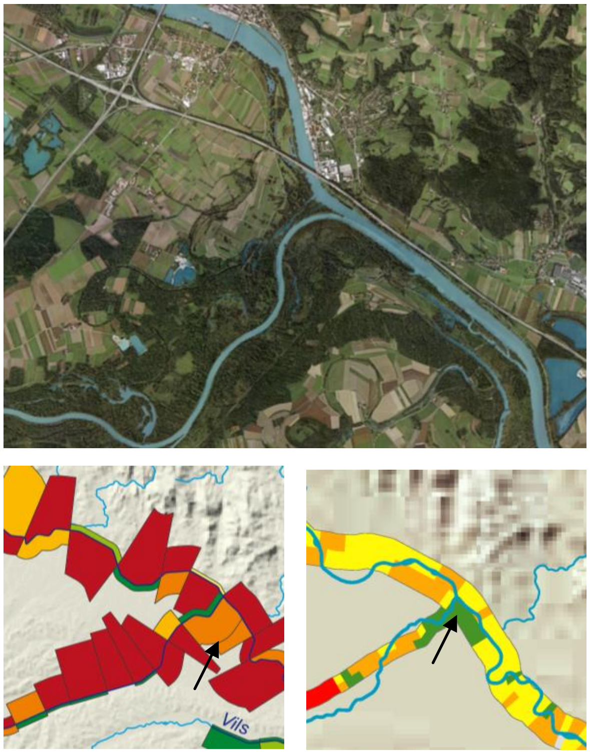

Figure 3a: Danube with Isar confluence

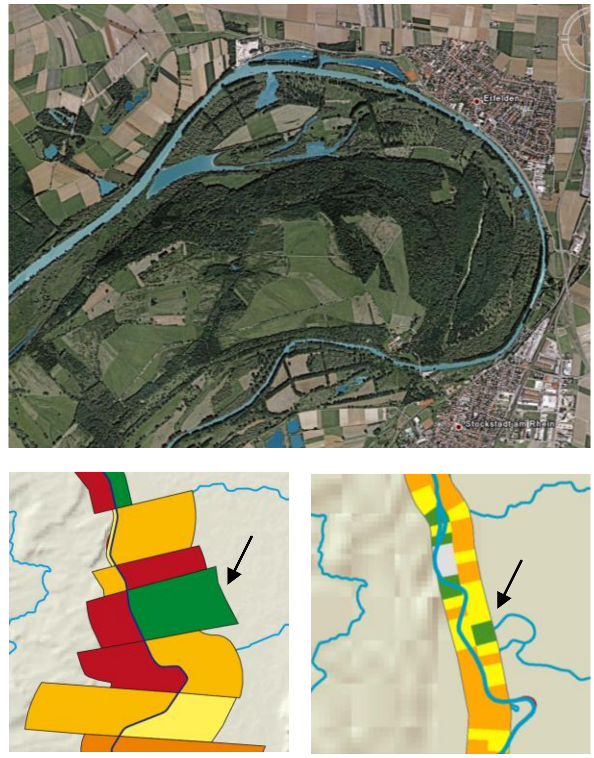

Figure 3b: Rhine floodplain with Kühkopf

Map sections: left = loss of floodplain area; right = floodplain status

The Federal Agency for Nature Conservation will provide the nationwide inventory of the loss and the status of floodplains in the form of a GIS-based internet service called “Flussauen in Deutschland”. The maps will present the area and status of the floodplains at variable scales (starting from 1:25,000). Users will be able to access and download summaries for any floodplain section.

4 Discussion

The status report on German floodplains is the first nationwide consistent inventory of the loss and current status of the floodplains of larger rivers in Germany. This inventory shows, for example, that only 0.1% to 0.2% of the former geomorphologic floodplain is currently covered with near-nature floodplain forest (Brunotte et al. 2009). This is insufficient to sustainably preserve the extraordinarily high biodiversity which has remained in these forests in active floodplains. Nevertheless, near-natural freshwaters and floodplains are hotspots of biodiversity (Robinson et al. 2002, Hughes et al. 2005). Therefore, more than 50 % of the area of rivers and active floodplains belong to the Natura 2000 network of protected sites (Brunotte et al. 2009). This emphasizes their importance as linking elements of a transnational network of protected areas. One of the main reasons for the high biodiversity in floodplains is the small-scale variability of habitat conditions, which enables different species communities to coexist (Naiman & Decamps 1990, Ward et al. 2002). Without measures to protect and restore rivers and their floodplains this biodiversity will continue to decline.

Floodplains are not only hotspots of biodiversity but also natural flood protection areas. They delay the discharge of flood waves and, thus, contribute to mitigate flood peaks (Acremann et al. 2003), especially when the floodplains are covered with near-natural forests. Even if the significance and acceptance of floodplain restoration programs increased over recent years, it remains difficult to put them into practice. Thus, the available inventory and assessment of floodplains can serve as a useful tool to identify nationally important floodplain areas and potential areas for restoration of near-natural floodplains as well as flood protection areas. This way the status report on German floodplains can contribute to the implementation of synergies between nature conservation and flood protection measures.

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Assisting integrated planning on waterways by modeling techniques - the Integrated Floodplain Response Model INFORM

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Keywords: ecological modeling, integrated planning, floodplain ecology, federal waterways, decision support

1 Why integrated planning?

Performing construction and maintenance works on German Waterways may cause interference with and impact on the adjacent environment due to functional hydro-ecological interrelations. If there is evidence for significant impact on nature caused by executing waterway training measures, the Waterways- and Shipping Administration (WSV) by law has to arrange for suitable compensation measures (BNatSchG 2009; UVPG 2010).

Nowadays integrated planning which means involving relevant stakeholders in a timely manner and at an early stage considering all impact related pathways is thought to be an appropriate means to realize a calibrated planning of constructional measures. In fact a commonly agreed planning process is likely to result in a project having only little impact on nature and environment. Additionally targets of European legislation like the EU-Water Framework Directive (EC 2000) and the respective National Water Management Plans can obviously be covered by applying such a procedure. As waterborne and riverine habitats hold a high portion of protected European Natura 2000 sites (EEC, 1992) and major parts of German Waterways are nominated as Natura 2000 sites a precautious handling of waterway planning is required. Even in an international perspective an integrated planning approach is supported by the World Association for Waterborne Transport Infrastructure PIANC, promoting its “Working with Nature” position (PIANC 2008).

Though the WSV already goes along with nature related aspects and stakeholders in their projects, especially for considering nature related impact a methodology being able to predict and evaluate ecological impact due to constructional interference is needed to assist effectively integrated planning particularly in early realization stages. In the scope of WSV tasks this allows for re-designing intended measures giving the opportunity to select such a planning alternative having only weak impact on nature, having a mitigating effect on impact or even having a positive effect on floodplain ecology. Because of a political shift in assignment of WSV tasks within the context of national and European nature and water-related legislation (BMVBS 2009) construction or maintenance works on waterways have to take care for ecological aspects in order to dispose both sustainable navigation and intact valuable nature.

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2 Assisting planning by modeling with INFORM

Against this background the German Federal Institute of Hydrology (BfG) developed the software system Integrated Floodplain Response Model INFORM (Fuchs et al. 2003). Its main goal is to support the evaluation and decision process during the planning stage of WSV measures along German waterways. The modeling framework allows predicting the impact on habitats of plants and animals due to natural or anthropogenic interference in riverine hydrology and morphology. Key and innovative components of INFORM are the biotic models (Rosenzweig & Hettrich 2007). These models in principle map and predict the occurrence probability, the distribution or the abundance of riverine organisms or habitats controlled by the specification of environmental predictor variables. At present models for vegetation (MOVER), carabide beetles (MOCAR), molluscs (MOMOR), macro-invertebrates (MOBER) and fish (MOFIR) are included.

INFORM is realized as an ArcGIS™ 9.3-Extension for ArcMap with corresponding toolbar, programmed by C# and Python. In ArcMap the so-called project-tree, a window similar to the table of contents, helps organizing each project with all its contents (Figure 1). The realization of INFORM as ArcGIS™ extension enables to create spatially explicit model results.

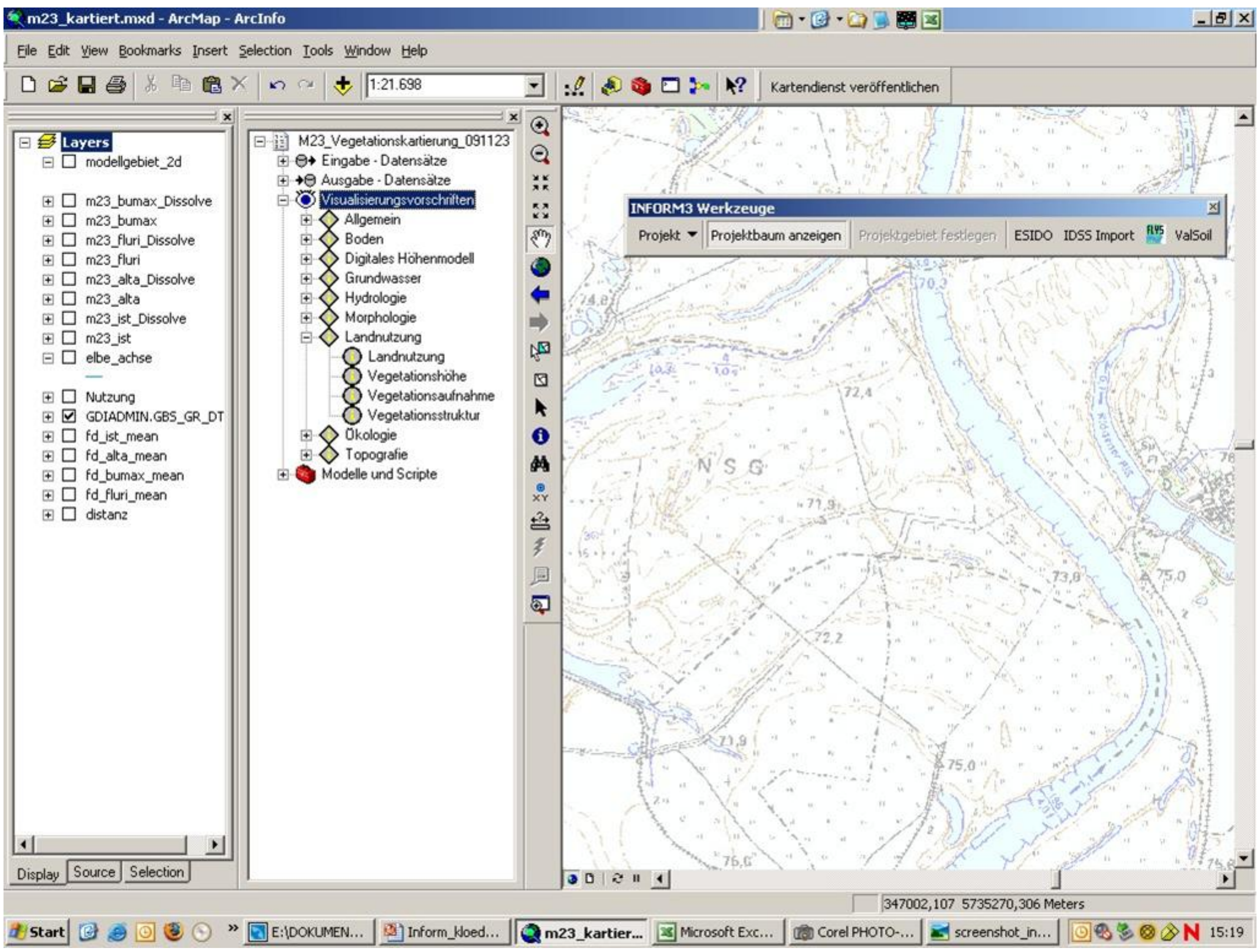

Figure 1. *Graphical user interface of INFORM*

The system architecture of INFORM is set up modular. This allows for joining new components according to various development levels or to clean up not needed or out-dated components. The currently available system components are illustrated in Figure 2.

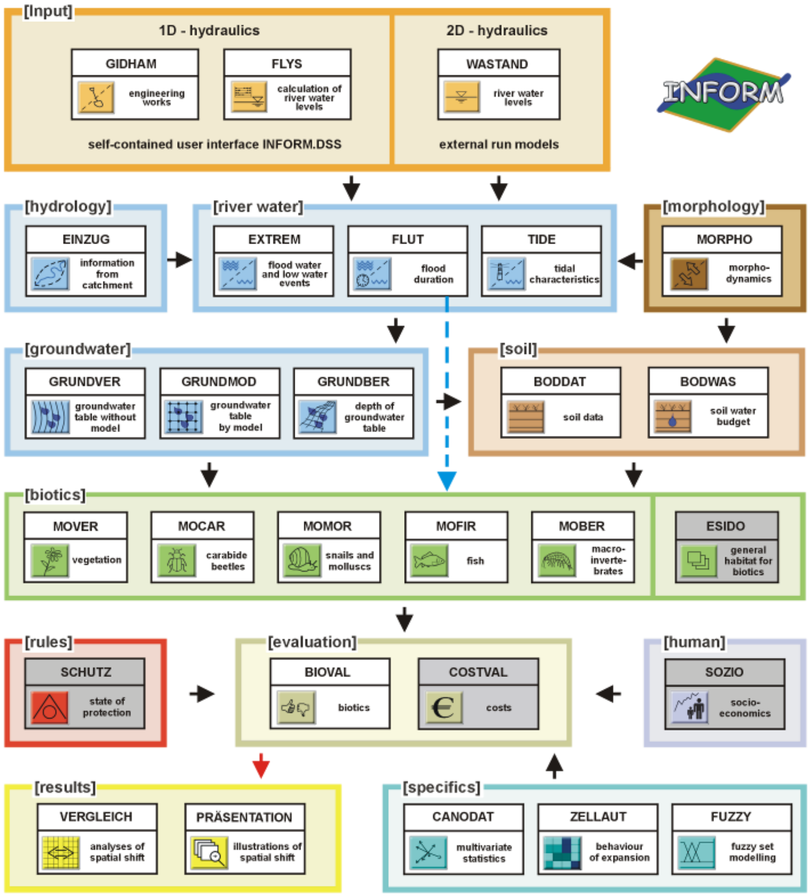

Figure 2. *System components of INFORM*

Implemented habitat models mainly base on empirical knowledge of the main functional interrelations in the floodplain ecosystem. Water of course is the main driver in this system. River water levels, the duration of inundation as well as parameters of the soil and groundwater budget are for example used as predictor variables for riverine vegetation.

A rough automatic evaluation of the predicted habitat situation can be performed. This is done in a formalized way using criteria applied in environmental impact assessment or environmental risk analyses. INFORM additionally offers to communicate to stakeholders and share their expertise and position when evaluating and discussing model results. Implementing their point of view in a multi criteria assessment, at present performed in a verbal argumentative manner, is the last step to come to an agreed decision on an optimum solution for a specific planning alternative.

Using this evaluation process INFORM can help to optimize the planning of measures by selecting designs that are ecologically meaningful and by avoiding expensive compensation measures.

3 Applying INFORM

Along the course of the River Middle Elbe a stretch of about 170 km length (rkm 120-290) is heavily affected by river bed erosion (BfG 2004). The subsequent decline in water levels probably will affect stability of river training constructions, groundwater and soil water budget of the adjacent floodplains, and potentially floodplain ecology. A bundle of optional counteracting solutions to mitigate or even stop the decline in water levels has already been set up (WSV 2009).

Applying INFORM will help the WSV for selecting measures from an ecological perspective. This decision support refers to the modeled impact on riverine plant or fauna habitats calculated by INFORM on the base of pre-computed hydraulic effect of each optional constructional measure (by Federal Waterways Engineering and Research Institute, BAW). Predicted change in vegetation pattern in the floodplain or in habitat quality for different fish species in groyne fields for example will give clear evidence on the ecological measure related alteration.

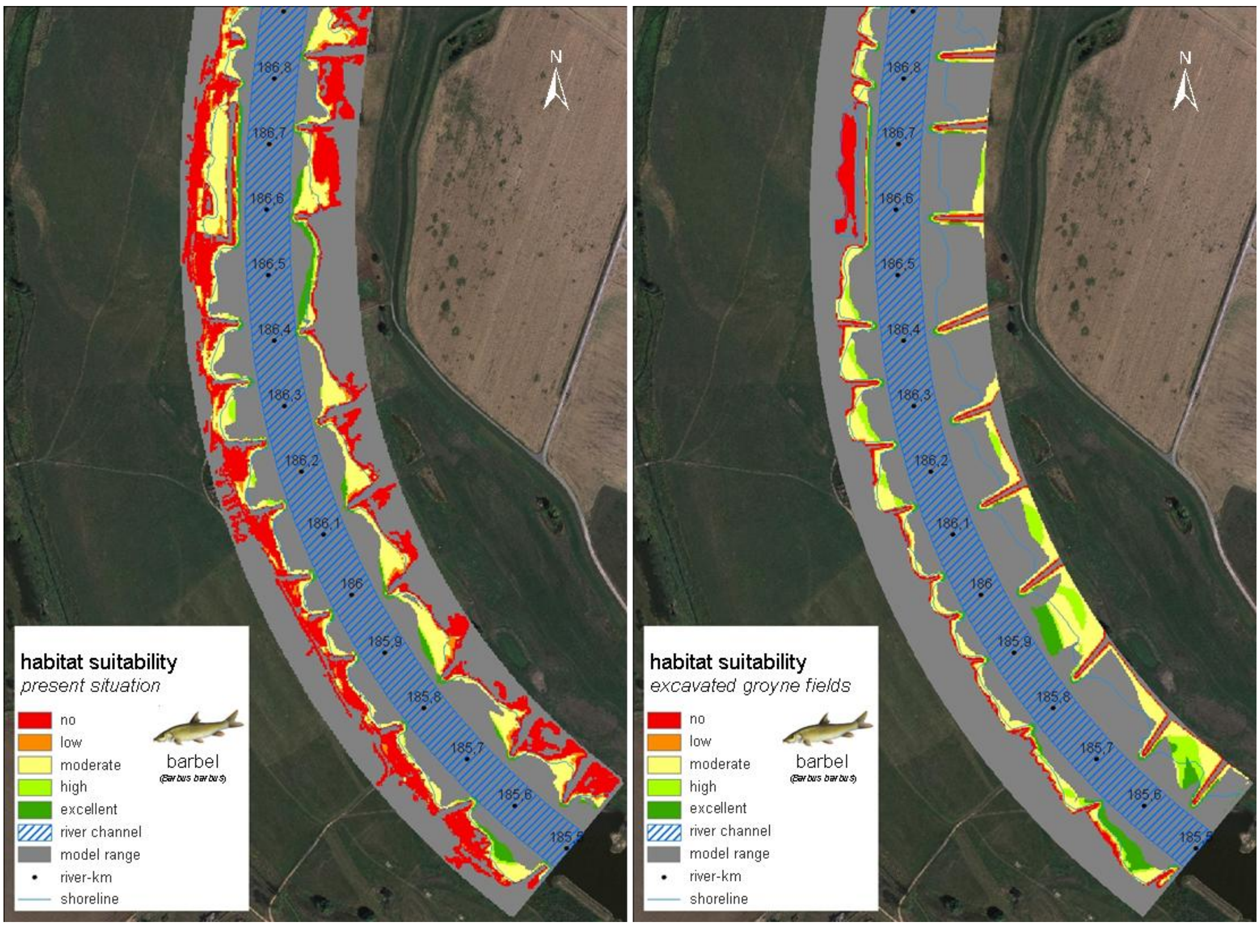

Figure 3. *Detail of pilot area "Klöden" showing the impact on the adult fish species barbel (Barbus barbus) modeled by INFORM (biotic model MOFIR 2) due to excavation of sediment filled groyne fields, on the left: initial state, to the right: future state, both referring to a situation of mean water discharge*

An example of use illustrates the effect of excavating groyne fields on the fish species barbel (*Barbus barbus*) in the pilot area Klöden (Elbe rkm 185-195, Figure 3). At present these groyne fields do not fulfill their initially intended hydraulic effect as they are filled with sediments due to omitted maintenance in the last decades. Sediment excavation aims at restoring the hydraulic effectiveness of groynes leading to reduced flow velocity within the river channel compared to the present situation. The morpho-hydraulic effect of this measure was modeled by the Federal Waterways Engineering and Research Institute (BAW). The biotic fish habitat model MOFIR 2 of INFORM predicts the habitat suitability for fish species (various fish cohorts) in relation to the predictor variables flow velocity, water depth, substrate of river bed, and the potential to hide.

Side-strips of the river close to the bank offer only poor living conditions for the barbel in the present situation. Excavation of groyne fields upgrades this situation by creating habitats of moderate to good quality for the adult barbel. This is of interest for the Middle Elbe region as the barbel plays a significant role for nature quality and fishery.

Evaluating the measure related effects on habitat alteration will result in advice for selecting or refusing a measure from an ecological point of view. In addition to the desired effect on hydraulics the selection of appropriate measures for mitigating river bed erosion at the mid-reaches of the River Elbe will include the effects on nature predicted by ecological modeling techniques. Obviously this process of well-considered and comprehensive pre-planning will finally result in a well-founded planning accepted and agreed by involved stakeholders and decision makers.

4 Conclusion

Applying the hydro-ecological software INFORM enables to assist the planner and decision maker in the Waterways and Shipping Administration in an early planning stage in taking optimum decisions targeting at only weak river training related interference with nature or even promoting nature. This option based on innovative modeling techniques will contribute to an integrated planning process where all relevant stakeholders are included in discussing measure related impacts by means of a transparent and comprehensible way.

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Plankton communities of the transboundary Ukrainian-Romanian section of the Tisa River

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Keywords: mountainous rivers, phytoplankton, zooplankton, the Tisa River, tributaries.

1 Introduction

Carpathian rivers are considered the most undisturbed and clean rivers in Ukraine. However, recently floods became more frequent in the Carpathians. They disturb banks of the rivers, ruin soils, and negatively affect biological diversity. Erosion of slopes worsens water-retaining ability of soils, disturbs evolutionary formed benthic and planktonic communities. Anthropogenic impact also causes damage on the river biota. Apart from hydromorphological alteration (partial banks reinforcement) the most negative is discharge of insufficiently treated industrial and municipal waste waters, accumulation of municipal litter and wood decay products of the timber-cutting industry in the river basins. Therefore, study and monitoring of the mountainous rivers are of essential importance. Results of such investigation enable to assess character and rate of the biota's response to these impacts.

Planktonic communities of the transboundary Ukrainian-Romanian section of the Tisa River Basin were studied in view of activities connected with assessment of ecological status of the water bodies and search of the reference sites according to the WFD principles. Though neither phytoplankton, nor zooplankton are recommended as quality elements for mountainous rivers, they are an important component of the aquatic ecosystems. They are closely connected by trophic relations with each other and with other biotic components (first of all with fish).

The Tisa River is the largest tributary of the Danube. Its length is 966 km (within Ukraine – 201 km), the catchment area 157 000 km² (within Ukraine – 11 300 km²). It starts at the Chorna and Bila Tisa rivers confluence, 4 km upstream of Rakhiv. Along 64 km (from Dilove to Tiachiv) it forms the state boundary between Ukraine and Romania. At this section it is a typical mountainous river with stony or gravel bed. Its peculiarity is a considerable fluctuation of environmental conditions, caused by dynamic discharge between floods and low water. Average velocity of flow amounts to 2–4 m/s. The river carries extremely high content of suspended matter due to erosive soils in the catchment. High turbidity negatively affects development of planktonic communities.

The aim of the study was to compare the present situation with the scarce data of earlier records that are significantly fewer in the upper river sections, and to document the changes of biological diversity.

2 Methods

In 2009 phytoplankton and zooplankton of the main channel (sites 1–3) and mouth areas of the main tributaries – the right-bank Kisva, Shopurka, Apshytsia, Teresva (sites 4–7) and the left-bank – Iza, Vişeu and Săpânța (sites 8–10) have been investigated. Phytoplankton samples were taken by filling of 0.5 l glass vessels. For zooplankton sampling 300 l of water were filtered using the plankton Apstein net №64. Samples were conserved by formaldehyde solution. Organisms were identified and counted using light microscope Carl Zeiss Primo Star. Numbers and biomass were calculated according to standard hydrobiological methods (Romanenko, 2006).

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3 Results

Phytoplankton of the studied section comprised in total 65 algal species of 4 departments; Bacillariophyta prevailed (61 species). On average their numerical density and biomass amounted to 98% and 99% of the total, respectively. Representatives of class Centrophycea were almost absent. It is worth noting that the significant portion was formed by periphytic forms: *Didymosphenia geminata* (Lyngb.) M.Schmidt, *Ceratoneis arcus* (Ehr.) Kütz. and species of the genera *Gomphonema* and *Rhoicosphaenia.* Species of other departments occurred sporadically (Euglenophyta – 2 species, Cryptophyta – 1 species and Chlorophyta – 1 species).

In the Tisa River 30 species were found, among them 29 of Bacillariophyta. Average numerical density amounted to 904 000 cells/l, average biomass to 1.48 mg/l. Along the studied section differences in phytoplankton species richness and quantitative characteristics were of minor importance (Figure 1). The most abundant taxa were *Achnanthidium minutissimum* Kütz. (15.7% of the total), *Gomphonema longiceps* Ehr. (10.1%), *Navicula cryptocephala* Kütz. (9.7%); in terms of biomass prevailed *Didymosphenia geminata* (42.8% of the total). It is worth noting that because of significant individual biomass this species dominated practically at all sites, even if its abundance was low.

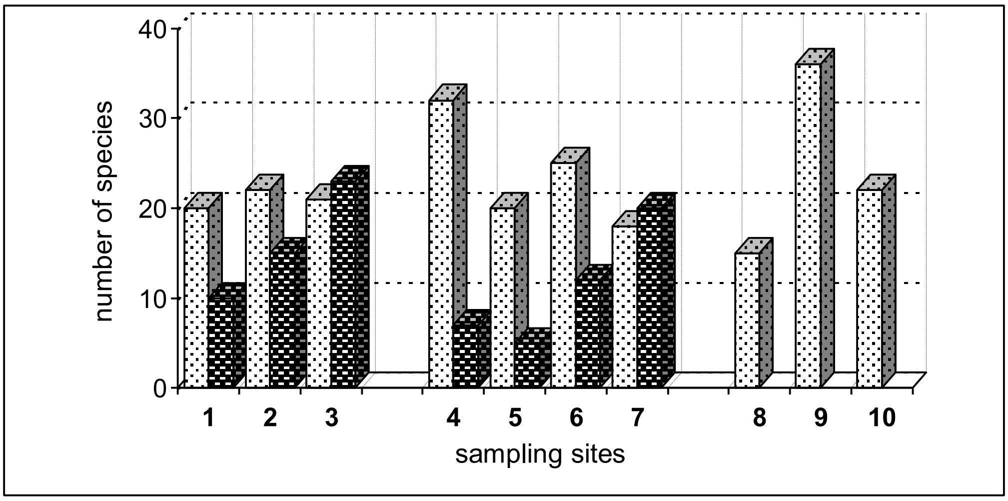

Figure 1. *Number of phytoplankton (Fpl) and zooplankton (Zpl) species. (Sites number as in the text).*

Phytoplankton in the mouth areas of tributaries was more diverse and abundant than in the main channel. Totally 61 algal species were found. Many species occurred in all tributaries; however, every tributary had its peculiar dominant species in terms of numbers (as mentioned above, *Didymosphenia geminata* dominated by biomass practically at all sites, except the Vişeu River, where it was not found at all). Also tributaries differed by quantitative characteristics. The lowest species richness, numbers and biomass were registered in the Vişeu River, where *Achnanthes minutissima* and *Gomphonema parvulum* (Kütz.) Grun. (23.9 and 10.9% of total numbers, respectively) were most abundant; in terms of biomass prevailed *Synedra ulna* (Nitzsch) Ehr. and *Cocconeis placentula* Ehr. (19.1 and 12.9% of total, respectively).

Maximum species richness was noted in the Iza River. Just here algae of four departments were found. The most abundant were *Achnanthidium minutissimum* and *Gomphonema longiceps* (13.2 and 8.5% of total, respectively); in terms of biomass prevailed *Didymosphenia geminata* (26.3%).

Maximal phytoplankton density was observed in the mouth area of the Kisva River – 2162 500 cells/l. The most abundant was *Gomphonema longiceps* (12.1% of total), in terms of biomass prevailed *Didymosphenia geminata* (50.9% of total). Maximal phytoplankton biomass was noted in the mouth area of the Teresva River; where biomass of *Didymosphenia geminata* amounted to 82.1% of total. Probably, peculiarities of hydrological regime of the Teresva River caused washing the cells off the substrata. It is also worth noting the interesting fact that just in this river phytoplankton samples contained microscopic thalloms of the cryophilic alga *Hydrurus foetidus* (Vill.) Kirchn. (Chrysophyta) of the early development stage (they were not accounted as phytoplankton). Its occurrence can probably indicate xenosaprobic conditions in the Teresva headwater. This alga is considered as indicator of reference conditions for mountainous Carpathian rivers (Afanasyev, 2006).

In the Sapintsa River intensive development of *Ceratoneis arcus* was observed (23.0% of total numbers and 17.7% of total biomass). Because of this fact it is possible to assume oligosaprobic conditions in the headwater of Sapintsa.

Thus, phytoplankton of the studied sections is quite diverse. Notable contribution into the species richness was formed due to periphytic and benthic forms, which were detached from the hard substrata. Large-cell forms contributed to the biomass which is peculiar for mountainous rivers.

Zooplankton of the studied section of the Tisa River (except the left-bank tributaries, which were not studied) comprised 47 taxa, among them 28 rotifers (Rotatoria), 9 Copepoda (Cyclopoida, Calanoida and Harpacticoida) and 10 Cladocera. Most of taxa were found in summer. Zooplankton species richness increased along the Tisa channel. At the site nearby Dilove only 10 taxa were found, and at the downstream site (nearby Tiachiv) 23 taxa were registered. Species number in the tributaries Kisva, Apshytsia and Teresva did not exceed 10 taxa, and in the Shopurka River only bottom forms of invertebrates were found (Fig. 1).

Rotatoria showed highest species richness. In the upper sections occurred only single specimens of Cladocera. Their number increased downstream. Copepoda were the most widely distributed group, they occurred at all studied sites. The most abundant were rotifers *Euchlanis dilatata dilatata* Ehrenberg (frequency of occurrence 62–86%), which are common for periphyton, and Cladocera *Bosmina longirostris* O.F. Müller and *Chydorus sphaericus* (O.F. Müller). These species and rotifers *Polyarthra vulgaris* Carlin, *Brachionus calyciflorus* Pallas, *Keratella cochlearis* (Gosse), *K. quadrata* Müller, Cyclopoida *Cyclops strenuus* Fischer, *C. vicinus* Uljanin, *Acanthocyclops vernalis* (Fischer), Cladocera *Daphnia longispina* O.F. Müller, *Moina rectirostris* Hellich are characteristic for the zooplankton of the Tisa Basin. On the whole at this section prevailed rheophilic invertebrates: Harpacticoida, rotifers *Cephalodella* sp., nonloricate rotifers of the family Philodinidae and Cladocera *Chydorus sphaericus*. In spring and summer rotifers and Cyclopoida prevailed, and in autumn Cyclopoida and Cladocera.

Significant amounts of drifted bottom invertebrates were also found in zooplankton samples. This is common for most mountainous rivers as caused by high velocity and turbulence of flow, especially in the highland sections. The most abundant macroinvertebrates were Oligochaeta, Nematoda, larvae of Chironomidae, Plecoptera, and Ephemeroptera.

Zooplankton of the studied section was scarce, depending mainly on the drift intensity (200–2700 specimens/m^3; biomass 0.01–0.03 g/m^3). Its composition and abundance varied within wide limits dependent on the discharge regime and water level. At the site nearby Dilove species composition was enriched due to forms associated with substrata (*Chydorus sphaericus* of Cladocera, *Paracyclops fimbriatus* Copepoda, *Harpacticoida* sp. etc.). In the studied tributaries zooplankton was less abundant than in the main channel, except of the Teresva River, where its numbers amounted to 20–470 specimens/m^3 and biomass to 0.01–0.02 g/m^3. These values are characteristic for the upper section of the Tisa River (Polischuk & Garasevych, 1986; Kharchenko et.al., 2003).

Thus, zooplankton of the transboundary section of the Tisa River was represented by few taxa and was not abundant though increasing downstream. Prevailing forms were associated with substrata and drifting bottom invertebrates.

4 Discussion and summary

At present biota of the mountainous rivers and their planktonic sub-system occur under disturbed ecological balance, conditioned by anthropogenic impact (unregulated construction of roads, power-lines, intensive agriculture and forest harvesting). Disturbance of the biota's habitats stability is undesirable as it diminishes species diversity. The risk of structural degradation drastically grows (decrease of species number, up to the elimination of whole systematic groups; significant fluctuations of number and biomass of some species, disturbance of the stable community structure etc.). Unfortunately, such signs are observed in the Upper Tisa Basin. Thus, a long-term tendency of decreasing zooplankton species richness was observed. At the end of the 1960s zooplankton of the

Upper Tisa comprised 126 taxa of aquatic invertebrates (Polishchuk et al., 1986). Later this list was reduced four times (Zsuga, 1999; Kharchenko et.al., 2003). We have found 47 taxa of invertebrates. According to literature data diversity of ichthyofauna also decreased (Natural resources…, 1987; Kharchenko et.al., 2003). Such tendency was not evident for phytoplankton (Hamar, 1999), which may be explained by beginning eutrophication contributing to the primary producers' development.

Different zooplankton (consumers) and phytoplankton (primary producers) development may be explained by their different response to changes of hydrological conditions (reduced flow velocity).

Planktonic communities of all rivers in the Tisa River Basin need further regular studies in order to reveal long-term tendencies and to assess the water bodies' ecological status.

Individual findings of the rare hydrobionts species (macroscopic alga *Hydrurus foetidus* of Chrysophyta, *Mixodiaptomus tatricus* (Wierz.) and *Macrocyclops distinctus* (Rich.) of Copepoda) in the studied rivers indicated the significance and originality of this area.

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Ecological benchmarking of the aquatic habitat changes in the Szigetköz floodplain of the Danube

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Keywords: eco-hydrology, restoration ecology, ecological impact assessment, Water Framework Directive, fish based assessment

1 Introduction

The Szigetköz is one of Europe's last extensive inundated floodplains in the upper part (rkm 1850-1794) of the Hungarian-Slovak section of the Danube. Under the pristine conditions the course of the river changed within the floodplain on a broad scale forming a delta-like ana-branching channel pattern characterized by multiple channels, bars and unstable islands. The dynamic equilibrium of the natural system has undergone hydro-morphologic alterations due to river regulations since the end of the 19th century. The pre-regulation habitat composition has been considerably changed and habitat turnover became restricted, but the landscape still shows a mosaic of the old floodplain elements. The trends in the landscape change are ongoing, in the direction of a general loss of aquatic areas, especially with respect to dynamic rejuvenation zones. Terrestrialisation, the process of loss of aquatic areas by the accumulation of organic and inorganic sediments but also by a lowering of the groundwater table in the floodplain, is strongly accelerated.

Since the operation of the Gabčikovo hydropower dam in 1992 the environmental problems of the Szigetköz are increasingly recognised not only in the scientific community but also in society and governments, and interest has grown in restoring ecological functions of the river-floodplain system. Despite of some mitigation measures the degradation of the river ecosystem is obvious. The feasibility of rehabilitation scenarios of the Szigetköz section of the Danube was currently investigated in a Strategic Environmental Assessment, and within its frame a preliminary ecological benchmark system was developed for evaluation of habitat changes in the Szigetköz. The proposed ecological benchmarking involves the "functional unit" concept (Amoros et al. 1987, Potyó & Guti 2010) of large river ecology and includes quantitative and qualitative elements. The quantitative benchmarks concern the areal extent and proportion of aquatic habitats, with the reference of the historical habitat distribution. The qualitative benchmarks are based on the calculation of the Habitat-specific Fauna Index (HFI) and its relation to the bed shear stress distribution.

2 Elements of the quantitative benchmarking

The historical habitat analysis of the Szigetköz floodplain (Schwarz 2009) showed the reduction of total extent of the aquatic habitats, the decrease in the proportion of the eupotamon type arms and the alteration of aquatic habitat composition. According to these changes the quantitative benchmarking has three elements: 1) change of areal extent, 2) proportion of eupotamon, 3) habitat composition (Table 1). The 'integrated quantitative quality grade' is calculated from the total areal extent of the aquatic habitats (AE), the proportion of the eupotamon habitats (PEu) and the habitat composition (HC), following the 'one bad all bad' principle (see below).

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Table 1. *The five grade evaluation system of the integrated quantitative quality grade for the Szigetköz section of the Danube and its floodplain branch systems.*

Change of areal extent (AE)	Proportion of eupotamon (PEu)	Habitat composition (HC)	Integrated quantitative quality grade
< 20%	> 80%	all habitat types occur	*excellent*
< 40%	> 60%	one habitat type is missing	*good*
< 60%	> 40%	two habitat types are missing	*moderate*
< 80%	> 20%	three habitat types are missing	*poor*
> 80%	< 20%	more than three habitat types are missing	*bad*

3 Elements of the qualitative benchmarking

The key factors of the qualitative benchmarking are the discharge-controlled geomorphologic processes which create the characteristic patch dynamics and spatial distribution of flow velocity, shear stress and substrate grain size. These hydrological and geomorphologic variables provide the specific habitat conditions for characteristic fauna elements, which reflects the ecological quality of the aquatic habitats. The composition of the specific assemblages can be expressed by the Habitat-specific Fauna Index (HFI) used here for fish. It is based on summation of species habitat preference metrics as the habitat value and the indication weight. In order to describe the species' habitat preferences numerically, 10 valency points were distributed among six habitat types (Table 3). The valency point distribution is based on autecological knowledge, field observations as well as literature data. Species-specific habitat values (HV) are calculated according to the following equation (Chovanec & Waringer 2001, Waringer & Graf 2002, Chovanec et al. 2005):

$$HV = (1{*}H_1 + 2{*}H_2 + 3{*}H_3 + 4{*}H_4 + 5{*}H_5 + 6{*}H_6) / 10$$

The criterion for the differentiation of the habitat types was the lateral connectivity with the main channel: H_1 = Eupotamon A, H_2 = Eupotamon B, H_3 = Parapotamon A, H_4 = Parapotamon B, H_5 = Plesiopotamon, H_6 = Paleopotamon (Potyo & Guti 2010).

The indication weights (IW) ranging from 1 for eurytopic species to 6 for stenotopic species (Table 2) have been allocated to each species in order to identify the responsive (habitat indicator) species (indication weight ≥ 4). The indication weight is calculated from the valency point distribution.

Table 2. *Definition of the grades of the indication weight (IW) of the species*

IW	definition
6	Favoured habitat is scored 8-10 valency point
5	Favoured habitat is scored 6-7 valency point
4	Favoured habitat is scored 5 valency point
3	Favoured habitats are scored 3-4 valency point, sp. occurs at 4 habitat types
2	Favoured habitats are scored 3-4 valency point, sp. occurs at 5 habitat types
1	Favoured habitats are scored 1-2 valency point

The HFI is based on the summation of the habitat values and indication weights of all native species occurring at a given location. It is calculated using the following equation:

$$HFI = \Sigma\, (HV * IW) / \Sigma\, IW$$

where HV is the habitat value and IW is the species-specific indication weight. The HFI is calculated for locations and results in a number between 1 and 6, indicating habitat preference of the assemblage at the given location.

Table 3. *Habitat preference of the native fish species in the Szigetköz considered in the Habitat Specific Fauna Index (HFI). HV: species-specific habitat value, IW: indication weight. Rheophilic (HV < 2.5) spp. are indicated by light blue, and stagnophilic (HV > 4) spp. are indicated by apricot colour.*

fish taxa	eu A	eu B	Para A	Para B	Plesio	Paleo	HV	IW
Abramis ballerus	5	3	2				1.7	4
Abramis brama	2	2	3	2	1		2.8	2
Abramis sapa	5	3	2				1.7	4
Acipenser gueldenstaedtii	8	2					1.2	6
Acipenser nudiventris	7	2	1				1.4	5
Acipenser ruthenus	7	2	1				1.4	5
Acipenser stellatus	8	2					1.2	6
Alburnoides bipunctatus	10						1	6
Alburnus alburnus	1	2	3	2	2		3.2	2
Anguilla anguilla	2	2	3	2	1		2.8	2
Aspius aspius	3	3	2	1	1		2.4	2
Barbatula barbatula	8	2					1.2	6
Barbus barbus	6	3	1				1.5	5
Blicca bjoerkna	2	2	3	2	1		2.8	2
Carassius carassius					1	9	5.9	6
Carassius gibellio			2	3	3	2	4.5	2
Chondrostoma nasus	6	3	1				1.5	5
Cobitis elongatoides			2	3	4	1	4.4	3
Cottus gobio	10						1	5
Cyprinus carpio	1	2	3	2	2		3.2	2
Esox lucius		1	2	3	3	1	4.1	2
Eudontomyzon mariae		8	2				2.2	5
Gobio albipinnatus	5	3	2				1.7	4
Gobio gobio	3	4	2	1			2.1	3
Gobio kesslerii	6	3	1				1.5	5
Gymnocephalus baloni	5	3	2				1.7	4
Gymnocephalus cernuus		2	3	4	1		3.4	3
Gymnocephalus schraetser	7	3					1.3	5
Hucho hucho	9	1					1.1	6
Huso huso	7	3					1.3	5
Leucaspius delineatus				1	6	3	5.2	5
Leuciscus cephalus	3	3	2	1	1		2.4	2
Leuciscus idus	3	3	3	1			2.2	3
Leuciscus leuciscus	5	3	2				1.7	4
Lota lota	5	3	2				1.7	4
Misgurnus fossilis				1	3	6	5.5	5
Pelecus cultratus	6	3	1				1.5	5
Perca fluviatilis	1	1	2	3	2	1	3.7	1
Rhodeus amarus		1	1	3	4	1	4.3	2
Rutilus pigus	8	2					1.2	6
Rutilus rutilus	1	2	2	2	2	1	3.5	1
Sabanejewia balcanica	6	3	1				1.5	5
Salmo trutta fario	7	2	1				1.4	5
Sander lucioperca	1	3	3	2	1		2.9	2
Sander volgensis		2	4	3	1		3.3	3
Scardinius erythrophthalmus				1	5	4	5.3	4
Silurus glanis	1	3	3	2	1		2.9	2
Tinca tinca				1	3	6	5.5	5
Umbra krameri						10	6	6
Vimba vimba	5	3	2				1.7	4
Zingel streber	8	2					1.2	6
Zingel zingel	8	2					1.2	6
FI	1.61	1.8	2.18	3.85	4.29	5.23		

The assessment of the ecological quality (Tab.4) is based on a comparison between the pre-regulation river-type-specific reference assemblage and the recent assemblage. The pre-regulation reference fauna can be taken into account by study of historical literature and autecological knowledge. The ecological quality is classified by a five grade sorting scheme corresponding to the WFD evaluation system. A preliminary benchmarking of habitat alterations in the Szigetköz floodplain has been developed on fish data (Table 3) and it is focused on fauna changes in the eupotamon-A and -B type habitats:

1) Calculation of HFI by change of fish fauna in the eupotamon-A type habitat

- change of rheophilic sp. num. < -4 and
  change of stagnophilic sp. num. 0 **HFI < 1.70** fish biol. quality grade = *excellent*
- change of rheophilic sp. num. < -9 and
  change of stagnophilic sp. num. < +3 **HFI < 2.00** fish biol. quality grade = *good*
- change of rheophilic sp. num. < -15 and
  change of stagnophilic sp. num. < +6 **HFI < 2.45** fish biol. quality grade = *moderate*
- change of rheophilic sp. num. < -22 and
  change of stagnophilic sp. num. < +8 **HFI < 3.10** fish biol. quality grade = *poor*
- change of rheophilic sp. num. >-21 and
  change of stagnophilic sp. num. > +7 **HFI >= 3.10** fish biol. quality grade = *bad*

2) Calculation of HFI by change of fish fauna in the eupotamon-B type habitat

- change of rheophilic sp. num. < -4 and
  change of stagnophilic sp. num. 0 **HFI < 1.90** fish biol. quality grade = *excellent*
- change of rheophilic sp. num. < -9 and
  change of stagnophilic sp. num. < +3 **HFI < 2.30** fish biol. quality grade = *good*
- change of rheophilic sp. num. < -15 and
  change of stagnophilic sp. num. < +6 **HFI < 2.90** fish biol. quality grade = *moderate*
- change of rheophilic sp. num. < -22 and
  change of stagnophilic sp. num. < +7 **HFI < 3.50** fish biol. quality grade = *poor*
- change of rheophilic sp. num. >-21 and
  change of stagnophilic sp. num. > +6 **HFI >= 3.50** fish biol. quality grade = *bad*

Table 4. *The five grade evaluation system for the ecological quality of the eupotamon-A and eupotamon-B habitats based on Habitat-specific Fauna Index (HFI) calculated from fish data in the Szigetköz section of the Danube and its floodplain branch system*

Eupotamon-A	Eupotamon-B	Ecological (fish biological) quality grade
HFI < 1.70	HFI < 1.90	*excellent*
HFI < 2.00	HFI < 2.30	*good*
HFI < 2.45	HFI < 2.90	*moderate*
HFI < 3.10	HFI < 3.50	*poor*
HFI > = 3.10	HFI > = 3.50	*bad*

4 Evaluation of the habitat changes in the Szigetköz floodplain

The historical areal extent of the aquatic habitats was 4500 ha (Schwarz 2009) and the recent extent is 2360 ha (Potyó & Guti 2010). The shrinking was 48 %; therefore the *AE quality grade* of the Szigetköz floodplain is moderate. The proportion of the eupotamon habitat is recently 78 %, consequently the *PEu quality grade* is good. The recent composition of the aquatic habitats is similar to the historical composition, all main types of the aquatic habitats of the ana-branching sector exist, and the *HC quality grade* is excellent. The *integrated quantitative quality grade* of the floodplain is moderate by the 'one bad all bad' principle.

Habitat quality of the eupotamon type side arms was evaluated according to the long-term change of fish fauna. The fauna changes were determined by literature study and using database of direct ichthyologic monitoring (from the end of the 1980s). According to the expert judgement 39 fish species occurred in the eupotamon habitats of the ana-branching channel system in the pre-regulation situation and 77 % of the species was rheophilic. Their proportion decreased to 68 % and 51 % in the eupotamon-A and -B type habitats, respectively, until the beginning of the 1990s, and their ratio dropped to 61 % and 38 % recently. In the same time the number of the stagnophilic species increased and their proportion changed from 0% to 12% and 17% in the eupotamon-A and -B type habitats, respectively. The fauna changes can be indicated by the increasing trend of the HFI. The *quality grade of the HFI* was good in the eupotamon-A and moderate in the eupotamon-B type habitats before the operation of the Gabčikovo hydropower dam; however, it recently is moderate in the eupotamon-A and poor in the eupotamon-B type side arms (Figure 1).

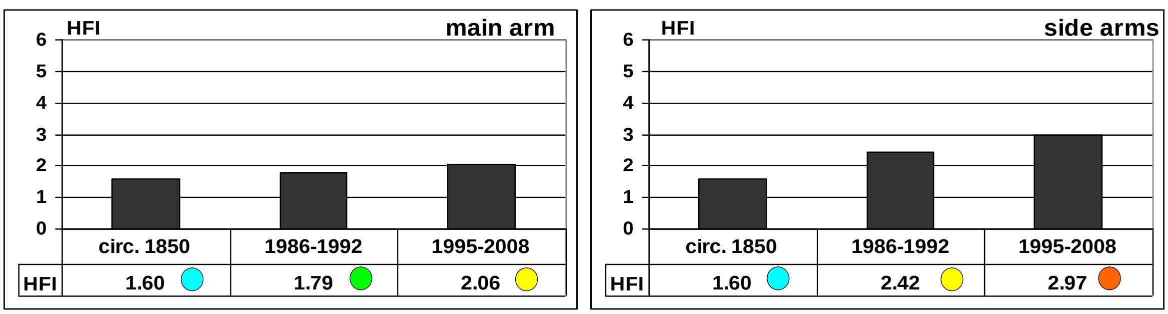

Figure 1. *Long-term change habitat quality is expressed by the Habitat-specific Fauna Index (HFI) for fish in the main arm (eupotamon-A) and in the side arms (eupotamon-B). Quality grade is indicated by colours: Blue = excellent, Green = good, Yellow = moderate, Orange = poor.*

The ecological status of the Szigetköz section of the Danube is good according to the biotic metrics of the official WFD assessment, and this grade seems overestimated if environmental deficiencies are taken into consideration. The evaluation of historical change and ecological quality of floodplain waters are neglected in the WFD assessment. On the contrary the proposed benchmark system takes the quantitative and qualitative attributes of the aquatic habitats into consideration; and it complements the recent assessment methods of the ecological status. Within the frame of its further development, application of the para-, plesio and paleopotamon habitats is reasonable, and the calculation of the HFI can be extended to other groups of aquatic organisms.

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A strategy to enhance migratory fish species in the Weser River Basin according to the aims of the European Water Framework Directive

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Keywords: Weser, river morphology, migratory fish, hydro power, EU-WFD

1 Introduction

The Water Framework Directive (WFD) has revolutionised water resources management in Europe over the last decade by adjusting the sustainable use of water not only to the supply of human needs but also to the ecological integrity of surface water. With the river basin management plans that were published in December 2009 and adopted in most of the European river basin districts, this new broad integrative approach has reached another milestone. River-basin management plans comprise an overview of the river basin, an analysis of pressures and impacts, a cadastre of protected areas, the assessment of water bodies, strategies and objectives to reduce the effects of significant water management issues and a summary of the programme of measures.

But the ambitious objective to achieve a good ecological status or to develop a good ecological potential failed by more than 80% of surface water bodies as indicated by biological quality components like fishes, macrophytes or macrozoobenthos in the Weser River Basin (FGG Weser 2009). Long-distance migratory fish species account for about 20 % of all fish species whereas potamodromous species constitute up to 40% of the fish community in potamal and epipotamal river stretches in the Weser River Basin (FGG Weser 2006). Most of the migratory species are in bad conditions due to low quality of spawning habitats and a high density of obstacles cutting the river continuity (Pusch et al. 2009).

In the Weser River Basin the hydromorphological structures of the surface waters have been subject to significant changes during the 19th and 20th century, caused not only by measures of navigation, hydropower or flood defence, but also for agriculture and urban development as in other large European Rivers (Tockner et al. 2009). Modifications in the river-channel morphology as well as in hydrological dynamics have strong impacts on the ecological conditions especially on the quality, suitability and availability of habitats for aquatic organism (Carling & Petts 1992; Poff et al. 1999) and particularly on fish fauna (e.g. Bischoff 2002, Schiemer et al. 2001).

Therefore a strategy for the improvement of river continuity both at regional and river basin scale has to be developed in close cooperation with the authorities of water resource management and all the affected stakeholders to answer the following questions:

- Which are the migratory fish species (diadromous and potamodromous) of concern in the Weser River- Basin?
- Where are sufficient and adequate spawning and juvenile habitat areas?
- What are the migration routes and is their continuity disrupted by dams?
- How can priorities of measures set in the future?
- What is the way to share problems and management issues with the main affected stakeholders?

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2 The Weser approach

Since 1996 in the Weser River Basin the idea of enhancing existing populations of migratory fish species has been realized. In 2003 the Ministries of Environment competent for the Weser River Basin (River Basin Commission Weser) decided to develop a fundamental strategy as a basis for the basin wide objectives in implementing the WFD. Concrete environmental objectives regarding migratory fish species have been identified, and priorities of measures and areas have been derived considering specific ecological demands of diadromous and potamodromous species as well as the cost effectiveness of measures.

The River Basin Commission Weser has decided to develop an approach to deal with this task at different levels – at a river basin scale focusing on the supra-regional migration routes and at regional or local scale concentrating on continuity as well as on the spawning and nursery habitats in small streams and rivers. In a first step native migratory fish species have been selected (Tab. 1) analysing historical data about spawning areas and fisheries activities and defining a reference of fish fauna for each water body separately.

Table 1. *List of target migratory fish species of the Weser River Basin*

species	scientific name	migration type	mobility
river lamprey	*Lampetra fluviatilis*	anadromous	long distance
sea lamprey	*Petromyzon marinus*	anadromous	long distance
twaite shad	*Alosa fallax*	anadromous	long distance
Salmon lachs	*Salmo salar*	anadromous	long distance
sea trout	*Salmo trutta f. trutta*	anadromous	long distance
smelt	*Osmerus eperlanus*	anadromous	medium distance
Three spine stickleback	*Gasterosteus aculeatus*	anadromous	medium distance
Barbel	*Barbus barbus*	potamodromous	medium distance
Ide	*Leuciscus idus*	potamodromous	medium distance
Vimba	*Vimba vimba*	potamodromous	medium distance
Burbot	*Lota lota*	potamodromous	long distance
Eel	*Anguilla anguilla*	catadromous	long distance

In a second step, tributaries which provide suitable and accessible spawning and nursery habitats and which contribute to an ecological network of habitats of diadromous species and populations of potamodromous species have been identified. The migration routes in between were identified and classified in supra-regional routes (Weser and the lower parts of Werra and Fulda) and routes of regional importance. Fig. 1 presents the maximum setting of migration routes in the Weser River Basin; it encompasses all target species and approximately 1,900 km including 212 obstructions.

In a third step the function of fish passes was evaluated by technical criteria (DWA 2006) and need for action was classified for each obstacle separately. Additionally, improvements including cost estimates of each construction for better continuity were recommended. Availability of spawning nursery habitats was estimated with respect to the expected efficiency of fish pass function.

In a last step the relevance of each obstacle was estimated by criteria for anadromous, catadromous and potamodromous species separately (Tab. 2). Priorities of measures have been identified for each obstruction with respect to the ecological relevance and the need for action to improve fish migration. Priorities were classified in four categories and for up- and downstream migration separately.

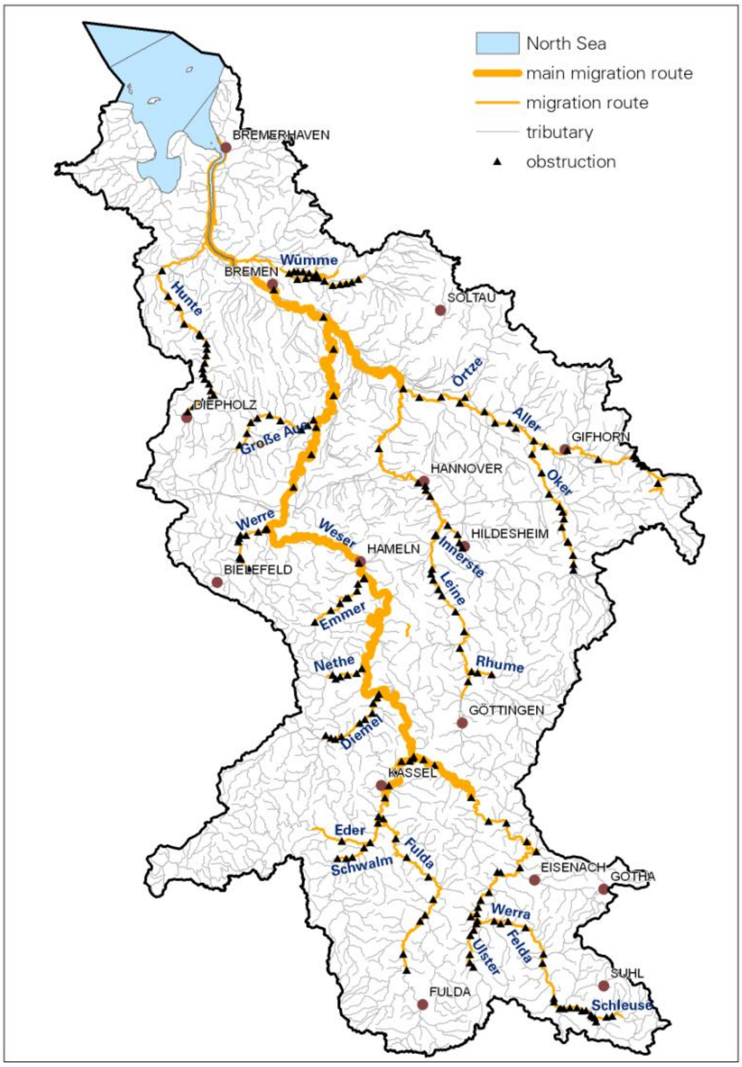

Figure 1. *Migration routes of basin wide interest in the Weser River Basin*

Table 2. *Criteria for assessing the relevance of each obstruction for the different migratory fish species*

	anadromous	**catadromous**	**potamodromous**
Potential of habitat network	Dimension and accessibility of potentially appropriate spawning and juvenile habitat areas upstream of the obstruction	Dimension of potential eel habitats upstream of the obstruction	Dimension of potential appropriate spawning and juvenile habitats Distance to the next reproductive population (stream effect)
Potential damages of downstream migration	Potential effects of damages at downstream migration caused by turbines	Potential effects of damages at downstream migration caused by turbines	-
Relevant assessment due to the EU-WFD	-	Part of the reference community in the water body upstream	Part of the reference community in the water body upstream

	anadromous	catadromous	potamodromous
			Comparison between current population status and reference conditions
Requirements due to the Natura 2000 Directive	Number and position of the Natura 2000 areas with anadromous fish species in the Weser River Basin	-	-

„-" criteria has no relevance for this fish species

From the river basin management point of view a separate process for the main migration route has been established to discuss the restoration of continuity with the hydropower companies, the administration for shipways, the association for fishery and the Federal States in charge with the water resource management issues. A small core working group has been installed supported by special surveys to answer questions on technical feasibility and cost effectiveness and to discuss different strategies of solutions. By combining all information a strategy has been elaborated by the head office of the Weser River Basin Commission to be adjusted to the requirements of the members of the core working group. This strategy contains elements to optimise the up- and downstream continuity in a three phase system (Tab. 3).

Table 3. *Weser River Basin fish strategy. Overview of measures regarding the necessities of each location and time schedule*

Schwerpunkt	location	status quo			Phase 1				Phase 2				Phase 3			
		fish ecological priority			measures	fish ecological priority			measures	fish ecological priority			measures	fish ecological priority		
		fish protection	down-stream	upstream		fish protection	down-stream	upstream		fish protection	down-stream	upstream		fish protection	down-stream	upstream
Schwerpunkt Weser	Langwedel	3	1	1	Turbine management and bypass,; optimisation of fishladder	4	4	implemented		4	4	implemented		4	4	implemented
	Dörverden	2	1	1	Turbine management	2	3	1	Fishladder and Bypass	2	4	implemented		2	implemented	implemented
	Drakenburg	4	2	2		4	2	2		4	2	2	Fishladder; Bypass and Turbine management	4	2	implemented
	Landesbergen	4	3	1		4	3	1	Fishladder	4	3	implemented		4	3	implemented
	Schlüsselburg	4	3	1	Fishladder and Turbine management	4	4	implemented		4	4	implemented		4	4	implemented
	Petershagen	3	2	1		4	2	1	Fishladder and Turbine management	4	4	implemented		4	4	implemented
	Hameln	3	3	2		3	3	2		3	3	2	Fishladder; fine screen	4	4	implemented
Schwerpunkt Werra	Hann. Münden			2	Fishladder			implemented				implemented				implemented
	Letzter Heller	4	4	2	Fishladder	4	4	implemented		4	4	implemented		4	4	implemented
	Hedemünden	1	4	4	fine screen and fishladder	implemented	implemented	implemented		implemented	implemented	implemented		implemented	implemented	implemented
	Bad Sooden-Allendorf	1	4	2	fine screen and fishladder	implemented	implemented	implemented		implemented	implemented	implemented		implemented	implemented	implemented
Schwerpunkt Fulda	Hann. Münden	1	4	2	fine screen and fishladder	implemented	implemented	implemented		implemented	implemented	implemented		implemented	implemented	implemented
	Bonaforth			4				4				4	Fishladder			implemented
	Wilhelmshausen			4				4				4	Fishladder			implemented
	Wahnhausen	3	4	2		3	4	2	Fishladder	3	4	implemented		3	4	implemented
	KS Voigtsche Mühle	1	4	2		1	4	2	fine screen and fishladder	implemented	implemented	implemented		implemented	implemented	implemented
	KS Neue Mühle	1	4	2		1	4	2	fine screen and fishladder	implemented	implemented	implemented		implemented	implemented	implemented

Priority 1 2 3 4

implemented

3 Outlook and Conclusions

The procedure described has been the basis for the identification of relevant areas and possible measures at the main obstacles in the supra-regional migration routes with respect to fish ecological demands concerning continuous passage of corridors and connectivity of habitats. The associated costs of potential measures have been estimated about 100 M€ and, hence, the technical feasibility assessed. Looking at ecological benefits and cost effectiveness priority measures have to be derived. Results and experiences from regional projects as well as already available data are taken into account and are being looked at from a river basin wide perspective.

Fish ecological priorities and the cost effectiveness analysis will provide the basis for a priority list of measures. The objectives are identified in an iterative process analogue to the set priorities at a river basin wide scale. These objectives will have an effect on local and regional objectives and, hence, a top-down and bottom-up process of information and negotiation is necessary, between the administration in charge with water resource management issues and the different stakeholder groups in the entire Weser River Basin. Such participatory procedures have been proven very successful and lower in costs than traditional top-down procedures.

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Changes of plant diversity in riparian grassland after extreme hydrologic events in the Elbe floodplain

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Keywords: Elbe, floodplain, riparian grassland, extreme hydrologic events, monitoring

1 Introduction

Floods are an essential component of active floodplain ecosystems. They play an important part in maintaining biodiversity by creating a successional landscape mosaic with high spatial and temporal habitat heterogeneity (Ward & Tockner 2001; Robinson et al. 2002). Floodplain organisms are well adapted to the different flood frequencies and groundwater levels encountered in these habitat types. In temperate regions, most of the adaptations aim to survive the ''usual'' winter and spring floods (Adis & Junk 2002). Theses floods, occurring in periods of low physiological activity, have little effect on most plant and animal species. Moreover, the alternating wet-dry cycle is of crucial importance for floodplain organisms (Crawford 1996). In contrast, summer flood events, such as the extreme flood of 2002 at the Elbe, may severely disturb both vegetation and faunal communities (Vervuren et al. 2003; Ilg et al. 2008). So far, the effects of unusual and extreme floods on floodplain ecosystems and their communities were little known because precise data describing the pre-flood situation were lacking.

The Elbe is one of the largest rivers in Europe with a length of 1,091 km and a catchment area comprising 148,268 km^2. The floodplain of the Middle Elbe in central Germany has a hydrological regime close to the natural state (Scholz et al. 2005), characterised by a higher discharge and some heavy floods during the winter and early spring and a lower discharge from June to November (Scholten et al. 2005). Therefore, the flood of August 2002 with a statistical recurrence interval of 168 years (Schiermeier 2003) can be considered as extreme both in terms of its timing and height, and led to the inundation of the whole active floodplain area.

Alluvial grasslands dominate the floodplains along the middle reach of the River Elbe. The study area is located within the UNESCO Biosphere Reserve ''Riverine Landscape Elbe' and under the direct influence of the River Elbe hydrodynamics (Henle et al. 2006; Scholz et al. 2009). In a monitoring project, vegetation data of a riparian grassland site were collected over twelve years. In the study presented here, the effects of two extreme hydrologic events, the summer flood of 2002 and the extreme low water of 2003 on plant diversity, were analysed. In August 2002, all sampling plots were inundated for at least two weeks. Water level ranged from 1.6 to 4.4 m above soil level.

2 Methods

The study site near Steckby (51°54' N, 11°58' E) in the active floodplain of the Elbe shows typical, extensively managed grassland communities (fig. 1). 36 sampling plots of a size of 100 m^2 each were established based on a stratified random sampling design (Henle et al. 2006; Scholz et al. 2009). The plots were measured with D-GPS so that they could be relocated exactly (Henle et al. 2006).

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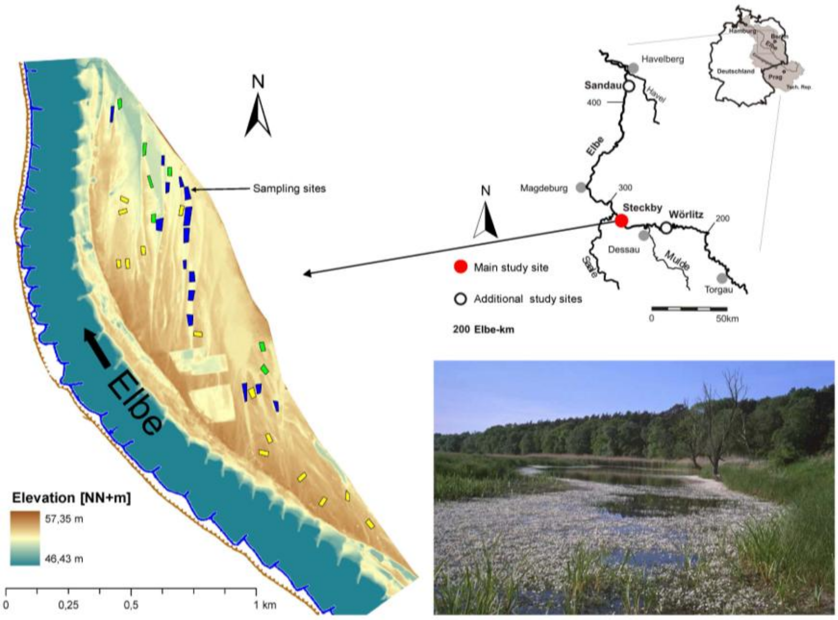

Figure 1. *Overview and detailed map of the study area. The photo shows a representative section of the study area. The coloured rectangles on the left show the sampling plots: blue: flooded depressions with amphibian vegetation, green: wet grassland and yellow: moist grassland.*

The study site is characterised by a high variation in the relief. Therefore, the plots were classified into three groups according to their hydrology: flooded depressions with amphibian vegetation (n = 15), wet (n = 7) and moist grassland (n = 14). Vegetation in these plots was recorded twice a year using the classical Braun-Blanquet scale (Braun-Blanquet 1964). The sampling periods were 1998 and 1999, 2003 to 2006 and 2009. For the description of plant diversity, species richness, Shannon's diversity index (Shannon & Weaver 1994) and Simpson's dominance index (Simpson 1949) were calculated.

3 Results

The study showed that between 1999 and 2003, species richness and Shannon's diversity index declined in all classes while Simpson's dominance increased (fig. 2). In the following years until 2009, species richness increased and reached even higher levels than before 2002 in wet and moist grassland. In these classes Shannon's diversity and Simpson's dominance indices reached values similar to those of 1998 and 1999. For the vegetation of the flooded depressions, these indices did not recover.

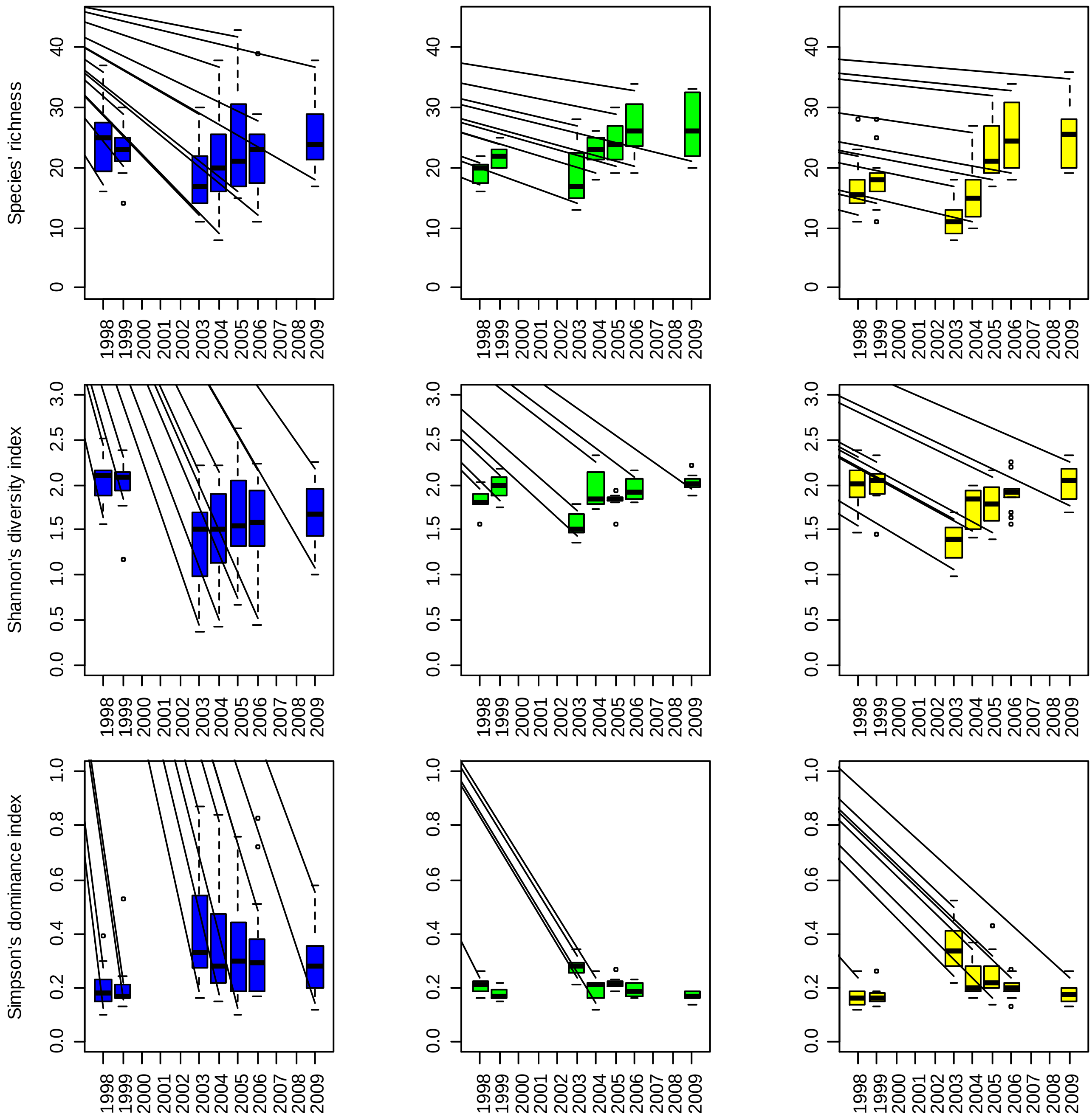

Figure 2. *Box-and-Whisker diagrams of a seven-year record of species' richness, diversity (Shannon's diversity index) and dominance (Simpson's dominance index) of three types of riparian grassland vegetation on the Middle Elbe floodplain. The black horizontal lines in the boxes represent median values. Blue, left column: flooded depressions with amphibian vegetation (n = 15). Green, central column: wet grassland (n = 7). Yellow, right column: moist grassland (n = 14).*

The observed extreme hydrologic events had a clear effect on species composition of the study site. While areas on higher elevations that are less frequently flooded gained species after few years, Shannon's diversity index reflecting the evenness of species' cover in the assemblage needed a few more years to reach the level before 2002. The shift of cover values towards a stronger dominance of certain species after 2002 is reflected by Simpson's dominance index. For example the cover value of *Lycopus europaeus, Stachys palustris* and *Xanthium albinum* declined in flooded depressions between 1998 and 2003. Whereas in moist grassland the cover value of *Alopecurus pratensis, Euphorbia esula, Plantago major* subsp. *major, and Ranunculus ficaria* increased, those of

Arrhenatherum elatius, Galium album and *Ornithogalum umbellatum* decreased. Details will be presented in Glaeser et al. (2009).

Diversity was most strongly affected in the vegetation of flooded depressions. Due to the higher disturbance regime, even after six years, species composition remained less balanced and more dominated by single species as compared to 1998 or 1999. However, it remains uncertain if the flood event of 2002 or the drought of 2003 or both led to the observed changes in vegetation.

4 Discussion and conclusions

This case study shows that changes in hydrology such as extremely high or low water levels can affect floodplain vegetation in a way that biodiversity declines and needs some years to recover. Similar effects have also been shown for other organisms such as ground beetles and molluscs (Ilg et al. 2009). If the hydrology of a site (habitat) would change to a new state, this would clearly lead also to a new habitat with a different species composition. If this shift would take place slowly, it is likely that plants or other organisms will be able to follow, i.e. the species composition of a given site will change to a new assemblage that is adapted to the new environmental situation (van Eck et al. 2006). Non-adapted species may move to sites that are better suited. The open question is what a slow shift means in this context. This cannot be answered by the results of the case study because the hydrologic situation after the extreme events of 2002 and 2003 returned to a similar average than before. Historical case studies such as the decline of groundwater along the Upper River Rhine due to Tullas's correction work resulted in a complete and drastical change of the former floodplain vegetation, leading to a completely different habitat (Huegin & Henrichfreise 1992). A yearly monitoring (KLIWAS project 5.06, BMVBS 2008) of these sites at least until 2013 may provide further understanding of the effect of extreme hydrologic events.

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Implementation of EC Nitrate Directive in the Czech Republic

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Keywords: vulnerable zones, nitrate pollution, action programme, Jizera, model SWIM, fertilization, monitoring

1 Introduction

The European Community Council found that nitrate concentrations in waters of some areas are rising and reaching values that are disproportionate to the requirements for drinking water quality, and that this trend is not consistent with the interests of protecting the natural environment. The EC Council has adopted Directive 91/676/EEC on the protection of waters against pollution caused by nitrates from agricultural sources (Nitrates Directive, EC 1991). The Directive has only one main objective - to reduce water pollution caused by nitrates from agricultural sources and to prevent such pollution. The Directive deals generally with all groundwater and surface waters polluted by nitrates or endangered by nitrates pollution with respect to nutrient input into surface waters as well as marine and coastal waters where the nitrogen-rich runoff from the land may facilitate eutrophication. The Nitrates Directive requests the identification of water pollution by nitrates from agricultural sources and to determine vulnerable zones. It is necessary to implement measures reducing leakage of nitrates from agricultural sources into such vulnerable zones, as requested by so called 'action programs'. In addition to action programs, whose measures are mandatory in defined vulnerable zones, binding good agricultural practices must be compiled as preventative measures.

The requirements of the Directive have been incorporated into the Czech Water Rights in §33 of Act No. 254/2001 Coll.

The first phase of implementation of the Nitrates Directive in the Czech Republic was completed in 2003 when Government Decree No. 103/2003 Coll. (GR 2003) was adopted on the designation of vulnerable zones and on the use and storage of fertilizers and livestock manure, crop rotation and implementation of erosion control measures in these areas. In March 2003, initial designation of vulnerable zones was announced under Article 3 Appendix I to the Directive and on January 1, 2004, the first action program was started. The vulnerable zones were revised at the end of the first phase of implementation of the Nitrates Directive in 2007. The revised designation was declared by Government Decree No. 219/2007 Coll. (GR 2007), amending Decree No.103/2003 Coll. The Action Program was revised at the end of 2007 and in April 2008 the changes were announced by the Government Decree No. 108/2008 Coll. (GR 2008), modifying Decree No. 103/2003 Coll.

The second revision of vulnerable zones will be announced in March 2011 as part of the regular four-year cycle of revisions.

The period between the two revisions (2007 - 2010) is used for finding new opportunities for improving accuracy of input data and better identification of water pollution from agricultural sources. The monitoring of surface waters for the Nitrates Directive has been optimized and the National Groundwater Monitoring Network has been reconstructed.

To assess the impact of fertilizers on agricultural land, we tested the possibility of using an eco-hydrological mathematical model SWIM (Soil and Water Integrated Model, Krysanova et al. 1998). The SWIM model is used in the national project Labe (Elbe River) to evaluate the impact of the changes in land use and potential climate change on the dynamics of nutrients in the Jizera River (Martínková et al. 2010, Fig.1).

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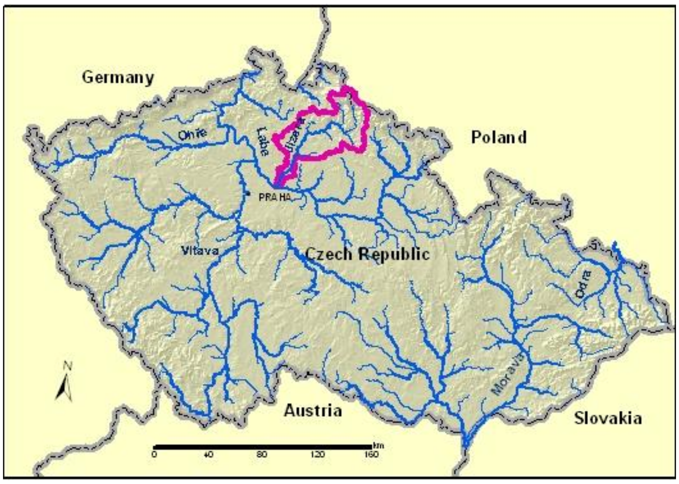

Figure 1. *Map of the Czech Republic with the outline of Jizera River test basin.*

2 Hydrography and land use

Czech Republic (CR) with an area of 78 866 km^2 and 10.2 million inhabitants is a land-locked country with mild climate. Three European continental divides of the North Sea, Baltic and Black Sea meet at Kralický Sněžník Mt. reaching an altitude of 1432 m above sea level. The main water-courses in Bohemia are Labe River (370 km long) and Vltava River (433 km), in Moravia Morava River (245 km) and Dyje River (306 km), in Northern Moravia and Silesia Region Odra River (135 km) and Opava River (131 km). Long-term average rainfall is 672 mm, the average rainfall ranges between 400 and 700 mm. Of the total area of the CR, 54% is agricultural land and 33% forests. More than 70% of agricultural land is arable land. The main crops grown on arable land are cereals (winter wheat, barley and fodder corn), potatoes, sugar beet and oilseed rape. The nitrate concentration in surface and groundwater is strongly depended on the typical land use of the watershed and on degree of dilution by infiltrated water. The concentration is also negatively affected by high percentage of sub-surface drainage all over agricultural regions. In addition, nitrate leaching is enhanced by large fields without balks and buffer strips.

3 Vulnerable zones designation

National environmental goals with respect to nitrate leaching and designation of vulnerable zones are similar as the Nitrate Directive requirements – 50 mg.l^{-1}. The CR has accepted the principle which identifies specific vulnerable zones and adopted stricter measures for those areas in the form of an action program. An extensive study of water pollution, part of the general pollution study of the Ministry of Environment, the project ran from 1998 - 2002 (Rosendorf 2003), formed the basis for the initial designation of vulnerable zones. Detailed maps of susceptibility of soil and rock substrate to allow nitrates penetration into water were prepared; at the same time the development of agriculture and its contribution to water pollution in different areas of the CR were evaluated. Vulnerable zones of surface water and groundwater were first evaluated by concentration of nitrates. The next step was to evaluate the danger of eutrophication of inland and marine waters. The resulting vulnerable zones were created by combining individual areas, by river basins of the 3rd order, in the case of deep hydrogeological structures also according to the knowledge of natural conditions. The use of soil was also considered as predominantly agricultural land. Vulnerable zones also include areas with insufficient data base but susceptible to pollution. The resulting vulnerable zones were then transferred to cadastral maps as required by the Government (Hrabánková et al., 2002).

The first several revisions in 2007 were based on the same procedure as in 2003, but special emphasis was given to the assessment of nitrates concentrations observed in surface and groundwater monitoring stations, and to establishing concentration trends (Hrabánková et al., 2007). For detailed evaluation of water pollution by nitrates, the entire territory of the CR was divided into two types of areas on the basis of predominant groundwater circulation. Areas with shallow groundwater circulation (in Paleogene and Cretaceous sediments of the Carpatian system, in Permo-Carboniferous deposits, in Proterozoic and Paleozoic crystalline rocks and in Zones of the top layer in Upper Cenozoic sediments) were evaluated together with surface waters and areas with deeper or more complex groundwater circulation (in Tertiary and Cretaceous basin sediments and in Upper Cretaceous sediments) were evaluated separately. In this case absence of surface waters pollution does not automatically exclude pollution of groundwaters.

National environmental goals with respect to eutrophication are not determined exactly. The level of eutrophication is most frequently evaluated in various studies on the basis of phosphorus concentration or according to the P:N-ratio. The assessment method is being developed by the T.G.Masaryk Water Research Institute (Rosendorf et al. 2008); it is related to concentration of total phosphorus and chlorophyll-a in flowing waters. The evaluation of eutrophication was also based on the contribution of point and diffuse sources of pollution. The contributions of the individual sources were differentiated on the basis of the ratio of nitrate nitrogen to total inorganic nitrogen in the monitored sites.

Monitoring of surface water in the CR is secured partly by the state monitoring network (operated by the Czech Hydrometeorological Institute, CHMI). Here, sites on large rivers evenly distributed over the whole country are monitored - a total of 325 such sites, monitored once a month, are used for the Nitrates Directive. The other important source of information on concentrations of nitrates in surface waters is a monitoring system set up specifically for the Nitrates Directive (EC 2003). This monitoring system is working with a network of major, operational and investigative sites. The main sites monitor significant water-courses in both vulnerable and invulnerable zones with sampling once a month. They are located in areas representative of the monitoring of water bodies under the EU Water Framework Directive (WFD) with emphasis on water bodies with the highest proportion of agricultural land (EC 2000). Operational sites monitor the major tributaries of water bodies or parts of the river basins in the vulnerable and invulnerable zones. They are monitored regularly every four years and focus on areas with agricultural activities. Investigative sites are especially useful for determining the effectiveness of measures implemented within the action programs. They monitor the most critical period with regard to nitrates leaching out of the soil into water during winter period October-March. Altogether 624 measuring sites were used for revisions in 2007.

Groundwater is monitored in the state monitoring network that is used as data source for the purposes of the WFD and the Nitrates Directive. This monitoring is to be performed at measuring sites that are representative for groundwater aquifers. The monitored sites are wells and springs, 408 sites have been evaluated for these purposes so far; their number will increase significantly after a complete reconstruction of the monitoring network in 2010. Groundwater is sampled each year in spring and autumn.

4 SWIM modeling

The Jizera River was used in simulating the impact of fertilization on nitrates concentrations in surface waters, applying the eco-hydrological model SWIM. This model simulates water and nutrient fluxes in soil and vegetation, as well as transport of water and nutrients to and within the river network (Krysanova at al., 1998). The Jizera Basin is situated in NW Bohemia, CR (Fig. 1). Drainage area of the Jizera Basin is 2180 km^2. The River Jizera is 185 km long and drains into the River Elbe. The altitude of the basin is between 168 and 1434 m above sea level. Point and diffusive nitrogen sources were included in the model. Calibration was carried out for winter wheat as a crop. Details on calibration and modeling of nitrogen dynamics are presented in Martinkova et al. 2010.

5 Results and discussion

Compared to the first designation in 2003, the area of vulnerable zones in 2007 increased by 3.2 % to 31 358 km^2, which represents 39.8 % of the area of the CR (Fig.2). Most zones designated as vulnerable in 2003 remained so, and some even deteriorated. Some vulnerable zones where nitrate concentrations in the groundwater decreased below 25 mg/l were excluded in 2007. On the other hand, new areas with much arable land and high amounts of livestock manure became vulnerable, as nitrate concentrations increased to 25-50 mg/l.

Table 1 shows a summary of measuring sites in surface and groundwater in the CR, together with the distribution of average concentrations of nitrates according to the categories prescribed by the European Commission.

Table 1. *Number of sites in each category according to the average concentrations of nitrates in groundwater locations and surface waters for the period 2004 - 2006.*

Nitrate concentration [mg/l]	Groundwaters		Surface waters	
	Number of sites	%	Number of sites	%
0-24.99	303	74.3	772	81.4
25-39.99	33	8.1	157	16.5
40-49.99	14	3.4	14	1.5
≥50	58	14.2	6	0.6
Total	408	100.0	949	100.0

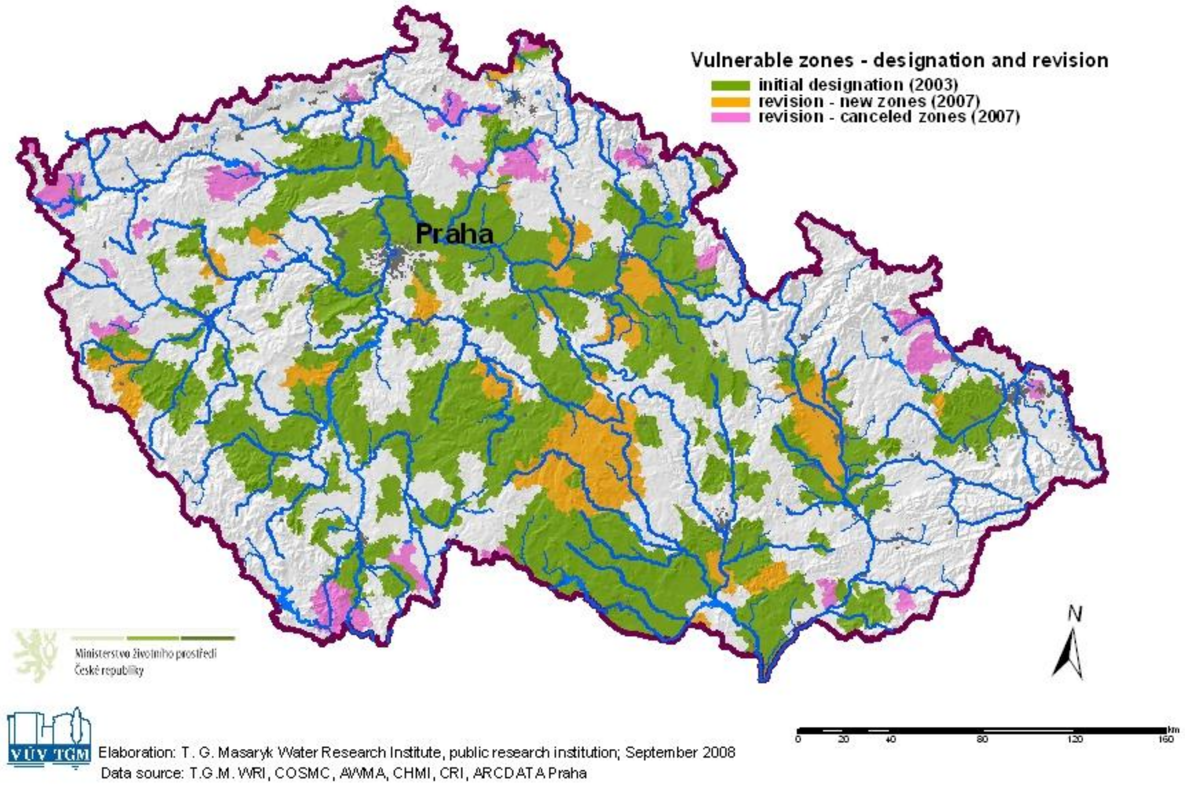

Figure 2. *Designation of vulnerable zones in the CR in 2003 and after revisions in 2007.*

In the Jizera River Basin, where was tested the SWIM model, vulnerable zones were designated because of increased concentrations in both ground and surface waters. Higher concentrations in surface waters (near 40 mg/l) were found in Kněžmostka River - the left tributary of the Jizera River. The SWIM model was calibrated for the outlet (monitoring station Předměřice, Fig. 3). Here, we present the results of several modeling experiments focused on fertilization: the monthly average concentrations of nitrates at the basin outlet increase no more than 20% in the ten-year period with a maximum dose of fertilizer (170 kg N per ha). Consequently, the mean nitrate concentrations would increase to a maximum of 20 mg/l.

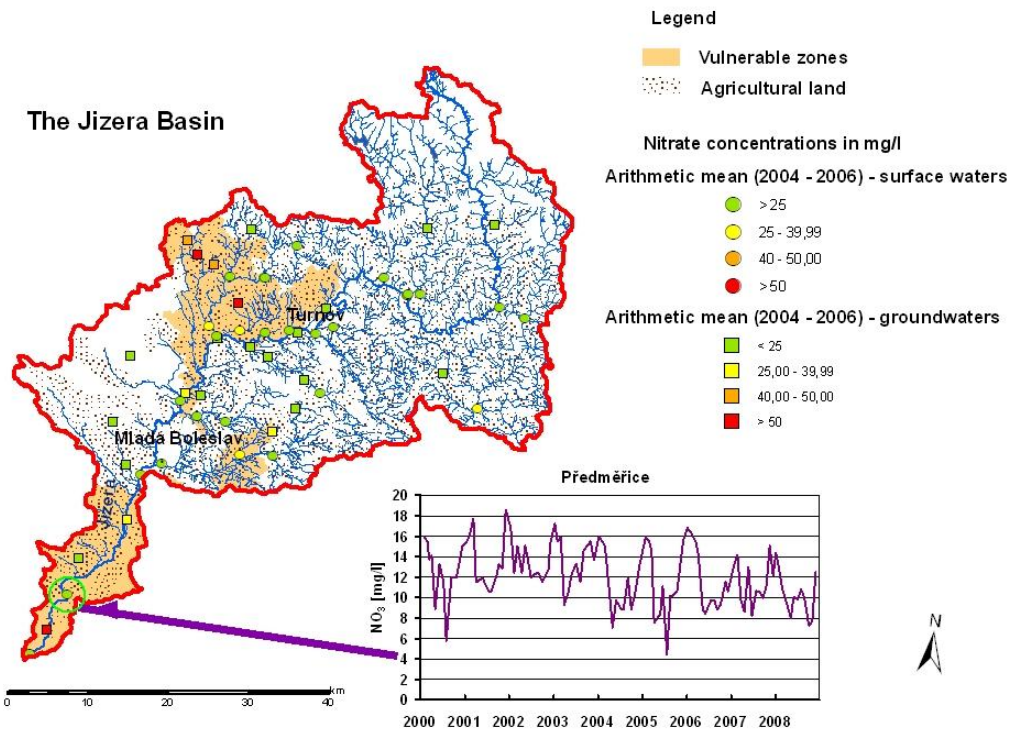

Figure 3. *Monitoring of groundwater and surface waters in the Jizera River Basin and the decreasing trend of concentrations of nitrates observed in the station Předměřice.*

6 Conclusions

Vulnerable regions in the CR are designated in cadastral maps. Their total area is 31 468 km^2, which represents 39.9% of the entire territory of the CR. The proportion of vulnerable agricultural land is 47.7 % of the total agricultural land in the CR. The results of modeling with the SWIM model proved that the influence of fertilization on nitrate concentrations in surface waters at the outlet of the Jizera Basin is not significant.

Subsequent implementation of the Nitrate Directive (by the first action programme in 2004) limited the effect of monitoring in the CR. The measures of the first action programme were applied mainly as a test. In the present period, the data from water monitoring and monitoring of farming practice are not well connected. The missing relationship is planned to be built up in 2010. A new revision of vulnerable areas is planned for March 2011. A modernized groundwater monitoring network and a monitoring system optimized for surface water Nitrates Directive will then be utilized.

Acknowledgements

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Specific organic pollutants in Serbian rivers-current state and the actions required

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Keywords: Danube, specific organic pollutants, priority pollutants, Water Framework Directive

1 Introduction

In accordance with the Water Framework Directive (WFD, 2000/60/EC) specific pollutants are all priority substances and other substances identified as being discharged in significant quantities into water bodies. The list has to be identified during development of the River Basin Management Plan. Both priority pollutants and specific organic pollutants are just a part of the puzzle called "organic micropollutants in water". Those chemicals are released into the aquatic environment by various routes (e.g. inadequate or insufficient waste and wastewater treatment, agriculture). According to the literature (Schwarzenbach et al., 2006: Loos et al., 2009) there are more than 100,000 registered chemicals in the EU, of which 30,000-70,000 are in daily use. Emerging compounds that enter the environment in various ways differ in biodegradability, emission loads and the effects they can cause to aquatic eco-systems and humans. They might be polar or non polar in their nature. In both groups one can find persistent compounds. If they are not persistent their continuous emission or transformation products might pose a problem. Their presence in water in small concentrations and in various mixtures is a great challenge for research related to both their effects in eco-systems and implementation of appropriate water treatment technologies (Schwarzenbach et al., 2006). Traditionally persistent organic pollutants (POPs) are hydrophobic molecules that tend to accumulate in sediments and enter food chains with a tendency to accumulate in organisms. Recently the significance of polar compounds has also been shown: polar herbicides, pharmaceuticals, complexing agents, surfactant metabolites etc. (Reemtsma & Jekel, 2006; Loos et al., 2010), which endanger water quality and might have a negative impact on water supply sources. Although the WFD is not yet implemented in Serbia, a certain amount of data referring to some organic pollutants has been obtained by official monitoring programmes of the Republic Hydrometeorological Service of Serbia (RHMS). This paper presents an overview relating to the presence of specific organic pollutants in Serbian watercourses obtained by the RHMS in 2004-2008 and the results of several GC/MS screening surveys performed by the Faculty of Sciences, Novi Sad.

2 Official monitoring performed by the Republic Hydrometeorological Service of Serbia

The hydrographic network of the Republic of Serbia is part of the Danube River Basin; it can be further divided into several sub-basins: the basins of the River Tisa, the River Sava, the Hydrosystem Danube-Tisa-Danube, the River Drina, the River Velika Morava, the River Zapadna Morava and the River Južna Morava. Between 2004-2008, RHMS monitored in total 17 pesticides and PAHs (fluoranthene,

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benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)-perylene, indeno (1,2,3-c,d)-pyrene). Since 2005, PCBs were also included in the programme (PCB 28, 52, 101, 138, 153, 180 and 194). Among those compounds, 9 pesticides, 6 PAHs and fenanthrene are listed in Annex I of Directive 2008/105/EC. Additional data was collected regarding heptachlor, heptachlor epoxide, DDE, p,p'-DDD, o,p'-DDT and methoxychlor. During 2009, the official monitoring programme was changed adding 20 new parameters: pentachlorophenol, octylphenol, nonylphenol, hexachlorobutadiene, pentachlorobenzene, terbutryne, prometryne, desethylatrazine, desisopropylatrazine, chlorphenvinphos, chlorpyriphos, alachlor, diuron, linuron, monuron, isoproturon, α-endosulphane, β-endosulphane, isodrin, trifluralin. Among those compounds, 14 are from the list of priority substances and 6 are additional. However, another 14 organic pollutants from the list of priority substances, including certain other pollutants, are still not included in the monitoring programme: anthracene, benzene, brominated diphenylether, carbon-tetrachloride, chloroalkanes, 1,2-dichlorethane, dichlormethane, di(2-ethylhexyl)-phtalate, naphthalene, tetrachloro-ethylene, trichloro-ethylene, trichloro-benzenes, tributyltin compounds and trichloro-methane.

The results analyzed below originate from the official monitoring and represent a synthesis of 139 sampling sites, located on 66 rivers. The monitoring was performed with a sampling frequency of 0-12 samples per year per location; the list of analytical methods is presented in Table 1.

Table 1. *Analyzed organic pollutants and their corresponding methods of analysis*

Parameter	**Analytical Method**	**Limit of detection**
Pesticides		µg/l
αHCH, βHCH, Lindane, Hexachlorbenzene, Heptachlor, Heptachlorepoxide, Aldrin, Endrine, Dieldrine, DDE, p,p'-DDD, p,p'-DDT, o,p'-DDT, Metoxychlor	1. EPA Method 8081A (GC-ECD), 2. EPA Methods: 8270 and 3510 (GC-MS, liquid-liquid extraction)	0.001, 0.001, 0.002, 0.001, 0.001, 0.001, 0.001, 0.002, 0.002, 0.002, 0.002, 0.002, 0.002, 0.003
Atrazine, Simazine, Propazine	1. EPA Method 507, Determination of Nitrogen- and Phosphorus-Containing Pesticides in Water by Gas Chromatography with a Nitrogen-Phosphorus Detector 2. EPA Methods: 8270 and 3510 (GC-MS, liquid-liquid extraction)	0.009 0.0020, 0.0030, 0.0015
PCB		
PCB 28, 52, 101, 138, 153, 180, 194	1. EPA Method 8082A (GC-ECD), 2. EPA Methods: 8270 and 3510 (GC-MS, liquid-liquid extraction)	0.001 0.0002-, 0.0002, 0.0003, 0.0002, 0.0002, 0.0002, 0.0003
PAH		
Fluroanthene, Benzo (b) fluoranthene, Benzo (k) fluoranthene, Benzo (a) pyrene, Benzo (g,h,i) perylene, Indeno (1,2,3-c,d)pyrene	1. EPA Method 8100, Summary: Polynuclear Aromatic Hydrocarbons (GC-FID) 2. EPA Methods: 8270 and 3510 (GC-MS, liquid-liquid extraction)	0.1 0.0001-0.0002

The total number of samples analyzed between 2004-2008 increased (Fig.1), and an increasing trend was recorded for the number of locations with at least one positive finding (Table 2). The term “positive finding” is used for samples where at least one compound was detected above the limit of detection of the method used. The list of pesticides detected between 2004-2008 is presented in Table 3. The most frequently detected pesticides in 2006 were hexachlorobenzene with a positive finding in 47 samples (15% of the analysed samples), followed by DDE in 34 samples (11% of total number of samples) and heptachlor in 20 samples (6% of total number of samples). In 2007, the highest frequency was recorded for triazine herbicides and β-HCH (40% of positive samples for atrazine, 12% propazine, 8% simazine, 6% β-HCH), while in 2008, the most abundant were triazine herbicides (49% of samples was positive for atrazine and 3% for simazine and propazine). In general, only a small number of samples exceeded the annual average environmental quality standards (EQS) for inland surface waters (2008/105/EC). The comparison was made based on each sample concentration and not on the annual averages.

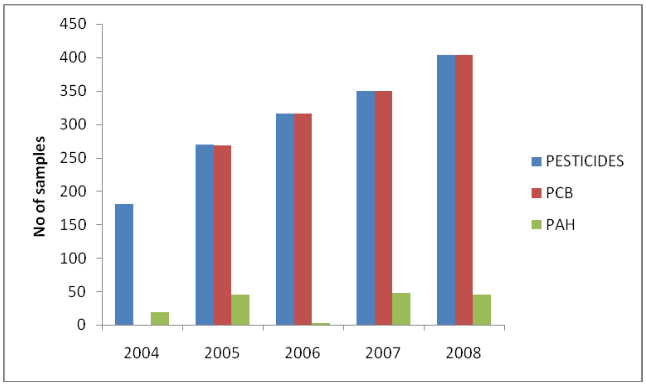

Figure 1. *Total number of annual analyses*

Table 2. *Number of locations with positive pesticide findings*

Year	Investigated locations	Positive locations	Ratio of positive locations (%)
2004	94	4	4.3
2005	100	12	12
2006	111	65	58.6
2007	114	81	71.1
2008	101	79	78.2

Table 3. *Number of positive samples*

	2004	2005	2006	2007	2008
Total number of samples	181	269	316	350	404
α-HCH	0	0	1	3	2
β-HCH	0	0	4	20	8
Lindan	2	3	11	8	0
Hexachlorbenzene	0	1	47	9	0
Heptachlor	0	5	20	15	0
Heptachlorepoxide	0	0	18	17	0
Aldrin	0	4	13	4	0
Endrin	0	0	12	5	1
DDE	1	0	34	6	4

Dieldrin	0	0	9	10	1
p,p'-DDD	0	0	6	11	1
p,p'-DDT	0	0	8	4	3
o,p-DDT	0	0	3	0	0
Metoxychlor	0	0	14	11	8
Atrazine	0	0	4	141	197
Simazine	0	0	0	27	14
Propazine	0	0	1	42	14

In total, there were 11 samples above EQS in 2006, 15 samples in 2007 and 3 samples in 2008; the values are listed in Table 4. For all other samples, positive findings values were below EQS. The concentrations of compounds which are not regulated by Directive 2008/105/EC were below 0.1 µg/l which is the maximum allowed concentration for drinking water. Regarding positive findings for PAHs and PCBs, there was 1 positive sample for PAHs in 2007 and 11 positive samples in 2008. There were 4 positive samples for PCBs in 2006, 4 in 2007 and 1 in 2008.

Table 4. *Pesticides concentrations above AA-EQS (Directive 2008/105/EC)*

Year	Results	AA-EQS [µg/l]
2006	**Hexachlorbenzene**: 3 samples with 0.011µg/l **Aldrin**: 1 sample with concentration 0.27 µg/l and 1 sample with 0.018 µg/l **DDT**: 1 sample 0.04 µg/l, 1 sample 0.053 µg/l **Atrazine**: 1 sample 0.889 µg/l and 1 sample 0.612 µg/l ***Pesticides not included in Dir. 2008/105/EC, above 0.1 µg/l*** **DDE**: 1 sample with concentration of 0.146 µg/l **Propazine**: 1 sample with value 0.1 µg/l	0.01 0.01 sum for cyclodiene pesticides 0.025 (total) 0.6
2007	**Dieldrin**: 5 samples (0.025-0.195 µg/l) **Endrin**: 2 samples (0.01 and 0.023 µg/l) **DDT**: 1 sample 0.087 µg/l **Atrazine:** 3 samples (0.6-2.4 µg/l) ***Pesticides not included in Dir. 2008/105/EC, above 0.1 µg/l*** **Methoxychlor:** 1 sample 0.931 µg/l and 1 sample 1.1 µg/l **Heptachlor:** 1 sample 0.24 µg/l **Propazine:** 1 sample 0.11 µg/l	0.01 sum for cyclodiene pesticides 0.025 (total) 0.6
2008	**Atrazine**: 1 sample 0.805 µg/l and 1 sample 0.788 µg/l ***Pesticides not included in Dir. 2008/105/EC, above 0.1 µg/l*** **Methoxychlor:** 1 sample 0.122 µg/l	0.6

3 Results of GC/MS screening surveys performed by the University of Novi Sad Faculty of Sciences

GC/MS screening surveys are a useful tool for tentative identification of a great variety of organic xenobiotics. The University of Novi Sad, Faculty of Sciences has performed several such surveys in the territory of the Autonomous Province of Vojvodina since 2004. A hydrographic characteristic of this region is its dense network of canals within the DTD Hydrosystem (a total length of 20,000 km). Non-purified or insufficiently purified wastewaters are discharged to the watercourses. They originate from about 500 point sources and agriculture as an important diffuse source of pollution. One of the earliest surveys was the investigation of organic xenobiotics in the Vrbas region which represents a “hot spot” with respect to contamination of the canals of the DTD Hydrosystem by industrial wastewaters (Ivančev-Tumbas, 2004). Various compounds were identified: phthalates, phenols (also including nonyl phenol), hydrocarbons, benzene derivates, methyl esters of fatty acids, PAHs and caffeine. Tentative identification was made after liquid-liquid extraction by HP5890 GC series II with 5971 MSD. Recently, screening of the Krivaja River (109 km) and the Tisa River was performed. Details on methodology and results are given in Agbaba et al., 2008, Ivančev et al., 2008. An Agilent Technologies 7890 A GC system with a 5975C Mass Selective Detector was used for screening. Results evaluation was made by Deconvolution Reporting Software (DRS) which combines the results from the Agilent GC/MS Chemstation with the NIST Mass Spectral Library and Automated Mass Spectral Deconvolution and Identification System (AMDIS). Search matches for all identified compounds were higher than 70%. The main classes of organic chemical compounds tentatively identified in the Krivaja River were hydrocarbons, phthalates, aldehydes, alcohols and their derivates, organic acids and esters, PAHs, substituted PAHs and phenols. Some of the identified compounds are priority pollutants: anthracene, atrazine, benzene, di-(ethylhexyl)-phthalate (DEHP), fluoranthene and naphthalene. Additionally, several emerging contaminants were tentatively identified as being present: organophosphate flame retardants (tributyl phosphate), personal care products (benzophenone), pesticides (carbofurane and atrazine), fragrances (vanillin), antioxidative agents (p-tert-butyl phenol) and caffeine, the detailed results being presented in Agbaba et al., 2008. In the Tisa samples, tentatively identified compounds were aromatic and aliphatic hydrocarbons, toluene, styrene, acetamide, indene, acetophenone, 1,4-dichlorbenzene, phenol and its derivates, vanillin, various phthalates, DEHP, fluorene, organic alcohols and organic acids, benzothiazole, tributyl phosphate, diphenylamine, benzophenone, anthracene, caffeine, pyrene, cholesterol, squalene, etc. In total, 81 compounds were identified, the results being presented in Ivančev-Tumbas et al. (2009).

4 Conclusions

The data presented in this paper shows that there is a certain number of positive pesticide findings in Serbian watercourses, as well as the presence of some other priority and emerging pollutants. The content of pesticides in rivers exceeded the annual average values defined by Directive 2008/105/EC in a very small number of samples (3.5% in 2006, 4.3% in 2007 and 0.7% in 2008). However, further revision of the Serbian list as well as the frequency and objectives of the official monitoring programme is required in accordance with EU lists and EU water policy. The presence of the tentatively identified compounds has yet to be confirmed and further investigation on the presence and relevance of organic micropollutants must be undertaken.

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EPA Method 8082A/2007: Polychlorinated Biphenyls by Gas Chromatography (GC/ECD)

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The macrophyte-floodplain habitat relationship: indicator species, diversity and dominance

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Keywords: aquatic plants, Water Framework Directive, river restoration

1 Introduction

Floodplain water bodies are essential, yet vulnerable and endangered habitats along European rivers. Little work focused on their macrophyte composition in relationship with the typology of floodplain waters, and especially not on those located in the riparian corridor of large rivers (Amoros & Bornette 2002, Bornette et al. 1998, Dos Santos & Thomasz 2004). The connectivity of floodplain habitats with the main river channel were described by Amoros & Roux (1988), and Ward & Stanford (1995). Relationships between several elements of aquatic fauna and floodplain habitats were reported for the Danube River corridor by Chovanec et al. (2005), who also developed a 'Floodplain Index'. Since aquatic macrophytes were not considered so far with respect to this index a preliminary study was carried out in the Eastern Reach of the Austrian Danube.

2 Methods

Macrophyte occurrence and abundance were assessed following the European Standard 14184 and the procedure published by Kohler & Janauer (1995), which was also applied during the Joint Danube Surveys 1 and 2, carried out in 2001 and 2007, respectively, by the International Commission for the Protection of the Danube River (Janauer et al. 2008). Macrophyte data used in our approach on macrophyte – Floodplain Index relationships were provided by Reckendorfer, whose data base was stocked by different contributors (Janauer 2003, Kum et al. 2003, Pall & Kum 2004, Schiemer & Reckendorfer 2004).

We distinguished five Habitat Types (HT) based on the connectivity with the main channel (C^d, for details see Reckendorfer et al. 2006) and water depth (derived from the Digital Terrain Model). The order of HTs parallels the description of habitats as classified by Ward & Stanford (1995) and by Chovanec et al. (2005), but relates directly to physical environmental components. The macrophyte data set was related directly to the HTs.

Our data set consisted of 601 individual survey units, recorded in 10 different water body ensembles in the Lobau area, a UNESCO Biosphere Reserve, and in the floodplains on the left and right side of the Danube River between Vienna and Hainburg, which are located mainly within the boundaries of the Danube National Park.

We used Indicator Species Analysis (Dufrêne & Legendre 1997) and Monte Carlo simulation test for determining the significance (McCune & Grace 2002), as well as Simpson's Index of Diversity and Berger-Parker index of dominance, for the statistical treatment of data (Magurran 2004). Multi Response Permutation Procedure (MRPP, Bray-Curtis distance measure) was used to test for differences between Habitat Types (McCune & Mefford, 2006).

The extensive table of Indicator Species Analysis is part of the data collected for the "Danube River Water Engineering project East of Vienna" (held, in part, by the Department of Limnology, University of Vienna), and is too large for including it in this publication (3 full pages in print, 8pt font size). Authors may be personally contacted in case of interest in some details.

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3 Results

A total of 119 macrophyte species had occurred in the 601 survey units. 49 species were observed in only a single Habitat Type (HT), whereas 31, 19, and 19 were recorded in two, three and four HTs, respectively. The only species found in all five HTs was *Stuckenia pectinata* (Kaplan 2008; syn. *Potamogeton pectinatus* L.), but in a wide range of abundance.

Our statistical analysis of Indicator Species revealed very low total species numbers, as well as low Indicator Species numbers for the most dynamic HTs, the main river channel of the Danube (HT-1) and side channels with through-flow of 120 to 330 days (HT-2, Fig.1). An increase in species number occurred with the reduction of disturbance by water flow in the other HTs.

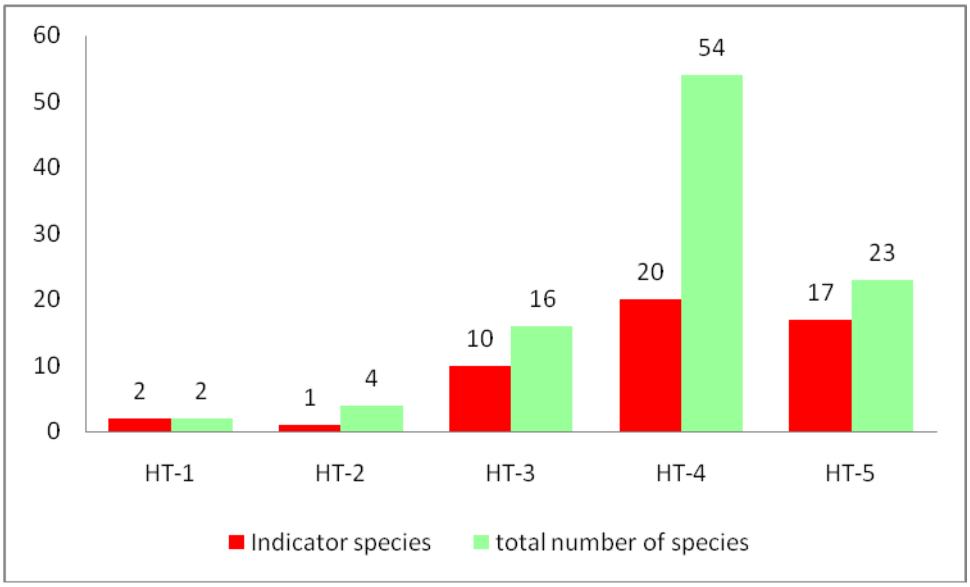

Figure 1. *Number of Indicator Species and total number of aquatic species recorded in the Floodplain Habitat Types. HT-1: Connectivity/C^d > 330 days; HT-2: C^d < 330 days; HT-3: C^d < 120days; HT-4: C^d < 5 days; HT-5: temporary waters.*

Table 1. *Multi-Response Permutation Procedure (MRPP) between Habitat Types: T-statistic describes the size of separation between Habitat Types: the more negative the T-statistic, the better the separation. The A-statistic describes how similar the survey units are. The multiple comparisons confirm the extremely high significance of all differences.*

Habitat Types	T	A	p
1 vs. 2	-27.86231926	0.16333319	<0.00000001
1 vs. 3	-46.21084743	0.06826439	<0.00000001
1 vs. 4	-59.51816262	0.03891881	<0.00000001
1 vs. 5	-22.00489047	0.21476034	<0.00000001
2 vs. 3	-24.78012187	0.03188525	<0.00000001
2 vs. 4	-95.36727018	0.0555638	<0.00000001
2 vs. 5	-28.38973469	0.11817932	<0.00000001
3 vs. 4	-155.717993	0.06912194	<0.00000001
3 vs. 5	-39.04108063	0.05088505	<0.00000001
4 vs. 5	-10.03077893	0.0063358	0.00000105

All HTs were significantly different to each other (much beyond p = 0.05), as based on species composition and abundance of species (Tab.1).

When studying the diversity of aquatic plants in the HTs we found an increase along a gradient of diminishing hydrological disturbance, from the main river channel into the floodplain, but the most distant floodplain water bodies, representing HT-5, revealed a slightly lesser diversity than HT-4, which is characterised by a higher connectivity with the main channel of the Danube River (Fig.2).

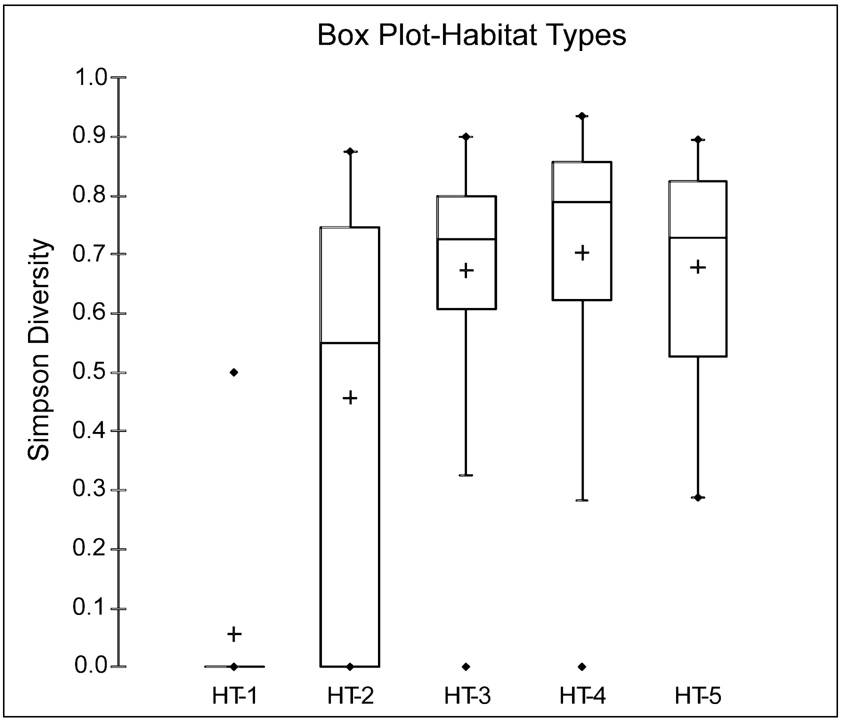

Figure 2. *Simpson Diversity values in the five Habitat Types.*

4 Discussion

In the water bodies of the Danube floodplain the overall species number (119) is at a high level, even when compared with other sections of the river. In the section of the main channel forming the basis for the present study only two species of bryophytes were detected, which is much lower than e.g. near Deutsch-Altenburg (river-km 1884.3 – 1885.4; unpublished data. 20 bryophytes were recorded). Yet, the restriction of mosses to the main river channel, and to their preferred substrate, the rip-rap along the river banks and the groynes, is a well known fact (Janauer et al. 2008), but records of vascular plants also exist from the main channel. Therefore the next step in characterising HT-1 in the main channel needs a survey of a larger number of lotic locations (HT-1was represented by only 17 units). 41% of the species recorded inhabited a single HT only, but the rest was distributed over more than one HT. This indicates the wider ecological adaptation exhibited by many aquatic macrophytes. Future studies will allocate habitat ranges for each species in this part of the Danube River floodplain corridor.

Regarding the characterisation of HTs by their macrophyte species composition and abundance it was possible to delineate Indicator Species (IS) for each of the five HTs. With decreasing impact of running water conditions both IS and total species numbers increased, except for the most remote HT, which represents the largest distances to the main channel and the lowest impact of water flow (see also: White & Jentsch 2001). The most preferred HT is located where no direct continuous water flow exists and, especially in our case, macrophytes seem to benefit from groundwater influx originating from the adjacent landscape behind the flood protection dam, whenever the river water level is low (Rezabek et al. 2003). Our study confirmed that the macrophyte vegetation can be used as an indicator that separates all the HTs from each other (Tab.1). Our study also revealed HT-4 as the macrophyte habitat with the highest species diversity (Fig. 2). But even more interesting are the ranges listed for the five HTs in the box-plots. The survey units allocated to HT-2, the HT of side channels, exhibit the widest range of diversity. The second largest range was detected for HT-5, which is dominated by still water conditions during most of the year. A promising investigation will be a deeper look into the assemblage of not only species, but also growth form types, which structure the macrophyte vegetation.

The role of aquatic plants in the river floodplain still holds some questions and shall be investigated with a larger set of locations. The authors hope to widen this knowledge in the near future and to surpass the still premature character of our present study.

5 Conclusion

With respect to the EC Water Framework Directive (WFD) authors provided some progress in filling the gap which is still present as regards the deeper knowledge of macrophyte composition in floodplain waters. We also gave numerical proof to the common knowledge that there is a rather great diversity in floodplain water vegetation, determined by connectivity with the main river channel. This study also provides a basis for further work on “what could the reference status be” for the biological quality element macrophytes in floodplains. Yet, as recent discussions in our interdisciplinary, abiotic/biotic group working on this Danube reach have shown, two major difficulties still need solutions: (i) as hydrologists and eco-hydraulic experts pointed out, the present status of “semi-separated oxbows” is not comparable with that of the original, active side channels, and (ii) full implementation of river restoration according to WFD would crash with the prime objective of the EC “Habitat Directive”, Natura 2000 areas and IUCN National Park regulations, as the present water bodies are typical results of the river regulation: in the pre-regulation floodplain similar macrophyte-rich oxbow types were located at much larger distance from the main channel, were less persistent in historical dimensions, and today their old locations are fully extinct due to flood protection levees, and agricultural development in the areas beyond. Reaching “good ecological status” may have to lead to a compromise between two competitive EC regulations - as the quest for primate of restoration over conservation will exterminate these last refuges of abundant floodplain macrophyte vegetation.

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2010 – The beginning of a new era of water management by river basin management planning

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Keywords: River Basin Management Planning; sustainable management challenges; justification of exemptions

1 Introduction

EUWMA, the European Union of Water Management Associations, represents public local and regional water authorities from, currently, eight EU member states[2]: EUWMA members are public entities, authorized by national law to perform water management tasks, including water supply, waste water treatment and discharge, flood and coastal protection, water quality management, drainage regulation and irrigation. Based on public interest and available scientific and technical data on both ecological and economic aspects EUWMA contribute to more effective collaboration and design in sustainable water management and to coherent ecological, economic and social development and identify all potential benefits and costs of action or non-action – thus pursuing Art 191 of the Treaty[3] even before the WFD came into force in 2000.

The river basin management plans, describing the programme of measures to realize WFD objectives, starts a new era of water management with obligations in assessment, setting realistic objectives and measurement strategies in 6 year planning cycles.

The Water Information System for Europe, WISE[4] compiles data, information and conclusions on projects, themes and policy on European water issues - last but not least on the outcomes of the EU Waterdirectors meetings and their endorsed CIS-papers. To summarize the development in water policy the following section (*italic*) is collected from relevant WISE pages:

> *With the first directives introduced in the 1970's, Europe has long been taking measures to ensure the quality of its water resources. Today, the challenge lies in tackling the pollution and overexploitation of freshwater in agriculture, industry and other human activities. Subsequently within the planning period of the WFD (i.e. 2000 to 2009) quite a few new regulations and directives on substantial issues came into force as Community policy concerning dangerous or hazardous substances in European waters was introduced almost three decades ago by Council Directive on pollution caused by discharges of certain dangerous substances (Directive 76/464/EEC)[5].*

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2 EUWMA members: Belgium - Verehttp://water.europa.eu/niging van Vlaamse Polders en Wateringen (VVPW); France – wateringues & Association Syndicales Autorisées (ASA); Germany - Deutscher Bund der verbandlichen Wasserwirtschaft (DBVW); Hungary - Vízgazdálkodási Társulatok Országos Szövetsége (VTOSZ); Italy - Associazione Nazionale Bonifiche, Irrigazioni e Miglioramenti Fondiari (ANBI); Spain - Federacion Nacional de Communidades de regantes de Espana (Fenacore); The Netherlands – Unie van epen (UvW); United Kingdom - Association of Drainage Authorities (ADA)

3 Article 191(ex Article 174 TEC) Official Journal of the European Union C 115/47 9.5.2008

4 http://water.europa.eu/ ; WISE is a partnership between the European Commission (DG Environment, Joint Research Centre and Eurostat) and the European Environment Agency

5 http://ec.europa.eu/environment/water/water-dangersub/76_464.htm

Directive 76/464/EEC has been codified as 2006/11/EC6. The Directive 76/464/EEC is integrated in the Water Framework Directive (2000/60/EC)7 and will be fully repealed in 2013.

Several substances have been regulated in specific directives8 (also called 'daughter' directives)9 in the 1980s by defining Community-wide emission limit values and quality objectives in the surface and coastal waters. The first list of priority substances in the field of water policy and amending Directive 2000/60/EC was adopted in 2001 (Decision No 2455/2001/EC)10. The aim of this decision was to identify a list of substances of concern (priority substances)[11] that present a significant risk to or via the aquatic environment in accordance with Article 16(2) and (3) WFD.

The new Priority substances Directive (Directive 2008/105/EC)[12] setting environmental quality standards for the priority substances and certain other pollutants is the result of the requirements set in Article 16(8) WFD. In addition, the Annex II to this new directive replaces Annex X of the Water Framework Directive referring to the list of priority substances. Member States shall take actions to meet those quality standards by 2015 as part of chemical status (Article 4 and Annex V point 1.4.3). For this purpose a programme of measures (according to Article 11) shall be in place by 2009, and become operational by 2012.

The Commission Directive 2009/90/EC[13] laying down, pursuant to WFD technical specifications for chemical analysis and monitoring of water status has been adopted and enters into force on 21 August 2009. The objective of this Directive is to establish common quality rules for chemical analysis and monitoring of water, sediment and biota carried out by Member States. The Directive shall be transposed within 2 years from entry into force.

Other directives came into force during the planning period of WFD regulating quite autonomously water related issues out of which are named:

Directive 2007/60/EC on the assessment and management of flood risks entered into force on 26 November 2007. This Floods Directive[14] now requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. With this Directive also reinforces the rights of the public to access this information and to have a say in the planning process.

Addressing Water Scarcity and Droughts[15]. the Commission Communication identify policy options to increase water efficiency and water savings.

The aim of The Marine Strategy Framework Directive[16] (adopted in June 2008) is to protect more effectively the marine environment across Europe. It aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The Marine Strategy Framework Directive constitutes the vital environmental component to achieve the full economic potential of oceans and seas in harmony with the marine environment.

With the forthcoming development of Marine Strategies under the MSFD (which will describe inter alia the programmes of measures required to achieve Good Environmental Status, also known as GES) there is great potential for duplication and confusion: both the WFD and the MSFD use the acronym GES for their objectives. Thus two (very different) GES targets will apply in the same water body. The now established use of the acronym 'GES' in coastal water bodies under the WFD refers to a carefully defined biological objective. GES under the MSFD is much broader. Two different

6 http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_064/l_06420060304en00520059.pdf
7 http://ec.europa.eu/environment/water/water-framework/index_en.html
8 http://ec.europa.eu/environment/water/water-dangersub/76_464.htm#specific_directives
9 http://ec.europa.eu/environment/water/water-dangersub/lib_dang_substances.htm#daughter
10 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:331:0001:0005:EN:PDF
11 http://ec.europa.eu/environment/water/water-dangersub/pri_substances.htm#list
12 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:348:0084:0097:EN:PDF
13 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:201:0036:0038:EN:PDF
14 http://ec.europa.eu/environment/water/flood_risk/index.htm
15 http://ec.europa.eu/environment/water/quantity/scarcity_en.htm
16 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0056:EN:NOT

strategic plans, which in some Member States will be developed and administered by different organisations, will set out different programmes of measures which will apply to the same water body. For several of the MSFD descriptors (e.g. contaminants, eutrophication, sea floor integrity), good environmental status in coastal water bodies will be delivered largely or entirely through the measures to be taken under the WFD.

An overriding issue is climate change and on 30 November 2009, Water Directors of EU Member States issued a guidance document on adaptation to climate change in water management. The document is the first result of numerous actions included in the European Commission White Paper Adapting to climate change[17]. The document includes guidance on how to take climate change into account in the implementation of the WFD, the Floods Directive and the Strategy on water scarcity and droughts.

2 The "new era"

Up to the end of 2009 the Water Framework Directive was seen primarily as an obligation of the national Competent Authorities which were provided to the Commission according to Art. 3 WFD

- to bring into force national laws, regulations and administrative provisions necessary,
- to identify the individual river basins laying within the national territory of the Member State,
- to undertake an analysis of its characteristics, a view of impacts and an economic analysis of water use,
- to establish a monitoring programme and a coherent and comprehensive overview on water status,
- to give inputs for the assessment and classification of status and at least
- to develop river basin management plans and programmes of measures after encouraging the active involvement of all interested parties.

Publishing the River Basin Management Plans by the Member States sustainable management principles have to be considered.

3 EU Commission view

"This Directive is based on a number of key principles : First, it is <u>*holistic*</u>, because it looks at the water system as a whole. It includes groundwater, surface water and marine water in a co-ordinated way to enhance synergies and avoid duplications. Secondly, it applies the <u>*integrated*</u> approach, because it aims to identify links with other policies, like maritime, agriculture, and land use planning, to name but a few. Thirdly, it is <u>*transparent*</u>, because public participation is one of its central features. Fourthly, it follows <u>*economic*</u> principles, because it seeks to promote the efficient use of water through proper pricing policies. And finally, it is <u>*ecological*</u>, because its core binding target is the "good ecological status", a true indicator of the health of the ecosystem and its biodiversity."[18]

4 European Parliament view

"Water is by far no single-issue topic for environmentalists alone. We are faced with a global challenge affecting our economy, our societies and our environment alike. The adaptation to climate change, risks of both flooding and water scarcity will be on the agenda as well as the influence of product design and different production processes. We will deal with the security of infrastructures, the necessity of ensuring

17 http://ec.europa.eu/environment/climat/adaptation/index_en.htm
18 Mr Stavros DIMAS Member of the European Commission responsible for the Environment
Opening Speech European Water Conference 2007 Brussels 22-23 March 2007

technological leadership by the European water industry and the relationship of water, health and biodiversity.

Water is of prime importance for both the household and industrial sectors, for the functioning of our ecosystems and agriculture. It is therefore essential to manage the supply and disposal of water wisely to ensure that clean water continues to be available at an affordable cost also in the future. How we manage and use our water resources will directly affect the quality of this resource itself as well as our environment and nature"[19].

Subsequently water reviews assessing the implementation of the EU Water Framework Directive (WFD) are on the agenda for the Barroso II term. National River Basin Management Plans, which had to be submitted by Member States in December 2009, will be closely scrutinised to verify whether Member States have introduced national pricing policies and water-saving measures, and whether water policy has been integrated into other policies, like agriculture. The Commission is to table a policy review on water scarcity and drought in 2012. Its main focus will be water efficiency. All other EU water policies and measures will be covered from a climate change point of view.

There are significant overlaps between these reviews and important interlinkages between water and other EU policies like inland navigation, industry, biodiversity, tourism and agriculture e.g. food security and the availability of water.

Under these general principles specific tasks are still to be clarified / harmonized:

- Classification of ecological status including confidence and precision of all (including supportive) quality elements (QE's), nutrient standards submitted by MS as well as ongoing activities on specific pollutants and hydromorphological QE's.
- Definition of ecological potential sensitive to biological assessment methods and hydromorphological pressures.
- Alien species affecting biological assessment methods.
- Information exchange with Marine Strategy Framework Directive. MSFD.

5 To make WFD operational – the view of Water managers

The process of implementing the WFD, the compliance check and assessment of the plans is a business among the EU-Commission and the EU Member States and their listed[20] Competent Authorities. Making the enhancement of status operational is an obligation of those organizations / authorities being responsible or in duty with it.

Member States delegate to their national water management structures to undertake measures to enhance the status of their water systems - at least consider the non-deterioration-principle.

In Germany as a Federal State the river management plans are mandatory for all Länder-authorities; i.e. whatever is or can be done should be reflected and proven in line with the objectives set in the plan.

Cultivated landscapes are a reality in many areas in Europe, which include mostly artificial and heavily modified water bodies. These require an EU-wide coherent procedure for setting normative values for their ecological potential.

Regional and local water management organizations cooperate to implement the WFD programme of measures and share the financial obligations; whereas discussions on water management issues and resulting decisions are often dominated by actors without these responsibilities.

Diverging interests in various national as well as EU policy areas constrain a coherent strategy to achieve the most efficient combination of measures and environmental objectives.

[19] Richard Seeber, MEP, President of the EP Intergroup on Water opening its first meeting on 27th January 2010.
[20] Art 3 WFD, see also http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm

The required international coordination on the river basin management level still needs to be further developed to become fully effective and serve as a platform where also regional water authorities can participate.

Dealing with the water management challenges, EUWMA members offer:

- Institutional and technical expertise to deal with water management issues;
- Ecological and cost efficient solutions to achieve realistic objectives;
- A tradition of involving stakeholders, acknowledging and using the insights of those that will be effected by the measures and creating common ownership of water issues;
- Proven experience in pragmatic and accountable performances on the realization of enhancement strategies, integrating nature conservation;
- An exchange of ideas, knowledge and experiences in water management issues throughout Europe, to strengthen our ability to meet objectives and improve our functioning;
- Compilation of knowledge on water management issues to contribute to a better common understanding on, among others, environmental objectives, performance compliance, reporting requirements, cost recovery and disproportionate costs.

To carry out their tasks and responsibilities, EUWMA members ask for:

- Under the commonly agreed EU principles, more attention for the importance of the subsidiarity principle with regard to proposed measures, implementation of measures, monitoring duties and reporting requirements;
- Increased acknowledgment of the importance and benefits of transboundary cooperation and coordination in international river basin management;
- Prioritization of water management issues in the allocation of European funds, with limited administrative requirements, to develop and carry out WFD related projects;
- The development of coherent European policy to minimize constraints for water management organizations to reach realistic objectives;
- The opportunity to share our knowledge and experiences with European decision makers with regard to water management issues;
- Clarification and harmonization for technical and legal issues for justification of exemptions:
- Uncertainties (for example in status of water bodies or effectiveness of measures) in setting environmental objectives and exemptions for water bodies; application of exemptions coordinated in a transboundary context;

  Determination of 'disproportionately expensive' underlying data and assessments; affordability arguments and considered relevant alternative financing mechanisms; consequences of non-action; administrative or legal constraints leading to disproportionate costs; reasons for measures to be not technically feasible; natural conditions that prohibit the (timely) achievement of the objectives.

Monitoring the Ichthyofauna in nature park Kopački Rit (Croatia) in 2008

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Keywords: Kopački rit, ichthyofauna, Danube, Drava

1 Introduction

Nature Park "Kopački rit" is one of the largest natural areas for spawning and breeding of freshwater fishes in Europe. It is located in the south-eastern part of Baranya (45˚15' – 45˚53' N, 16˚06' – 16˚41' E), on the flooded area of two largest Croatian rivers, the Danube and the Drava, and is directly exposed to their water regime.

Biological productivity and ichthyofauna diversity of Kopački rit depends on the Danube River and its flooding. Water level oscillations caused by physical barriers, such as hydroelectric power plants, significantly affect the flooding of Kopački Rit. Also, the river course was often modified, curves were cut and the river bank is reinforced with stone in order to enable safer river navigation and transport. Migratory fish routes from the Danube to Kopački rit are limited during low water levels (below gauge +500 cm at Apatin measurement station), especially because many hydrological connections, channels (so-called "Foks") and side-arms ("Dunavci") are being narrowed and covered up with different materials (sand, gravel and wood). All this reduced the Danube flooding at lower water levels and disrupted migratory fish routes to Kopački rit.

As a part of the management program for Nature Park "Kopački rit" it was decided to carry out research for assessing the current status of ichthyofauna (Fulton condition index and ABC curve) as baseline for future monitoring. Based on the previous research and older literature (Aničić et al., 2000; Mrakovčić et al., 2006), area of Kopački rit inhabitates 37 to 44 freshwater species from 12 families.

2 Material and methods

The ichthyofauna was monitored at 8 sites (Figure 1) in June and October 2008, using fishing nets and electro-fishing gear. Fishing nets about 100 m long, with different mesh size (10, 12, 14, 16 and 18 cm^2) were set in the afternoon (6-7 pm) and retrieved the next morning (6-7 am). Electro-fishing was done with boat-mounted electro-fisher (EL 65 II, manufacturer AGK kronawitter, 13 kW DC output, without pulse for 30 minutes) by sampling a 200 m long river bank area of Lake Sakadaš and Vemeljski Dunavac. Taxonomic identification of catch was carried out according to Vuković (1982). Fish length, weight and biomass were measured by standard technique (Murphy & Willis, 1996). The ratio of sexes in prussian carp (*Carassius gibelio*) was determined by a dissection of sexually mature individuals.

3 Results and discussion

The total catch of fish was 371 individuals, classified in 6 families and 12 species (Table 1). Total biomass was 468 kg. The most diverse family was Cyprinidae with 7 species. Prussian carp dominated in abundance (76%) and biomass (47%), followed by common carp (30%), and predatory fishes, such as pike and catfish (7% and

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9%, respectively). Beside fish, 3 individuals of crayfish *Astacus astacus* were recorded. The American crayfish (*Orconectes limosus*) was not found, although its occurrence in Kopački rit was confirmed in 2004 (Maguire & Gottstein-Matocec, 2004).

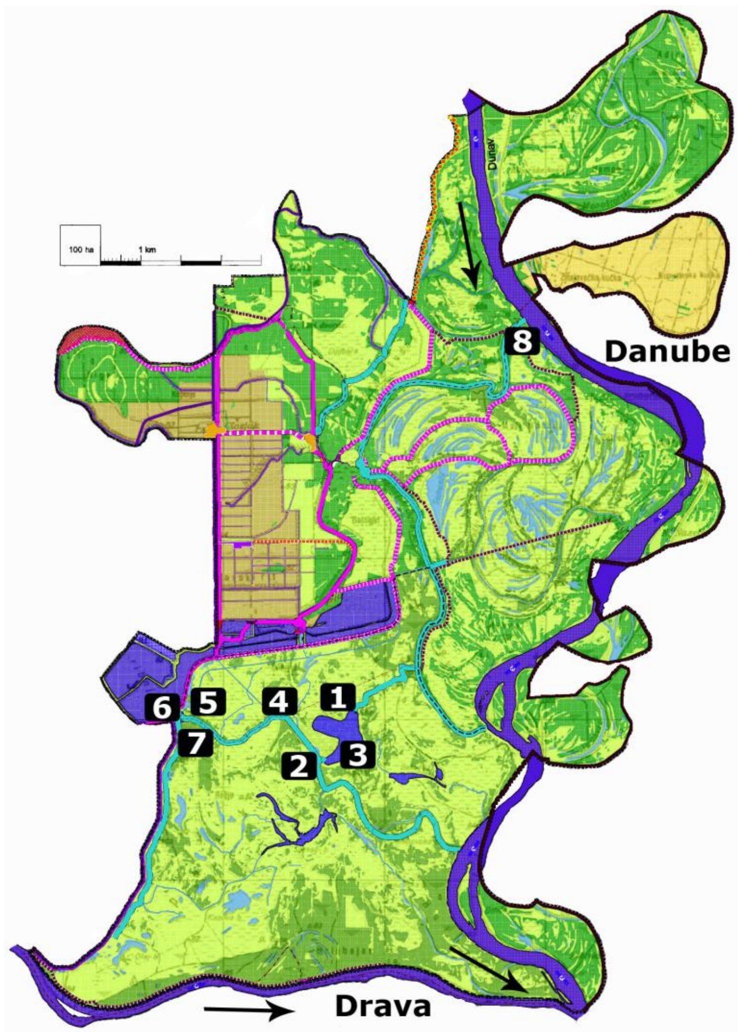

Figure 1. *Map of Nature Park Kopački rit with marked sampling sites (1,3 Lake Kopačko; 2,4,7 Channel Čonakut; 5 Channel Novi; 6 Lake Sakadaš; 8 Vemeljski Dunavac)*

Absence of fishes in size up to 20 cm and weight up to 300 g was noticeable in the catch, caused by direct impact of the predating Great Cormorant (*Phalacrocorax carbo sinensis*) colonies. Based on fish size and individual mass (Opačak et al. 2004), and size of cormorant throat, we can conclude that after certain time following the flooding, only very small fish or very large specimens remain in Nature Park Kopački rit. Neither group is of interest to cormorants, so most birds daily migrate to local fishponds and cause high damage to the commercial production. Cormorant nesting population in Kopački rit is estimated around 2000 to 2500 pairs. Population is far more than Kopački rit can support. Cormorant is protected species in Croatia, so there is no legal method for controlling the cormorant population, and there are no natural predators of cormorants.

Table 1. *Qualitative and quantitative composition of the catch in Nature Park Kopački rit in 2008*

Family / Species	**Abundance**		**Biomass**	
	pcs[2]	%	kg	%
Cyprinidae				
Common carp *(Cyprinus carpio carpio)*	37	9.97	139.10	29.73
Ide *(Leuciscus idus)*	3	0.81	7.14	1.53
Asp *(Aspius aspius)*	3	0.81	7.30	1.56
Bleak *(Alburnus alburnus)*	10	2.70	0.10	0.02
White bream *(Blicca bjoerkna)*	6	1.62	1.00	0.21
Common bream *(Abramis brama)*	11	2.96	19.10	4.08
Prussian carp *(Carassius gibelio)*	281	75.74	217.90	46.58
Esocidae				
Northern pike *(Esox lucius)*	8	2.16	31.00	6.63
Siluridae				
Wels catfish *(Silurus glanis)*	8	2.16	44.26	9.46
Percidae				
European perch (*Perca fluviatilis*)	1	0.27	0.50	0.11
Lotidae				
Burbot (*Lota lota*)	1	0.27	0.30	0.06
Cotidae				
Bullhead (*Cottus gobio*)	2	0.53	0.10	0.02
TOTAL	**371**	**100**	**467.8**	**100**

In order to estimate stress-level on fishes, the ABC (Abundance Biomass Comparison) diagram (Figure 2) was made according to Clarke (1990). ABC curves have a theoretical background in classical evolutionary theory of r- and k-selection. In undisturbed states, the community is supposed to be dominated by k-selected species (slow-growing, large, late maturing), and the biomass curve lies above the abundance curve. With increasing disturbance, slow-growing species cannot cope, and the system is increasingly dominated by r-selected species (fast-growing, small, opportunistic), and the biomass curve will be below the abundance curve (Yemane *et al*. 2005).

[2] pcs - number of caught specimen

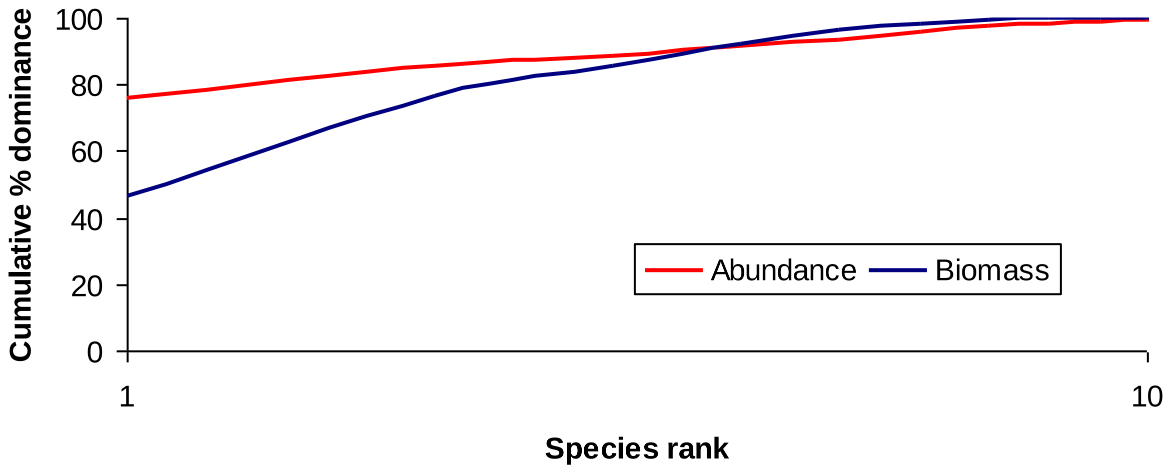

Figure 2. *Abundance biomass comparison diagram*

Our comparison between abundance and biomass indicated high disturbance (left part of Figure 2) to moderate disturbance (right part of Figure 2); hence, we conclude that fish communities in Nature Park Kopački rit are exposed to moderate stress. From data gathered during research, Fulton condition index (K_{TL}) is calculated according to Murphy & Willis (1996) for commercially important fish species (Table 2).

Table 2. *Fulton condition index (K_{TL}) of the catch in Kopački rit 2008.*

Species	**Fulton condition index (K_{TL})**		
	minimum	maximum	average ± SD
Common carp (*Cyprinus carpio carpio*)	1.139	2.261	1.496 ± 0.31
Prussian carp (*Carassius gibelio*)	1.094	2.500	1.466 ± 0.34
White bream (*Blicca bjoerkna*)	1.736	1.924	1.875 ± 0.28
Asp (*Aspius aspius*)	1.926	2.400	2.174 ± 0.24
Wels catfish (*Silurus glanis*)	0.529	0.700	0.609 ± 0.06
Northern pike (*Esox lucius*)	0.583	0.823	0.734 ± 0.10
Common bream (*Abramis brama*)	1.600	2.344	1.951 ± 0.37
Ide (*Leuciscus idus*)	0.888	1.435	1.211 ± 0.29

Average condition index indicates satisfactory general condition of ichthyofauna within the Kopački rit, and it is similar to ichthyofauna in surrounding rivers. In prussian carp females dominated by 61 % (n=36) over males (39 %, n=23). Based on previous research, it is obvious that males were slightly increasing over the years, which is in accordance to adaptive capabilities of this allochthonous species.

4 Conclusion

Although we tried to avoid selectivity by using different fishing gears, number of species in the catch were below that recorded in literature. So, based on given results, further research and monitoring on ichthyofauna in Nature Park Kopački rit are suggested, in order to make timely measures for ensuring protection of habitat and endangered fish species. The existing hydrological connection between Kopački rit and the Danube is far from optimum for fish migration under low water levels in the Danube. Even at medium water level, during the spawning period of Cyprinidae (April - June), the flooding of Kopački rit by the Danube is missing. Thus, the spawning of migratory fish in Kopački rit is possible only in years with extremely high water level. Since high water levels in the Danube and the Drava are rare and short, the flooding area and water volume in the Nature Park are reduced. All that impairs fertilized fish eggs during the incubation and reduce survival chance for larvae and fingerlings. For the optimum function of the unique hydrological system of the Danube and the Drava under low water levels, maintenance and deepening of channels in Nature Park Kopački rit are needed. That will provide sustainability of Kopački rit and optimum conditions for growing and spawning, not only for fish, but also for other members of fauna in the Nature Park. Recreational fishing associations suggest management with cormorant population in a way that is already implemented for the brown bear (*Ursus arctos*), which is also under protection in Croatia. However, national scientific institutions do not have consensus on this issue, and the problem with cormorant population is still unresolved.

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First records on effect of renewed flooding of three wetlands from Belene Island (Lower Danube, Bulgarian stretch)

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Keywords: river marshes, nutrients, phytoplankton, zooplankton, wetland restoration

1 Introduction

The importance and role of riparian wetlands based on their diverse functions and services were thoroughly reconsidered over the last 10-20 years. In that sense the future functions of restored wetlands on Bulgarian Belene Island are focused mainly on protecting, sustaining and developing biodiversity of this important part of the natural park. These functions have been extremely limited and even damaged by the years of permanent isolation of wetlands from the Danube River. Therefore the core of the wetland restoration is the establishment of a well functioning surface connection between marshes (floodplain) and main river, preventing wetlands from drying and securing effective flushing at times of high river levels. Only this combination of measures can provide the necessary precondition for achieving good ecological status of this wetland. Such an approach is not only supported by world-wide practice but also by monitoring restoration of another Bulgarian Danube wetland – the Srebarna Lake. Many publications dealing with ecological investigations of this lake clearly showed that the observed unstable improvement of lake status is connected with lake water level fluctuations and the thick mud layer still present on the lake bottom 15 years after its reconnection to the river (Kalchev et al. 2007, Beshkova et al. 2008, Vassilev et al. 2008, Kalcheva et al. 2008). All this is a result of ineffectively established connectivity to the river by only one inlet channel.

Therefore monitoring progress of Belene island wetland restoration is an obligatory measure, which will provide society and stakeholders with the necessary information and probable solutions in order to accelerate or correct the development of ongoing wetland restoration. This might help to avoid repetition of mistakes experienced on Srebarna Lake. The quick and reliable estimation of efficiency of the restoration process is substantially facilitated by available information for the ecology of Belene wetlands from the period before reconnection to the Danube River (Beshkova & Botev 2004, Beshkova et al. 2003).

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2 Material and methods

The Belene Island situated at Danube River km 561 -576 presently has four distinct water bodies (Fig.1).

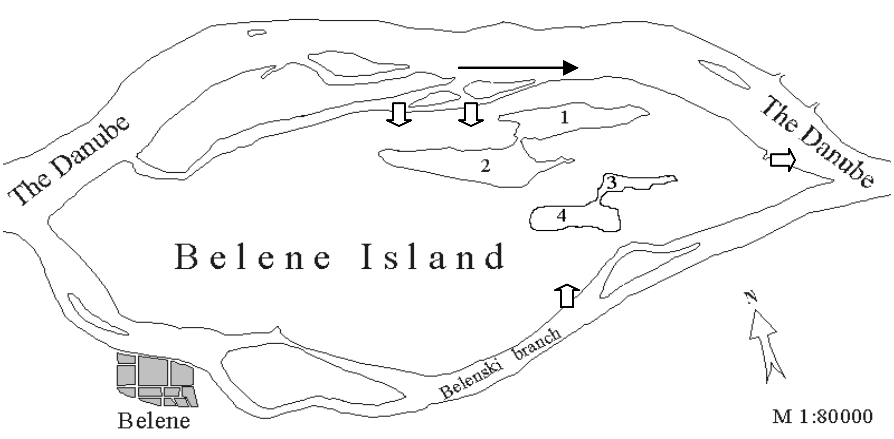

Figure 1. *Schematic map of the Belene (alias Persina) Island with localization of four marshes: Murtvo blato (1), Peschinsko blato (2), Dyuleva bara (3) and Staroto blato (4); block arrows mark places of inlet and outlet devices and line arrow indicates the river flow direction; the small-scaled network of channels crossing the island is not shown. Modified after Beshkova & Botev (2004).*

The latitude of Belene islands is about 43° 40' N, the longitude 25° 12-15' E and the altitude amounts to 18 m a.s.l. approximately. The total aquatic area before wetland restoration measured on topography maps amounts to 314 ha (Kalchev et al. 2010), while according to the Management Plan (MP 2006) the total area is 386 ha distributed between Peschinsko blato (182 ha), Murtvo blato (123 ha) and both Dyuleva bara and Staroto blato (81 ha). The geology of the island consists of gravels, sands and clays (alluvium), while the soil is fluvisols – calcaric (Kalchev et al. 2010). In the past all four marshes were completely isolated by dykes from the river for many years and were fed by underground waters only, thus some of them occasionally got dry and converted to temporary waters. Recently there are three inlet and one outlet devices (Fig. 1), whose function is to supply or retain the water in the marshes depending on the Danube River levels. Additionally the marshes are interconnected and the island area crossed by several draining channels built in the past with the aim to keep most of the island area dry. Now these channels are permanently full with water and part of them should serve the water circulation between the marshes. However, since the elevation of inlet and outlet devices is approximately the same there is almost no flow in the channels and, hence, no significant water exchange between marshes.

The data of 1997 (June), 1998 (June) and 2000 (April) characterizing the status of three wetlands in the period before restoration are derived from Beshkova & Botev (2004) and Beshkova et al. (2003). Additionally we got some data from Ninov (2008) who published information about aquatic chemistry of Peschinsko blato and Murtvo blato in June 2004.

The samplings of the period after reconnection of marshes with the Danube River were carried out in August and November 2009 within a project dealing with Danube wetland investigations funded by the National Science Fund of Bulgaria.

Despite the variety of data provided by literature and recent investigations it appears that only a limited number of characteristics are in common, allowing a comparison of wetland status before and after reconnection to the river. The set of comparable data includes measurements of pH, oxygen, NH_4-N, NO_3-N and PO_4-P concentrations, oxygen saturation of water, numerical and biomass abundance of phytoplankton and zooplankton of three marshes (Peschinsko blato, Murtvo blato and Dyuleva bara). The phytoplankton species were additionally separated into functional groups after Reynolds et al. (2002). There were no published data for Staroto blato marsh for the period before wetland restoration, which might be due to its more prolonged and probably complete drying.

Due to the limited number and partly taxonomic nature of data available we decided to apply less strict statistical approaches like cluster analyses (hierarchical, k-means clustering) and a subsequent multidimensional scaling (MDS) in order to establish the difference between the periods before and after renewed flooding of the wetland. For the sake of analysis performance and easier understanding samplings of marshes were marked by codes applied throughout the whole report. Thus a sampling of **D**yulova bara in **J**u**n**e 19**97** was indicated by DJn97 (Figs. 2-4).

3 Results and discussion

The pH values ranged from 7.2 to 8.4 only, while oxygen concentrations (Fig.2) and oxygen saturation (Fig. 3) varied on a wider scale (0.24-10.08 g m^{-3} and 2.6-126%). The occasionally discovered oxygen shortage during summer months in such eutrophic shallow waters is considered as a natural phenomenon; however, oxygen depletion in all three marshes in cold November 2009 rather presents an alarming evidence for intense processes of decomposition in the anoxic wetland sediment. With three exceptions when N:P ratios were between 23 and 48, the period June 1997 - August 2009 was characterized by an N:P ratio close to or below 10, which suggests nitrogen limitation. November 2009 was distinguished by high N:P ratios varying from 49 to 76.

Fig. 3 clearly shows that the biomasses of zooplankton and of single phytoplankton sampling (DJn98) varied within several orders of magnitude throughout the considered time span. We prefer to present these variables by biomasses instead by numbers because high zooplankton biomass values are generally caused by large sized individuals, which are more indicative for the intensity of grazing pressure of zooplankton (especially of Cladocera) on phytoplankton. The biomass of Cladocera might be influenced by fish that were introduced by reconnection to the river with all its consequences for top-down cascade effects on the pelagic food-chain down to phytoplankton. During complete isolation from the river the wetlands were extremely poor in fishes (only 8 species reported, Kalchev et al. 2010) and with one exception (DJn98) the phytoplankton biomass was always low, most probably due to high grazing pressure by zooplankton. Unfortunately this tendency seemed to continue after the renewed flooding e.g. in 2009, when in August the low biomass of Cladocera and Copepoda indicated fish pressure while in November the opposite situation occurred supposing fish absence. After unofficial communication based on visual observations of the Persina national park staff there were no indications for fish kills during the whole year. Most probably the grown up fish larvae prefer other food than zooplankton and stay in the deeper channels in autumn avoiding the shallow parts of the marshes where we took our samples. Unfortunately, for organizational reasons the start of fish samplings of the restored wetlands was postponed for the next year (i.e. 2010) and the above speculations about fish presence and absence have a conditional character.

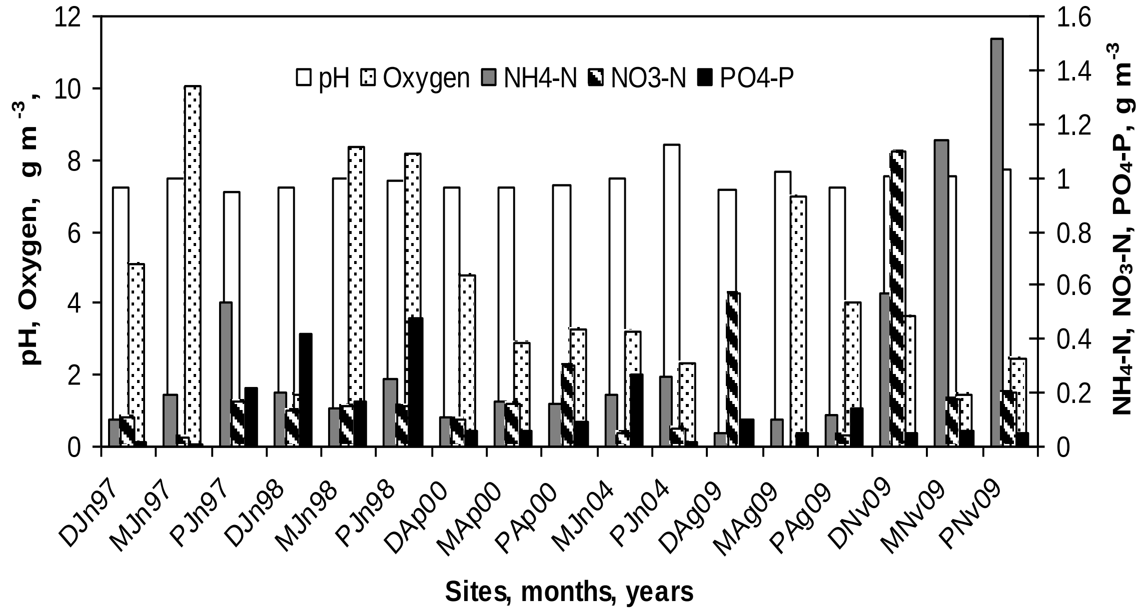

Figure 2. *Variations of pH and concentrations of oxygen and nutrients in the period before (1997-2004) and after (2009) renewed flooding of the wetlands*

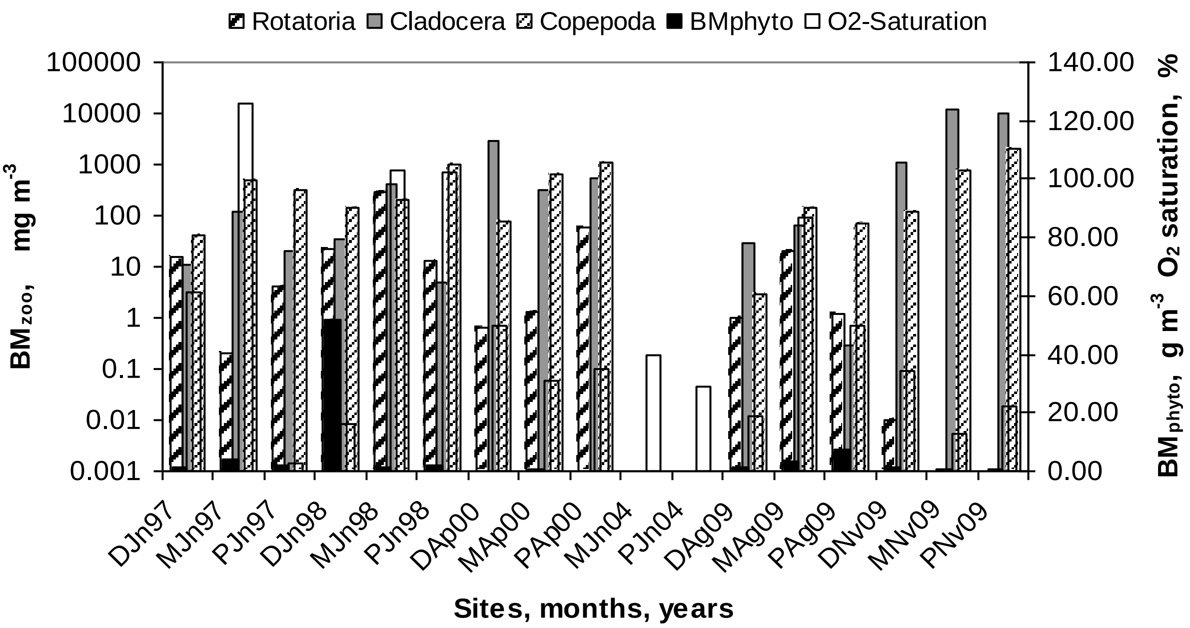

Figure 3. *Variations of water oxygen saturation, phytoplankton and zooplankton biomass (Rotatoria, Cladocera and Copepoda) in the period before (1997-2004) and after (2009) renewed flooding of the wetlands. Note the log scale on the left y-axis.*

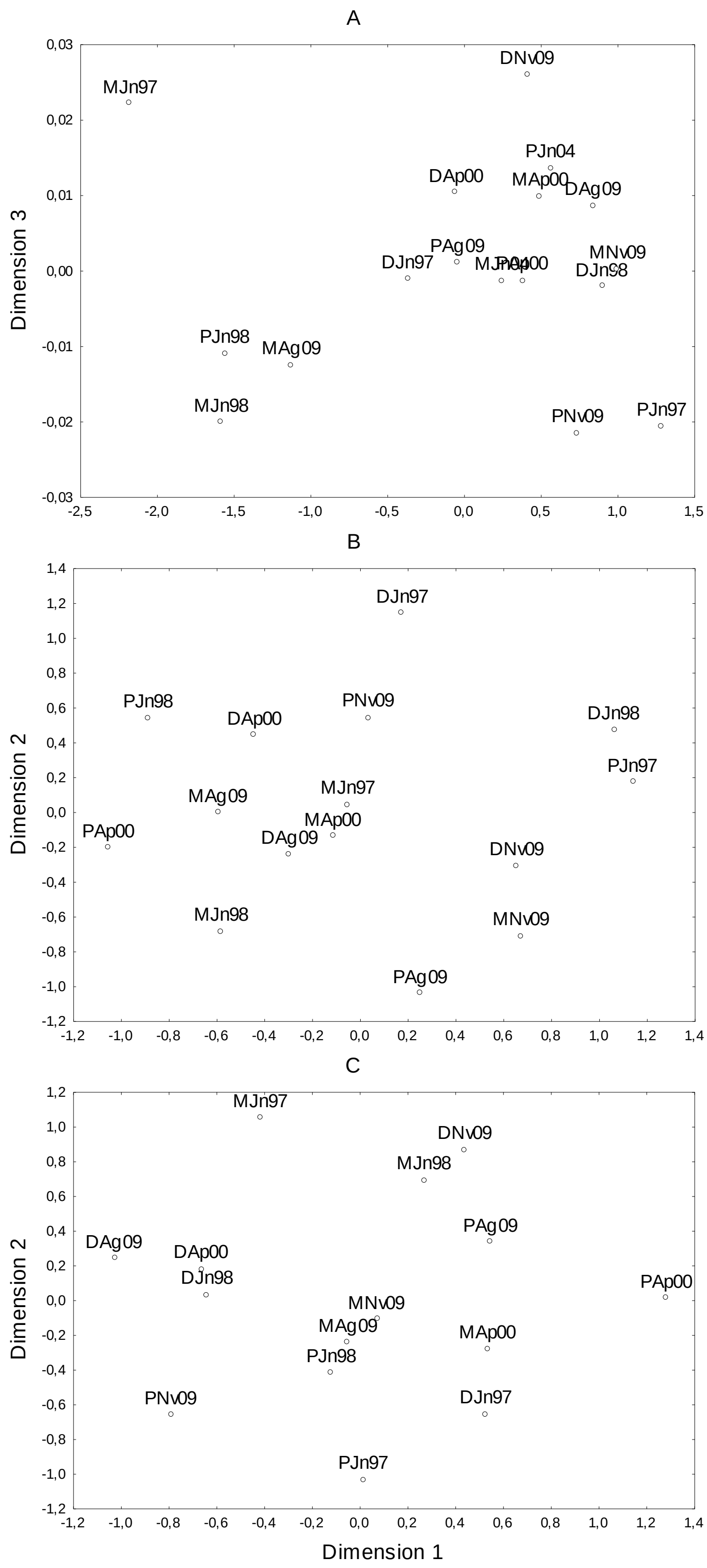

Figure 4. *The ordination diagram of samplings by MDS based on (A) squared Euclidian distance index of 6 environmental variables presented in Fig.1 and 2; (B) Chi-squared index calculated with numerical abundance of 162 phytoplankton species separated in 22 functional groups; (C) Bray-Curtis non-metric index of 100 zooplankton species.*

The taxonomic and functional group structure of phytoplankton and zooplankton communities offers further opportunities to evaluate the supposed differences between two periods of wetland development. As mentioned in the methodological part we applied various indices for clustering all 15 to 17 samplings available in order to test their separation in a meaningful way. Unfortunately, the cluster analyses and the subsequent MDS deliver either a clump of samplings with few outliers scattered around or more or less distinct separation of samplings without clear cluster differentiation. Even if we assume to have discovered some separate clusters soon we noticed that they all consist of mixture of samplings representative for both periods before and after reconnection (Fig. 4 A-C). Obviously the lack of separation between the periods before and after the wetland restoration is due to the small number of analyzed samples; however, the considerable spatial fragmentation causing heterogeneity of chemical and biological parameters typical of wetlands makes such a comparison difficult.

However, the presented data and analyses clearly confirm the first impression from the times of wetland visits. In summer most of the aquatic area was covered by floating-leaved macrophytes, which indicates long lasting absence of substantial water movement. In autumn there were no macrophytes and no single fish could be noticed in the clear water. However, the surrounding water body got easily turbid by touching the loose dark colored muddy often covered with numerous plant rests sediment, whose thickness seems to vary between 0.2-0.3 m. The staff in charge of in- and outflow water regulation put much efforts and succeeded in keeping enough water in the marshes the whole year around. However, according to unofficial statements, due to rapid fluctuations of Danube water levels and similar elevation of inlet and outlet devices a true flushing effect could not be realized and the mud accumulated in the marshes during their isolation from the river in the past could not be removed. These rapid changes in river level were produced by Iron Gate reservoir operation. The final result is that all in- and output devices connecting marshes with the river function, when opened, either as inlets or as outlets only. Thus a substantial flushing effect could not be achieved.

4 Conclusions

Unfortunately the first records on the effect of wetland restoration on Belene Island let us conclude that the result is rather negative, still far away from expectations. Despite the provision of enough water and avoiding the danger of wetland drying, the ecological status of the marshes has not changed substantially after renewed flooding. The restoration of marshes on Belene Island seems to share the fate of another Bulgarian Danube wetland “restored” recently - the Srebarna Lake. Inadequate hydrological measures led to an insufficient connectivity between the stagnant waters and the main river in both cases. The improvement of hydrological connectivity of these wetlands to the river seems the only possible solution for restoration. Sediment dynamics and formation are natural processes that need to be reactivated. The sediments of Belene Island are not toxic but moderately contaminated with wastes from farming and cattle breeding practiced on the island; hence, by flushing there is no danger to severely pollute the Danube River. Sediment removal by dredging is not recommended due to the high protection status of the area. Moreover, such a large-scale engineering solution will not remove the cause of mud accumulation and after a short period of improvement the old problems will emerge again. The presented research program was recently extended by additional chemical analyses, primary production, bacteria, macrozoobenthos, macrophyte and fish samplings. This will provide a more detailed picture of wetland status and will help to direct efforts of the limited resources of Persina national park staff to monitoring the most critical parameters for wetland development.

Acknowledgments

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Diversity of beetle communities from ground level to canopy in the Danube floodplain forests between Neuburg and Ingolstadt (Germany)

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Keywords: Flood plain forest, flooding management, floodplain restoration, arthropod monitoring, beetle community, vertical stratification, canopy fauna

1 Introduction

In Germany, most of the floodplain forests along the Danube River lost their typical character since the 19th century due to river regulations and embankment. Flooding periods were drastically reduced and became rare events. As a consequence and supported by forest management, tree stand structure developed into moist hardwood forests. Starting in 2010, a former floodplain forest between Neuburg and Ingolstadt will be restored by installing a new permanent watercourse and following natural river flow dynamics (Stammel et al. 2008). The combination of a permanent watercourse with additional flooding ranging from one flooding period in several years to repeated floodings in one year will cause significant alterations in water balance, thus effecting directly and indirectly all strata of the ecosystem. Environmental conditions relevant to plant and animal communities will be modified, but the dimension is hardly predictable. At the restoration area current stands are dominated by mature ash and oak trees, whereas sycamore, Norway spruce and Scots pine are scattered as admixed tree species.

Intact floodplain ecosystems are characterized by very high diversity of habitats on a very small spatial scale, and marshy areas are in close vicinity to dry soils. Moreover, forests in general exhibit high vertical diversity (Unterseher et al. 2007). The gradient from forest floor to the canopy implies not only pronounced differences in abiotic factors such as radiation, humidity, air movement etc., but also a high variability in living plant biomass, plant structures, epiphyte cover and necromass. High diversity of abiotic and biotic conditions in horizontal and vertical direction in floodplain forests should result in a richness of arthropod communities (Gruppe et al. 2008). In general it is well known that arthropod communities and particularly certain groups of insects play an important role as sensible indicators for alterations in ecosystems. Especially beetles are a highly suitable insect order for monitoring programs describing differences in the environment (Ammer et al. 2003, Müller et al. 2005). They frequently occur in all kinds of habitat, respond quickly on changes of abiotic factors, have a high diversity in species number, and can easily be identified; therefore, a comparison of similar projects in Central Europe is possible (Bonn & Kleinwächter 1999, Schröder et al. 2003, Strätz et al. 2006, Bail & Schmidl 2008). Moreover, beetles exhibit a broad range of ecological demands. Many species are restricted to distinct conditions of humidity in their environment. Thus, beetles are an ideal taxon to study ecological consequences of restoration of floodplain dynamics.

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2 Concept of beetle monitoring

The monitoring approach is developed to investigate alterations in zoocoenoses, particularly in beetle coenoses, caused by hydrological change through restoration measures. Short- and long-term effects of these measures will be compared to base line data. We started with the definition of four habitat classes according to expected increase of soil moisture, caused by a newly established permanent watercourse, and expected frequency of flooding. These predicted changes in hydrology defining the habitat classes base on a model of the surface relief (Haas unpublished): (a) habitats close to the new watercourse, (b) habitats flooded up to four times per year depending on the Danube water level, (c) habitats flooded only once in 100 years, and (d) habitats on dry stands due to gravel deposits (so called “Brenne”) (Fig.1). Each habitat class was monitored in five replicas leading to a complete block design with twenty plots.

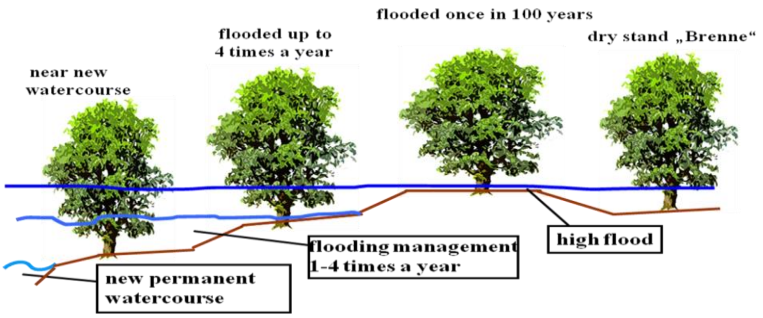

Figure 1. *Habitat classes according to expected increase of soil moisture and frequency of flooding, modelled from surface relief.*

Each plot is represented by three mature oak trees (*Quercus petraea*). On these trees and on the forest ground close to them, different types of traps are used to collect arthropods (Gruppe et al. 2008). Surface active species are captured with: (i) pitfall traps (PT) and emergence traps (ET) on the forest ground, (ii) trunk traps (TT) at approx. 2m above ground, and (iii) branch traps (BT) close to the trunk in the canopy (on average 11m above ground). Each trap type intended for surface active species is installed on an individual tree within each plot to avoid experimental interference. Flying arthropods are captured by flight interception traps (FIT) close to the ground (2m above ground) and in the core of the tree crown (on average 15.1m above ground) at the same tree (Fig.2). This set of traps allows analysis of arthropod communities within each vertical stratum (surface, trunk and canopy) as well as analysis of migration between strata. All traps are active during the whole season from end of March to end of October. Copper sulphate solution (3% w/v) is used as conservation fluid and traps were emptied monthly. Thus, samples represent activity densities of the coenoses throughout the vegetation period.

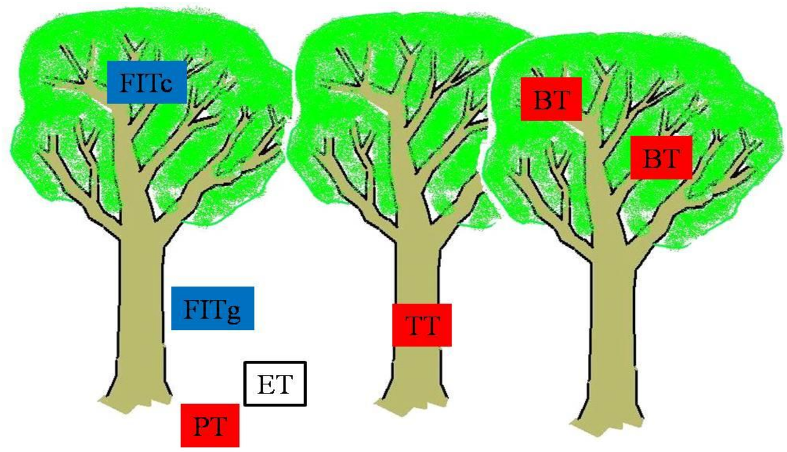

Figure 2. *Experimental design: pitfall trap (PT), emergence trap (ET), trunk trap (TT), flight interception trap ground (FITg), flight interception trap crown (FITc) and branch trap (BT).*

3 Preliminary results 2007

Since changes in flooding dynamics were expected to begin in 2010, we started assessment of beetle communities in 2007. Thus we are able to establish base line data for at least three years. Up to now (February 2010) samples obtained were sorted to order level. In total, 99,661 specimens of arthropods (excl. Collembola) were captured in 2007. Here we present data on the vertical distribution of beetles within arthropod communities pooled over all plots and habitat classes (Tab.1). In total beetles were one of the dominant arthropod taxa (12,612 specimens = 12.6 %; total rank sum: 35). Regardless of whether surface active (Fig.3; $H= 47.06$; $p<0.01$, Kruskal-Wallis-Test) or flight active (Fig.4; $Z= -3.35$; $p<0.01$, Mann-Whitney-Test), percentage of beetles is significantly higher on or near the forest floor than in higher strata.

Table 1. *Percentage of ten most common arthropod taxa per trap system and evaluated rank numbers (0-10). Rank numbers in sum for surface (PT, TT, BT) and flight (FITg, FITc) actives and total rank sum. Highest rank sum in total for Coleoptera and Araneae.*

	PT		TT		BT		FITg		FITc		rank sum of surface actives	rank sum of flight actives	rank sum total
	%	rank	%	rank	%	rank	%	rank	%	rank			
Coleoptera	26.8	10	4.9	4	4.0	4	17.6	9	10.3	8	18	17	35
Araneae	12.2	8	21.3	10	40.2	10	4.1	3	4.0	4	28	7	35
Nematocera		0	9.0	8	7.1	6	21.0	10	15.3	9	14	19	33
Brachycera	6.0	5		0	10.4	8	12.7	7	35.6	10	13	17	30
Apocrita	6.4	6	3.9	2	11.9	9	5.0	5	7.6	7	17	12	29
Formicidae	10.4	7	15.6	9	7.1	7	4.9	4		0	23	4	27
Heteroptera		0	6.5	7	1.6	1	5.7	6	5.7	5	8	11	19
Acarina	14.6	9	4.1	3		0	4.0	2		0	12	2	14
Thysanoptera		0		0		0	12.9	8	5.7	6	0	14	14
Isopoda	5.6	4	5.5	5	1.8	2		0		0	11	0	11
Larvae	4.3	3	3.5	1	4.3	5	2.8	1	2.0	1	9	2	11
Cicadina		0		6		0		0		0	6	0	6
Trichoptera		0		0	2.9	3		0	2.5	2	3	2	5
Lepidoptera		0		0		0		0	2.7	3	0	3	3
Chilopoda	2.9	2		0		0		0		0	2	0	2
Diplopoda	2.9	1		0		0		0		0	1	0	1

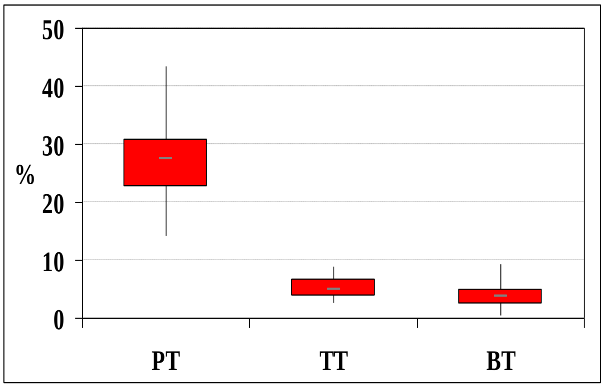

Figure 3. *Percentage of beetles from surface active traps decreased with increasing height*

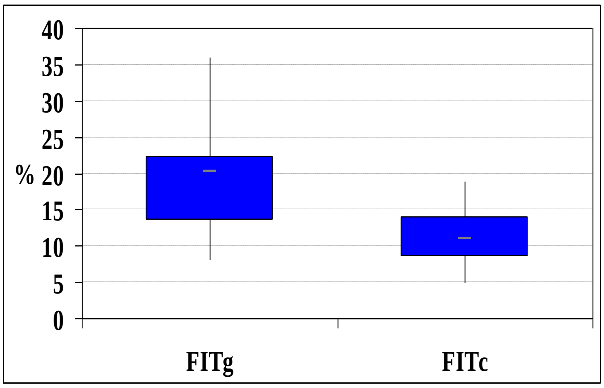

Figure 4. *Percentage of beetles from flight active traps is higher close to the forest floor than in canopy*

4 Outlook

Effects on beetle communities during hydrological restoration of the floodplain will be evaluated in short- (2010, 2011) and long-term (2015, 2016) periods. The alteration of communities will be studied for defined habitat classes, vertical stratification and mode of locomotion (surface- or flight active). We will test following three null hypotheses (H1-3): H1) Restoration of floodplain dynamics causes changes in beetle communities of all habitat classes. We expect an increase of species adapted to moisture in the two most affected habitat classes (near new permanent watercourse, flooded up to four times a year). Occurrence of species preferring dry stands will decrease in these habitat classes, but not in drier ones. H2) Changes do not depend on vertical distribution, and beetle communities near ground or on forest floor respond in the same way as communities in canopy. We assume that beetle communities on forest floor respond stronger than communities in the canopy on hydrological changes. Communities of the upper vertical stratum (tree crown) are not directly affected and changes will be hardly detectable. H3) Communities of surface active and flight active beetle species are influenced in the same way. Flight active species have a better chance to survive flooding by changing strata or leaving the area. Surface active beetles will have less chance to leave flooded areas and need more time to reintroduce. Therefore adaptation on periodical flooding within the community of surface active beetles will occur earlier and to a larger extend. At present, baseline data on order level are available from the year 2007 only, and species level data of beetles from 2007 to 2009 will be ascertained late 2010.

Acknowlegements

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Functional diversity of Heterotrophic Flagellates (Protozoa) in the plankton of the river Danube at Göd (Hungary)

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Keywords: heterotrophic flagellates, functional diversity, niche, guild, coexistence, river plankton

1 Introduction

The description of an alternative trophic pathway, the microbial loop in the middle of the 1980s (Azam et al. 1983) revealed the crucial trophic role of protozoa in planktonic food webs. This facilitated strongly first the quantitative, later the taxonomic investigation of heterotrophic flagellates. Recent ecosystem studies cannot ignore this trophically important group. In spite of their trophic role, there are few quantitative investigations of heterotrophic flagellates in the river Danube (Vörös et al. 2000), and modern taxonomic studies are completely lacking. However, heterotrophic flagellates have the highest biomass among protozoa in an annual mean in the plankton of the river Danube in Hungary (Kiss et al. 2009), and they are one of the most important consumers in the planktonic microbial food web (Kiss 2007).

Most ecosystem studies have considered heterotrophic flagellates as a functionally uniform, bacterivorous 'black box'. In the past few years information is growing about the functional diversity of heterotrophic flagellates (Arndt et al. 2000). Most classifications establish functional groups according to the morphological and behavioural properties of flagellates. Field studies, which investigate the resource utilization of species in nature are sparse. Many functional data from species are based on investigations of cultures (Boenigk & Arndt 2000). As heterotrophic flagellates are a trophically important group with a huge consumption, it is very important to reveal their functional properties and functional diversity. Besides the functional investigation of the most abundant species, the investigation of local functional diversity would be also important from the viewpoint of the functional diversity - ecosystem stability relationships (Loreau et al. 2001).

The main goal of this study is to reveal the local functional diversity of heterotrophic flagellates in the plankton of the river Danube. Species utilizing the same resources belong to the same niche, and if the method of research utilization is also the same, they belong to the same guild. Applying these definitions in the present work, we reveal the species groups belonging to different realized niches by investigating the utilized resources of species instead of grouping them according to their morphological or behavioural properties. We also investigate the number of guilds by measuring those ecological parameters of species, which influence the method of research utilization. Finally we try to give explanations for the coexistence of species according to the results.

2 Material and methods

To investigate the local diversity, a single plankton sample was collected from the left river bank of the Danube, 10 meters from the shore at Göd, Hungary (1668 riv. km) on 16th March 2008. Fifty litres of water (5 dipping by bucket) was filtered through a 10 μm mesh-sized plankton net. All equipments were sterile or disinfected with ethanol. The 150 ml remnant was transported to laboratory, poured into a wide glass bowl, and let undisturbed for the microbial succession. The sample was monitored for 37 days. After stirring, subsamples were taken and investigated in a microaquarium with an inverted microscope (Olympus IX-70), 100xHI-1.3NA objectives, and strong Nomarski DIC contrast. Videos were taken by an analogous 3CCD camera (JVC KY-F30B), the sign of which was digitalised by an A/D converter (Dazzle Hollywood DV-Bridge), and recorded on computer. Videos were taken from all individuals of species, except of the very abundant ones. Videos were later analysed by additional digital contrast enhancement, in many occasions

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from frame to frame. Seven functional variables were measured/determined from the videos. Four variables, which determine the utilized resources are: 1. Primary source of energy (light, dissolved organic matter or particulate organic matter). 2. The food particle suspended or attached to aggregates. 3. The size of ingested food particle. To parameterize this variable we measured the size of the smallest, the mean and the largest ingested food particles in specimens of every species. We applied the simple approximation that species are non-selective for the quality of food. 4. The presence of a predator avoidance mechanism (lorica) against the predatory pressure of a carnivorous flagellate (*Rhynchobodo* sp.). Three further variables, which influence the method of resource utilization are: 5. For flagellates grazing suspended particles the quotient of the moving speed of the flagellate and the speed of the flow field generated by the flagellum. This quotient is 0 for suspension feeders and almost 1 for free swimming raptors. 6. For gliding flagellates the frequency of wobbling/beating illustrated as the function of swimming speed may be informative from the efficiency of food searching. 7. The relative importance of the motoric forces of beating (mostly the anterior) and gliding (mostly the posterior) flagella, in relation to the moving speed is informative from the efficiency of food searching, and the position and attachment of consumable food particles.

3 Results

Altogether 130 heterotrophic flagellates and other hardly classifiable picoeukaryote species were found in the sample during the investigation period. The distribution of species along the seven variables were the following: According to the primary source of energy (1. variable) two species were obligate osmotrophic, and 128 were able to ingest particulate food. Three from them were facultatively mixotrophic and contained presumably cleptoplasts (*Notosolenus apocamptus*, *Protaspis gemmifera*, *Collodictyon triciliatum*). According to the suspended or attached localisation of the food particles (2. variable), 38 species grazed suspended and 90 species grazed attached particles. The size distribution of food particles (3. variable) among suspended food grazing flagellate species was continuous from 0.1 to 20 μm. Smallest food particles were consumed by choanoflagellates and small chrysomonads, larger sized particles were consumed by free swimming raptors (*Rhynchobodo*, *Kathablepharis*, *Collodictyon*, *Gymnodinium*) and large chrysomonads. The distribution of food size among attached particle grazing flagellate species were continuous between 0.2-48 μm. Smallest particles were ingested by the smallest, 2-3 μm long raptors (spheric undescribed picoeukaryotes, *Kiitoksia ystava*, undescribed *Ancyromonas*, *Heteromita minima*). Most species grazed food particles between 0.4-1.5 μm. Larger-sized particles were consumed by large euglenids, and large *Protaspis* and *Cercomonas* species. Presumably 11 species had an efficient predator avoidance mechanism (lorica or cell wall; 4. variable).

The distribution of suspended particle grazing species along the quotient of the moving speed of the cell and the speed of the flow field (5. variable) showed an interesting transition between the two extremities. At zero value flagellates are attached to the substratum and bring food particles to themselves by the flow filed of the beating flagellum. These were suspension feeder choanoflagellates, bicosoecids and pedinellids (12 species). Transitional groups with low quotient value (0.1-0.4) were the swimming forms of small chrysomonads, large *Spumella* species and *Collodictyon* (13 species). Species near value 1 were the free swimming raptors (12 species).

Investigating the attached particle grazing species, many groups can be differentiated according to the speed of the flagellates and the wobbling/beating frequency (6. variable). Zero speed belongs to the non gliding diffusion feeders (7 species). Very slowly moving (0-0.5 μm/s), non-wobbling species usually use their filopodia for the movement. These were mostly small spheric radially symmetric undescribed pikoeukaryotes (16 species). The beating/wobbling frequency illustrated as a function of the speed for faster gliding species (>0.5 μm/s) is illustrated in Fig. 1. Three main groups can be differentiated with continuous transitions. Non-wobbling, smoothly gliding species are located at the abscissa (circle of dashed line in Fig. 1). Most euglenids, *Allantion*, *Thaumatomastix* species and some *Protaspis* and *Cercomonas* species belong to this group (19 species). Gliding and wobbling species are situated along the diagonal; slow species near the origo, fast gliding and wobbling species far from there. Very fast wobbling, but slowly moving species are near the ordinate (continuous circle on Fig. 1). These are *Ancyromonas sigmoides* and undescribed *Heteromita*, *Discocelis* and *Parabodo* species.

The supposed ratio of the motoric forces of the beating and gliding flagella in relation with the swimming speed is illustrated on Fig. 2. (7. variable). Species using only the gliding forces are situated on the left side of the figure with increasing moving speed; 41 species belong here. Considerably high moving speed can be achieved by using only gliding forces (30 μm/s). The fastest species were large euglenids (*Heteronema, Peranema*).

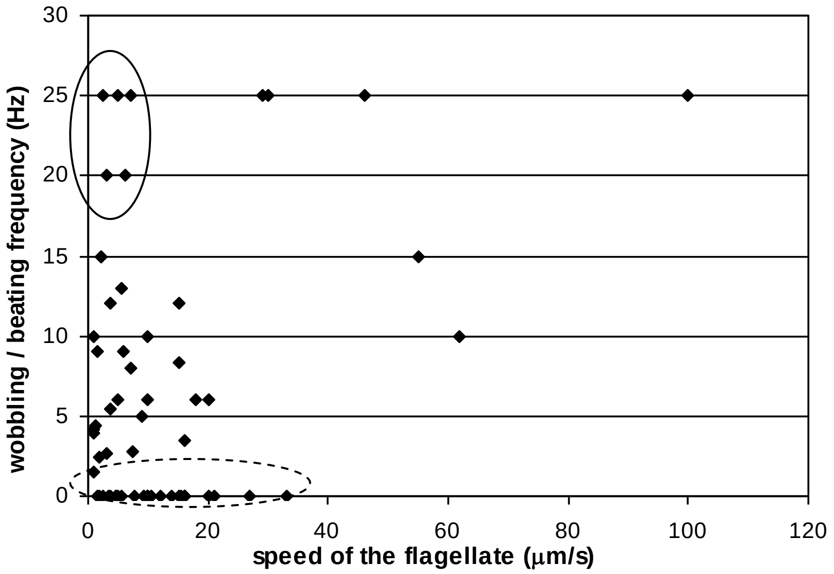

Figure 1. *The wobbling/beating frequency of flagellate species illustrated as the function of gliding speed. Beating frequency of euglenids gliding on their anterior flagellum were considered to be zero, as they do not wobble. Non-wobbling species are marked by the circle with dashed line, very fast wobbling, but slowly moving species by the circle with continuous line.*

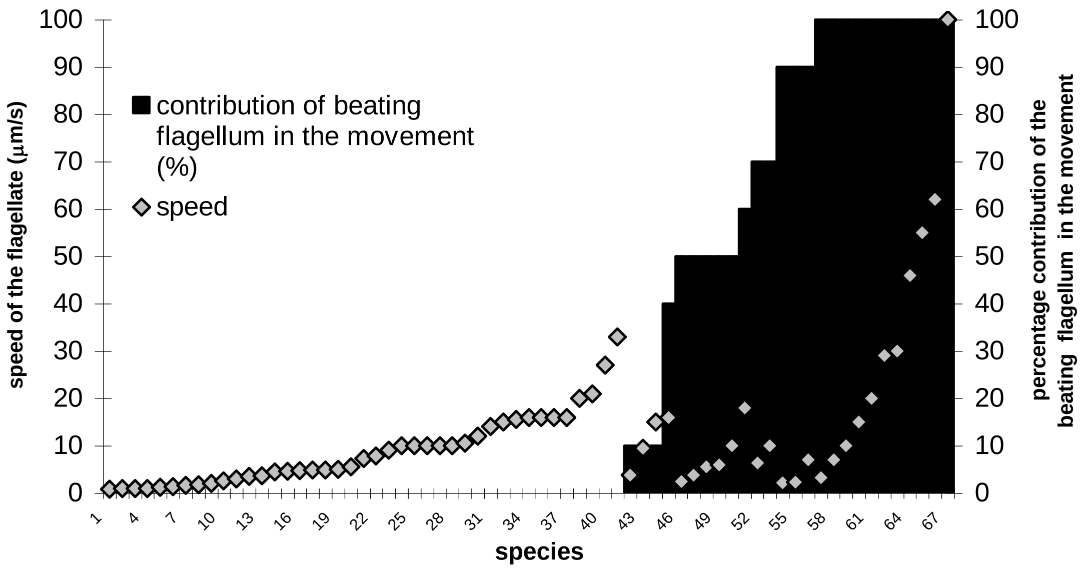

Figure 2. *The contribution of the beating flagellum in the movement in relation with the swimming speed.*

Species using the pulling force of the beating flagellum are indicated on the right side of the figure (black columns); 26 species belong here. The slowest species beats often with high frequency. Species moving faster than 15 μm/s are attached to the substratum with only the distal part of their gliding flagellum (*Protaspis* species). Species moving faster than 30 μm/s have only temporary contact with the substratum (*Bordnamonas tropicana*, *Goniomonas* spp., *Neobodo designis*, undescribed *Kathablepharis*).

Species belonging to the same niche can be grouped together according to the first 4 variables, which determine the utilized resources. Although the size distribution of the consumed food shows continuous transition, a number of non-overlapping food size ranges can be defined (4 for suspended particle feeders, 5 for attached particle feeders). By this splitting, the functional diversity still remains underestimated.

Accordingly, 15 functional groups can be differentiated, which belong to different realized niches. According to the method of resource utilization (variables 5-7), we can group species further to guilds. By the method of food acquisition we could differentiate diffusion feeders, slow gliders using pseudopodia, suspension feeders, raptors gliding on flagella and raptors swimming over surfaces. Taking these into account, altogether 27 guilds can be differentiated. Guilds comprising the most species among suspended particle feeders were the followings: smallest particle feeder loricate choanoflagellates (6% of total species); suspension feeder small chrysomonads and pedinellids that feed particles between 0.6-1.4 μm (6%); raptors (*Colpodella*, kathablepharids, *Rhynchobodo*, 6%). Guilds comprising the most species among attached particle feeders were: smallest particle feeder picoeukaryotes, which move by pseudopodia (12%); gliding raptors that graze particles between 0.3-0.6 μm (18%) and gliding raptors that graze particles between 0.7-1.2 μm (21%).

4 Discussion

This study revealed a huge local species diversity of heterotrophic flagellates in the plankton of the river Danube, which considerably exceeds the species number found by other morphological studies (comparison: Kiss et al. 2008). Besides the general knowledge about the total potential functional diversity of the described heterotrophic flagellate species (eg. Sleigh 2000), most field surveys containing functional investigations did not use deep taxonomic resolution, thus only a few coexisting functional groups were detected (Arndt et al. 2000, Boenigk & Arndt 2002). By this detailed study with long observation period, a high number of species could be detected, and by the videomicrography technique many important functional properties of species could be successfully analysed. The huge local functional diversity of heterotrophic flagellates found by this study highly exceeds our previous knowledge, and gives new insights to the possible ecological potential of these organisms. Ecosystem studies should be taxonomically refined at those habitats, where flagellates have large importance. In these cases the simple concept, which considers heterotrophic flagellates as bacterivorous ‘black boxes’ have to be improved in order to reveal finer trophic relationships.

Among suspended particle grazing flagellates, suspension feeder small chrysomonads were the most abundant group in freshwater plankton (Arndt et al. 2000). They were accordingly rich in species in this study. Besides them, loricate choanoflagellates and free swimming raptors also had high species numbers. The first group had a presumably efficient predator avoiding strategy; the second group could exploit the rich food supply (flagellates and other microeukaryotes) with possible sharing of the diverse resources. Among attached particle grazing species, gliding pikoeukaryotes represent a yet unknown, but markedly diverse eukaryotic organization type. Albeit they move very slowly, they have an efficient feeding strategy as indicated by their occasionally high abundance. This group of organisms should clearly call larger attention in future research.

The investigation and quantitative analysis of variables influencing food acquisition methods of flagellates revealed some interesting new relationships. The species rich transitional group between suspension feeders and raptors among suspended particle grazers (5. variable) would call more attention in the plankton, as many abundant species, which channel large carbon fluxes belong here. The interesting group of very fast wobbling but slowly moving species (found in the investigation of the 6. variable) keeps some questions open. This strategy hardly seems to be advantageous for the species, when compared to other gliding raptors: high frequency wobbling requires much energy, and these species move very slow. Diffusion processes are also needed for food capture. The subsistence of this strategy may indicate the lack of strong selection among attached particle feeders. The food searching strategy of the slowest gliding raptors vs. the fast swimming ones (differentiated by the 7. variable) represents two extremities, which may differ in the utilized food resource also. The smallest and slowest species are closely attached to the substratum. They screen and sense the aggregates continuously. They are able to capture the smallest and mostly wedged bacteria in the pores of the aggregates. On the other hand, the almost free swimming raptors sense the substratum only during the short and more random contacts. Chemotaxis may also be an important sensory method for them (Fenchel & Blackburn 1999). They are able to screen a much larger area, and they might therefore find patches very effectively (eg. bacterial colonies).

5 Conclusion

The coexistence of a huge number of flagellate species in the river plankton may be partially explained by the results. The large number of functional groups with different niches, and the lack of competition for certain resources is an important cause of coexistence. The presence of different utilization methods of the same resource, however, is still an interesting question. Some strategies using the same food source are very different in their efficiencies. The localisation of the species is often separated in these cases. Besides the presumably most efficient, and thus abundant species, a considerable number of other species, which use the same source, but different food acquisition strategies are manifestly coexist in much lower abundances. Many rare species thus do not 'suffer' from competitive exclusion, only their abundance remains low. The coexistence of a large number of attached particle grazing species may be explained by the heterogeneity of their habitat: the surface of riverine aggregates. Heterogeneity may manifest in the random colonisation of aggregates, in the structural, chemical, bacteriofaunistic, etc. diversity of aggregates, and also in the temporal changes of the aggregates, which fall into the generation times of flagellates.

Despite the well visible competition between the most abundant species in growing season, resources are not scant enough and the environment is heterogeneous enough to ensure the survival of a large number of rare species besides the abundant ones. The actual environment does not favour their proliferation, but in a changing environment – and functional diversity have the real importance here – new species can grow up. With the benthos, as a continuous species source, and the possibility of long term planktonic survival, the riverine plankton can maintain a really huge diversity of heterotrophic flagellates.

Acknowledgements

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Spatial differences of the zooplankton assemblages and chemical characteristics of water in a plesiopotamal side arm of the active floodplain at the Danube (rkm 1442-1440)

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Keywords: zooplankton, water chemistry, floodplain, Danube

1 Introduction

River-floodplain landscapes are dynamic areas exhibiting a high biodiversity. The exchange of matter and energy between the different landscape elements of these areas is facilitated by the hydrological connectivity. Floodplains are keystone ecosystems characterised by a high level of habitat heterogeneity and by a diverse biota adapted to the high spatio-temporal heterogeneity (Tockner & Stanford 2002).

The Gemenc and Béda-Karapancsa Danube floodplains (Duna-Dráva National Park, Hungary) represent an exceptional example of river-floodplain systems in Europe with big meanders, oxbow lakes, marshlands and extended hardwood forests. Due to the river regulation works in the 19th century this area has changed, the floodplain remained more or less isolated from the main stream and the length of the side arms has been shortened. Currently numerous side arms and backwaters with various hydromorphological characteristics are still located completely in the active floodplain. The water-supply of this area is totally determined by the Danube.

The detailed investigation of this typical near natural active floodplain zone started in 2002 by examinig the differences between the water bodies (Schöll & Kiss 2008; Schöll et al. 2008). In this paper the results of the hydrobiological monitoring focusing on the plesiopotamal Mocskos-Duna are summarized. This was the first hydrobiological survey in this side arm with high nature conservation value, which included the monitoring of zooplankton assemblages and of chemical characteristics of the water.

2 Materials and methods

The Mocskos-Duna side arm (rkm 1442-1440) is situated in the active floodplain of Karapancsa area (Hungarian Lower Danube valley), approximately 3.4 km long, 60 meter wide, with shallow water (average depth: 1.5 m) and very dense macro-vegetation. There were two sampling occasions on 22 June and on 28 July of 2009. The side arm is connected with the Danube by an artificial channel. The Danube starts to overflow into the floodplain after it reaches a water level of 550 cm at Mohács in the main channel of the river; during the sampling, there was no connection with the main stream (the water level was 359 cm on 22 June and 508 cm on 28 July). The following sampling sites were examined:

Main stream (D1437) (N 45º 55' 58,00", E18º 46' 26,00") — At this reach of the Danube the mean discharge is about 2449 m^3 sec^{-1}, the slope is 5 cm km^{-1}, the mean velocity is 0.5-1.2 m sec^{-1}. The difference between the minimum and maximum water level fluctuation is near 9 m.

Mocskos-Duna (1, 2, 4 and 7 sites: longitudinal transect of the side arm)

1. (N 45º 57' 24,78" E18º 46' 24,67") — Open water site in the southern end of the side arm.

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2. (N 45º 57’ 35,27” E18º 46’ 38,22”) — Open water area with dense *Ceratophyllum* stands 20-30 cm below the water surface.

3. (N 45º 57’ 36,87” E18º 46’ 36,25”) — Special habitat with *Salix* trees and emergent *Typha* stands. Water depth: 30 cm.

4. (N 45º 57’ 58,65” E18º 46’ 43,94”) — Open water area with dense *Ceratophyllum* stands 20-30 cm below the water surface.

5. (N 45º 58’ 06,20” E18º 46’ 37,07”) — Vegetated area with *Ceratophyllum demersum* L. and *Trapa natans* L. The coverage of macrophytes is 100%. Water depth: 120 cm.

6. (N 45º 58’ 06,95” E18º 46’ 17,85”) — Open water area at the end of the shorter side arm of the Mocskos-Duna with emergent *Phragmites* stands on the banks. Water depth: 35-40 cm, the coverage of macrophytes is 5% (*Polygonium amphibium* L.).

7. (N 45º 58’ 18,26” E18º 45’ 57,13”) — The northern end of the side arm with *Hydrocharis morsus-ranae* L. and *Trapa natans*. The coverage of macrophytes is 100%. Water depth: 100-120 cm

The measurement of hydrochemical parameters (temperature, pH, conductivity, dissolved oxygen and oxygen saturation) was performed *in situ* using WTW Multiline-P4 portable meter (WTW, Germany). The cation and anion concentrations we analyzed in the laboratory, with Dionex DX-120 ion-chromatograph after filtration (0.2 μm).

Suspended matter, CO_3^{2-}, HCO_3^- and chlorophyll-a concentrations were determined using standard analytical methods (Golterman et al. 1978). The composition and coverage of macro-vegetation was estimated with a 1 m^2 quadrate according to Braun-Blanquet (1951). Rotifers were sampled with a plankton net (mesh size 40 µm), by filtering 20 litres of water. Crustaceans were concentrated on a 70µm mesh and fixed in 5% formaldehyde solution. Microcrustacean abundance including the developmental stages of copepods (copepodids) was evaluated by enumerating individuals in the whole sample. Data were analysed by hierarchical cluster (HC) and non-metric multidimensional scaling (MDS) method with Euclidean distance by using the PAST program-package (Hammer et al. 2001).

3 Results and discussion

3.1 Water chemistry

The examined sampling habitats differed especially in their vegetation cover, water depth, oxygen saturation and chlorophyll-a content. The oxygen saturation, the chlorophyll-a content and the suspended matter content were higher in the open water habitats than in the vegetated areas (Table 1).

The hydrochemical parameters slightly differed in the two sampling times; however, the site 7 in July was remarkably different from the other sites in terms of extremely high water temperature (32^0 C) and sites 2 in June and 7 in July in very high (217 %) oxygen saturation (Figure 1).

There were no significant differences in the chemical parameters of the main stream and the side arm, with the exception of the NO_3^- concentrations, which were notably higher in the Danube, than in the Mocskos-Duna side arm.

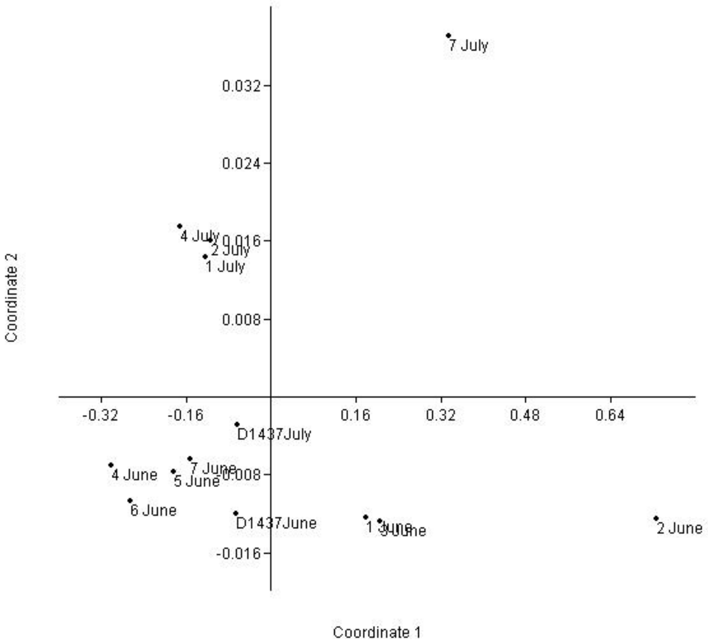

Figure 1. *The NMDS plot of the examined habitats on the basis of the hydrochemical parameters in the two sampling days (22 June and 28 July, 2009)*

3.2 Zooplankton

18 *Cladocera,* 9 *Copepoda*, 3 *Ostracoda* and 35 *Rotifera* taxa were recorded in the Mocskos-Duna; *Synchaeta pectinata* Ehrenberg (Rotatoria) and *Disparalona rostrata* (Koch) (Cladocera) were found only in the main stream. In the Danube mostly rotifers (especially *Synchaeta pectinata* Ehrenberg, *Anuraeopsis fissa* (Gosse), *Keratella cochlearis* (Gosse)) dominated the zooplankton assemblages with an average of 98.7% of total abundance.

The zooplankton assemblages in the Mocskos-Duna, similarly to the main stream, were clearly dominated by rotifers, which in the open water (sites 1, 2, 3, 4 and 6) made up to 86.3-99.6% and in the vegetated areas 63.5-66.1% of the total abundance. In the open water habitats the rotifer assemblages were characterized by euplanktonic taxa, especially *Keratella cochlearis* (Gosse) (29.4%), *K. tecta* (Gosse) (29.6%) and *Polyarthra dolichoptera* Idelson (17.7%) and *Brachionus* spp. (11.3%). The highest Rotifera, tychoplanktonic Rotifera taxon number and the highest Shannon-diversity were recorded in the vegetated habitats (Table 1).

Table 1. *Minimum and miximum values of selected abiotic and biotic parameters in the Danube and the longitudinal transect of the Mocskos-Duna (sites 1, 2, 4, 7) measured on 22 June and 28 July, 2009*

	D1437		1		2		4		7	
	min	max	min	max	min	max	min	max	min	max
Temperature (C^o)	19.4	21.6	19.6	25.9	20.1	26.4	20.4	26.7	20.7	32.0
pH	7.9	8.4	7.7	8.6	7.4	7.9	7.5	7.7	7.7	8.6
Conductivity (μS cm^{-1})	349	352	333	401	324	325	383	386	333	349
O_2 (mg L^{-1})	8.5	10.3	8.4	15.1	8.5	25.1	4.5	7.3	7.3	15.8
O2 saturation (%)	117	118	102	178	105	315	58	90	95	217
Suspended matter (mg l^{-1})	24.4	41.8	10.9	23.6	2.9	5.6	4.4	5.4	2.8	6.9
NO_3-N (mg l^{-1})	1.20	1.30	0.10	0.30	0	0.30	0.10	0.10	0.20	0.20

PO_4-P (μg l^{-1})	10	45	21	240	36	50	43	64	6	55
TP (μg l^{-1})	97	123	98	701	103	152	110	146	83	177
Water depth (cm)	359	508	35	40	190	200	190	200	100	120
Coverage of macrophytes (%)	0	0	0	5	0	0	0	0	100	100
Chlophyll-a (μg l^{-1})	10	52	30	118	25	51	30	35	21	25
Rotifera taxon number	5	6	8	11	13	16	10	13	16	16
Tychoplanktonic taxon number	0	0	2	0	4	6	3	4	9	8
Rotifera density (ind l^{-1})	22.5	32.5	245	3460	137.5	722.5	677.5	1010	227.5	457.5
Rotifera Shannon diversity	1.48	1.68	1.43	1.48	1.95	2.14	1.27	1.53	2.19	2.25
Crustacea taxon number	2	7	1	6	3	7	2	15	15	18
Tychoplanktonic taxon number	1	5	0	6	2	2	2	10	14	14
Crustacea density (ind l^{-1})	0.2	0.7	0.1	12.4	1.7	4.3	0.1	3.2	19.9	20.5
Crustacea Shannon diversity	0.45	1.29	0	1.37	0.41	1.60	0.64	1.84	1.09	1.13

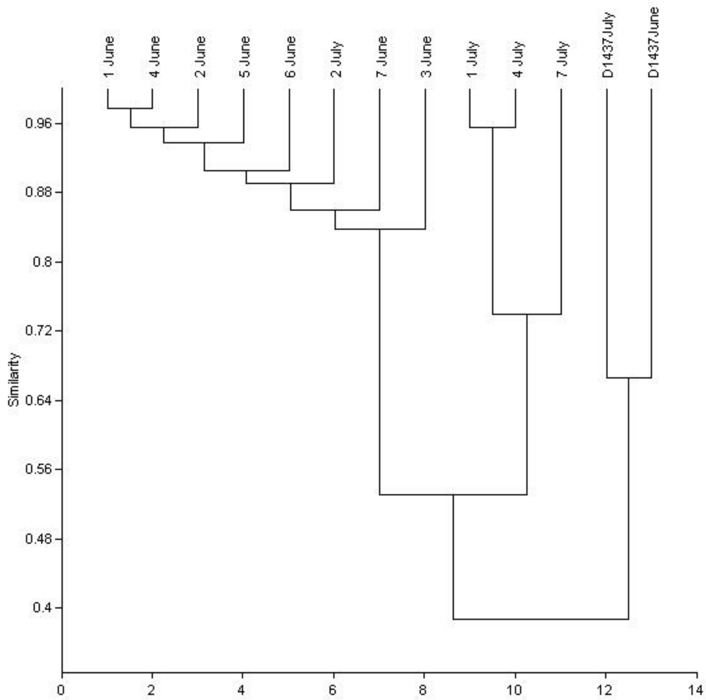

Figure 2. *Cluster analyses of rotifer abundances in the two sampling days (22 June and 28 July, 2009)*

Maximum abundance of rotifers (7450 ind l^{-1}) was found at site 6. Besides the frequent species mentioned above, *Anuraeopsis fissa* (Gosse), *Brachionus angularis* Gosse, *Filinia terminalis* (Plate) and *Trichocerca birostris* (Minkiewitz) reached high densities in this habitat. The average rotifer density was highest in open water habitats (3718 ind l^{-1}) and decreased notably in the vegetated sites (343 ind l^{-1}).

Samples taken from the main stream and from the side arm in June and July (with the exception of site 2 in July), were clearly separated from each other (Figure 2). The rotifer abundance and chlorophyll-*a* concentration were positively correlated (y = 476.83x-8674.4, R^2 = 0.81). This relationship was also described in other floodplain waters (Schöll et al. 2006, Pithart et al. 2007). This can be explained by either less top-down control (absence of large filtrators) easing competition (Lampert & Rothhaupt 1991), or increased bottom-up control (elevated concentration of suitable food, Merriman & Kirk 2000).

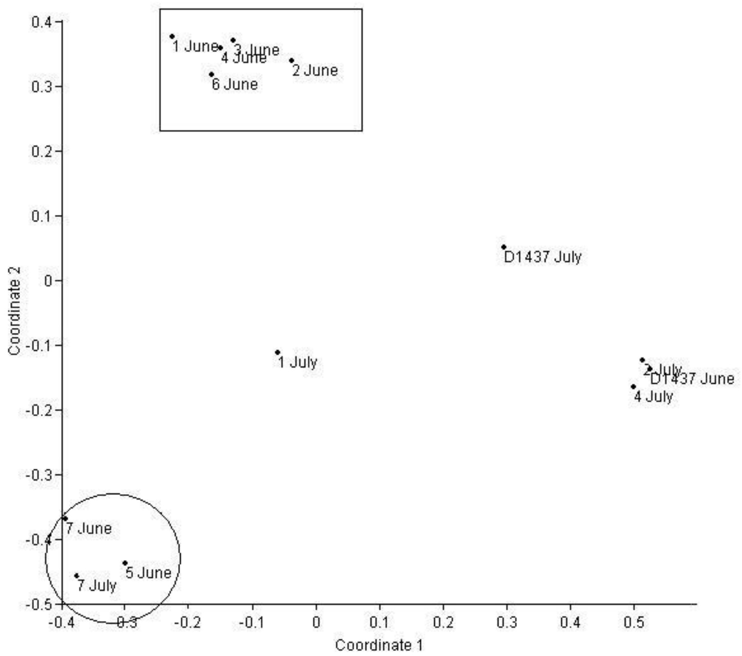

Figure 3. *Comparison of sampling sites based on crustacean assemblages (NMDS) in the two sampling days (22 June and 28 July, 2009)*

The crustacean dynamics in the sampled habitats varied extremely in term of abundance and species composition (Figure 3). The open water habitats and the vegetated areas (sites 5 and 7) differed significantly, but the several open water habitats were similar (sites 1, 2, 3, 4, 6). There were no significant differences in the crustacean assemblages among the different macrophyte types. In the open water habitats the crustacean taxon number and abundance slightly decreased in July. Highest densities of crustaceans were detected at site 5 (*Ceratophyllum* and *Trapa stands*) with over 88.5 ind l^{-1}. In the open water habitats the average density of crustaceans was low (4.5 ind l^{-1}), copepodids accounting for over 45-83% of the total abundance the number of euplanktonic taxa (*Bosmina longirostris* (O. F. M.), *Moina brachiata* (Jurine), *Acanthocyclops robustus* (Sars), *Eurytemora velox* (Lilljeborg), *Thermocyclops crassus* (Fischer)) was high. The taxon number (R^2 = 0.581), total abundance of microcrustaceans (R^2 = 0.598) and the abundance of cladocerans (R^2 = 0.618) were significantly higher in the vegetated sites than in open water, mostly due to higher densities of *Chydorus sphaericus* (O. F. M.) (R^2 = 0.644), *Simocephalus vetulus* (O. F. M.) (R^2 = 0.908), ostracods (R^2 = 0.889) and *Graptoleberis testudinaria* (Fischer). Many studies showed that aquatic macrophytes may contribute to the increase in microcrustacean abundance but only a few focused on river-floodplain system (Basu et al. 2000, Grenouillet et al. 2001). Protection from predators and availability of food are the two main factors generally invoked to explain the high density of zooplankton in vegetated habitats (Carpenter & Lodge 1986). In unregulated river sections with well-developed floodplains the zooplankton of the main arm is imported from adjacent slow flowing or lentic areas depending on the hydrological connectivity with the river (Reckendorfer et al. 1999).

4 Conclusion

This short hydrobiological survey carried out on the Mocskos-Duna, little known side arm of the Béda-Karapancsa floodplain-system, confirmed other results on river-floodplain systems focusing on the role of macrophytes. The different macrophyte beds in the side arm increasing habitat heterogeneity enhance the zooplankton diversity by providing food and shelter against predation and the taxon number (including tychoplanktonic taxa) and diversity were significantly higher in the vegetated habitats than in the open water. Our results showed that zooplankton studies of floodplains demand extensive monitoring and a detailed survey of the different floodplain habitats.

Acknowledgements

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Climate change analyses used for river basin management in the rivers Danube and Elbe

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Keywords: climate change, Danube, Elbe, multi-model approach, navigation

1 Introduction

Increasing global temperatures as indicated by the climate projections of the Fourth Assessment Report of the IPCC (2007) may lead to changes in the hydrological cycle. These changes could cause major changes in precipitation, water flow, water quality, and the ecosystem. This triggered a discussion among experts how aquatic systems and water-resources management practices can be adapted to become "climate proof". Because all elements are interlinked in a complex way, an appropriate evaluation of adaptation options requires (1) the assessment of regional climatic and hydrological effects taking into account different sources of uncertainty in data and methods, and (2) the integrated assessment of the main impacts on water quality, water quantity as well as ecological and economic functions of waters.

Figure 1 shows the exemplary interrelationships of the system components of waterways influenced by external climate forcing, national and international policies and the economy to demonstrate the importance of considering system relationships and feedbacks in the discussion of adaptation strategies.

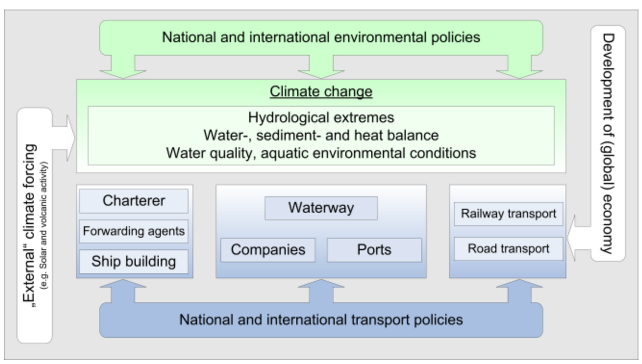

Figure 1. *Interrelationships of the system components of waterways influenced by external forcings (changed after Moser et al. 2008)*

These aspects are addressed by the interdisciplinary research projects "KLIWAS – Impacts of climate change on navigation and waterways – options to adapt" funded by the German Federal Ministry of Transport as well as by the two EU funded projects "AdaptAlp – Adaption to Climate Change in the Alpine Space" (INTERREG IV) and "ECCONET - Effects of climate change on the inland waterway networks" (EU FP 7) on the catchments of the Rivers Danube (Figure 2) and Elbe (only project KLIWAS). The projects KLIWAS and AdaptAlp were mentioned as "good practice examples" in the just released

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“Guidance document No. 24: RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE” (European Communities 2009).

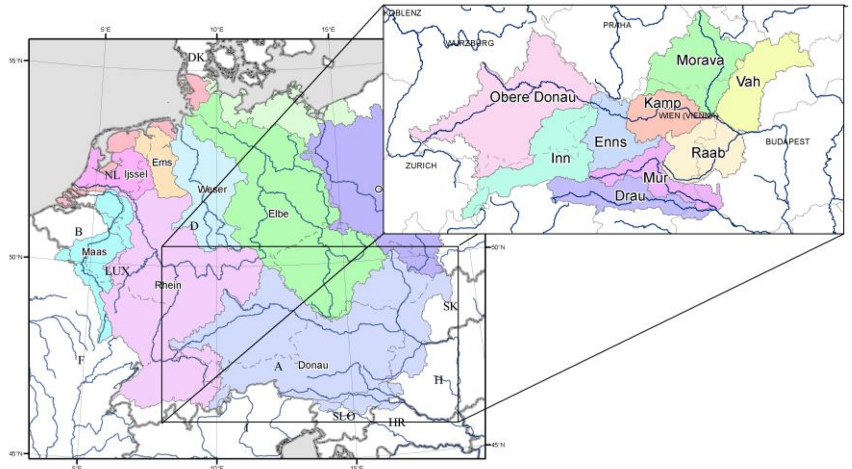

Figure 2. *Study areas in the catchment of the River Danube, AdaptAlp: German Danube and Inn, ECCONET: Rhine/Danube, KLIWAS: All international catchments shared by Germany*

2 Database and multi-model approach

In recent years, global and regional climate modelling achieved significant improvements, so that the results of the models are getting more and more reliable. Due to the low resolution, the simplification of processes and assumptions about initial and boundary conditions, the model results still have large bias and uncertainties which can be grouped in two categories (for a more detailed analysis of the different sources of uncertainty see Krahe et al. 2009):

1. Uncertainties inherent in the system (aleatoric), e.g. deterministic-chaotic behaviour of the climate system.
2. Uncertainties related to incomplete knowledge about the system (epistemic), e.g. measuring errors, simplification of the system (bias).

Due to these uncertainties, there is not a single “true” climate-model run, and most likely never will be. Hence, an ensemble, as e.g. generated via a “multi-model approach” using different global climate models, different regionalization models, and different hydrological models must be used to account for the uncertainties that lead to a range of possible changes.

The “Coupled Model Intercomparison Project” (CMIP 2009) has provided a large number of global climate projections of the Fourth Assessment Report of the IPCC (2007). For Europe, the European joint research projects PRUDENCE (2007) and ENSEMBLES (2009) provided a large number of regional climate projections based on different global climate projections and concepts for probabilistic evaluation and analysis of model results.

Besides the regional climate projections from these two projects, some additional projections are used from national and international climate-change projects. An overview of the emission scenarios, global climate projections, regional climate projections, bias-correction models, and water balance models considered in KLIWAS and other projects on the River Danube is presented in Figure 3.

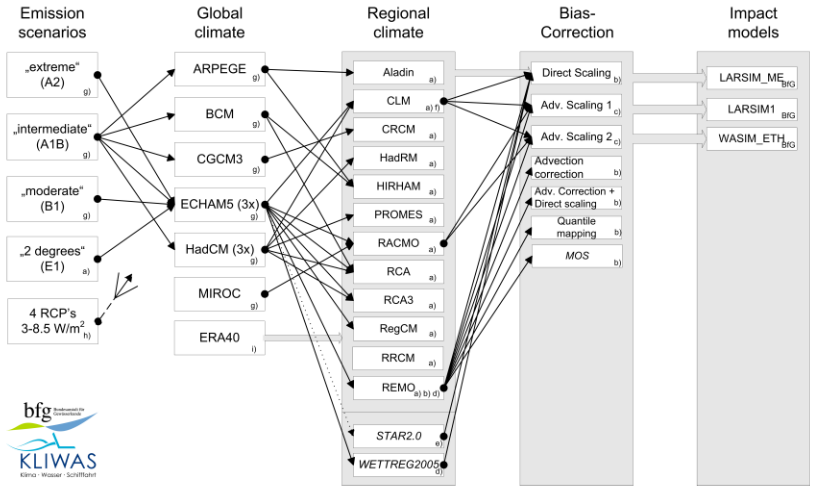

Figure 3. *Model chain and database for the multi-model approach in KLIWAS PJ 4.01 Hydrology and Inland Navigation. Sources: (a) EU-ENSEMBLES, (b) BMVBS-KLIWAS, (c) KHR-Rheinblick2050, (d) REMO_UBA, (e) PIK-STAR, (f) BMBF-CLM, (g) CMIP3/IPCC_AR4, (h) CMIP5/IPCC_AR5, (i) ECMWF (changed after Nilson et al. 2010).*

Simulations of the climate of the 20th century show that all regional climate models have limitations in reproducing the present climate (Figure 4). Hence, many bias-correction methods are currently being developed. Current transboundary projects (KLIWAS, AdaptAlp, and RheinBlick2050) test different statistical bias-correction methods for various climate-model runs for the catchment of the River Rhine. These methods are applicable also in other catchments like that of the Danube.

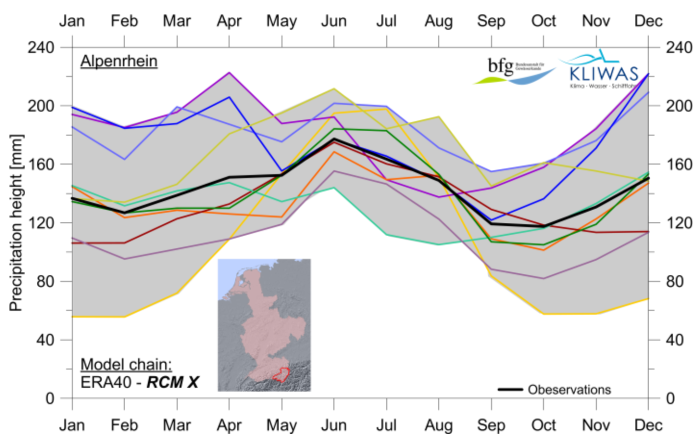

Figure 4. *Multi-annual (1971-2000) mean monthly precipitation sums in a subcatchment of the River Rhine with 10 different regional climate model runs (ENSEMBLES 2009). The black line is based on observations.(Bülow et al. 2009, Krahe et al. 2009)*

To analyse the uncertainty of the water-balance models, several models with different spatial and temporal resolutions (Table 1) are used in the Danube Basin to calculate discharge projections using ERA40-data and bias-corrected climate-model runs as input data. The model LARSIM_ME is currently being developed in the context of the research project KLIWAS with a resolution of 3 km x 3 km, and it will cover the national and international tributaries of rivers in Germany. Only this model and the model WatBal (Danube Countries 2006) will cover the whole study area of the River Danube as shown in Figure 2.

Table 1. *Spatial and temporal resolutions of the Water-balance models WaSiM-ETH (Schulla & Jasper 2007), LARSIM (Ludwig & Bremicker 2006) and WatBal (Danube Countries 2006) applied in the projects AdaptAlp, KLIWAS, ECCONET*

Catchment	Model	Spatial Resolution	Temporal Resolution
Alz	WASIM	1 km	1 h
Alz	LARSIM1	1 km	1 h / 1 d
Inn	WASIM	1 km	1 d
Upper Danube	LARSIM_ME	3 km	1 d
Danube	WadBal	Basins	1 month

3 Climate change in the Upper Danube Basin

Figure 5 shows the changes of the multiannual (30 years) mean seasonal precipitation sums relative to the period 1961-1990 of 18 global climate projections. All simulations are based on the same emission scenario SRES_A1B. The span between the models results from the uncertainties described before. There is a large difference between the projected precipitation changes ranging from about 0% to possible decreases/increases depending on the season of about 20 %. These results confirm the importance of the multi-model approach in view of an uncertain future.

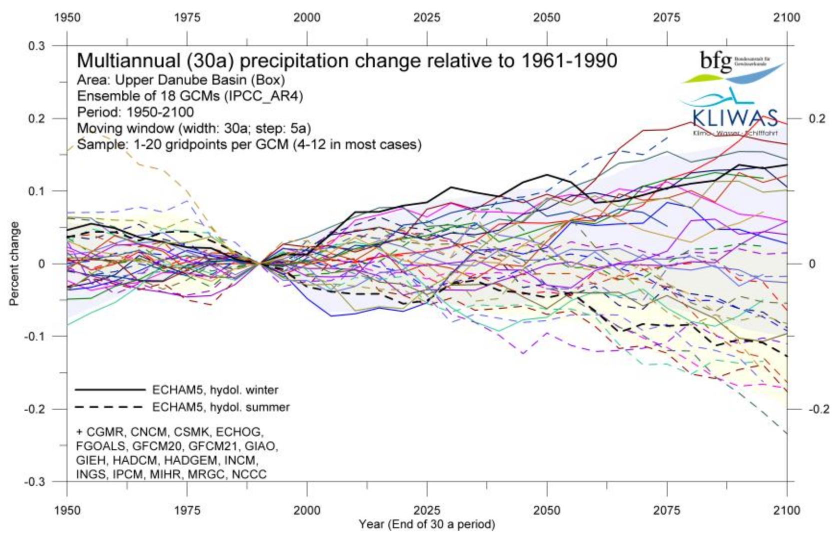

Figure 5. *Span of the seasonal (summer, winter) precipitation changes in the Upper Danube Basin (German part) between 1950 and 2100, simulated by 18 global climate models (AR4 of the IPCC 2007) using the emission scenario SRES_A1B. Shown are the changes of the multiannual (30 years) mean precipitation sums relative to the period 1961-1990.*

4 Outlook and conclusions

Despite all their uncertainties, climate projections should be used to improve river-basin management as these simulations are based on the best available scientific information. Especially for projections of the distant future they are more reliable than other methods as e.g. the extrapolation of the measured change into the future by statistical methods. Adaptation strategies in river-basin management should be based on a range of possible changes in the system to take all available information and the existence of uncertainty into account. Ideally, the whole ensemble of available projections should be considered in the impact models to evaluate the possible changes and adaptation options. As consequence of the large uncertainties the model results have to be analysed and evaluated to make them available to the different stakeholders involved in river-basin management. In KLIWAS and Rheinblick2050, a methodology was generated to select “representative projections” as scenarios based on the ensemble of discharge projections and the scenario horizon.

Figure 6 demonstrates this with focus on summer low flows at selected gauging stations on the River Rhine. The graph is based on an climate projection ensemble consisting of 20 members for the period 2021-2050. All members are bias-corrected and taken as input for a hydrological model (HBV134). The ensemble does not show a clear tendency of change. The main corridor spans changes from plus to minus 10%. The “representative projections” are selected subjectively on the outer rim of the main corridor as indicated by fat lines. The time series behind these projections will be used as a basis for investigations of other impacts on the aquatic system like water quality and ecology. A similar approach is currently under development for the Danube and Elbe, too.

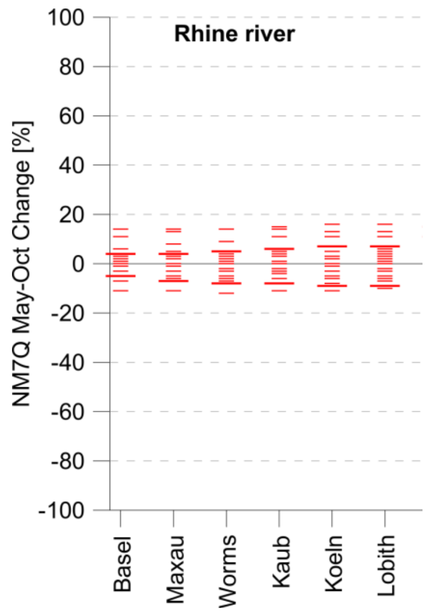

Figure 6. *NM7Q at major gauges along the River Rhine during the summer half year according to an ensemble of 20 discharge projections. NM7Q is lowest 7-day mean discharge. Values are expressed as percent change in period 2021-2050 (near future) compared to 1961-1990.*

Acknowledgements

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Monitoring of selected pharmaceuticals in surface waters of the Vltava River Basin

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Keywords: Vltava River Basin, OTC medicines, antibiotics, anticolvulsants, contrast agents, LC-MS/MS

1 Introduction

The Framework Monitoring Programme (MoE 2007), developed in line with EU directives (EU 2000, 2008) by the Ministry of the Environment and Ministry of the Agriculture of the Czech Republic in cooperation with the Czech Hydrometeorological Institute (CHMI), defines the lists of chemical and microbiological indicators for the assessment of chemical and ecological status of surface waters. In the last 5 to 10 years, the list of monitored active substances of pesticides used in the Czech Republic for plant protection products, wood preservatives etc. is been expanding along with the rapid development of instrumental analytical separation methods with mass detection. To respond to the positive findings of substances belonging to the specific group referred to as PPCPs (Pharmaceuticals and Personal Care Products) in environment, new multi-analytical methods have also been developed, allowing to identify these substances, including, e.g., synthetic musk compounds, complex-forming compounds, hormones, active ingredients of pharmaceuticals. These substances are discharged into aquatic ecosystems via municipal sewage treatment plants (STPs) effluents. An efficient technology of PPCPs degradation in the process of waste water treatment is yet to be developed, PPCPs are not monitored in STPs effluents, so consequently, mass balance cannot be calculated. Health risks and adverse impacts on the biological components in the river ecosystem are the subject of many scientific and technical publications around the world. The situation is complicated by the diversity of pollutants and their biological activities, which enable the formation of degradation products whose impacts and risks may differ substantially from those of the initial substances (Fuksa et al. 2010b). This paper is focused on the monitoring of pharmaceuticals belonging to OTC (Over-The-Counter) drugs – ibuprofen and diclofenac from the group of NSAIDs (non-steroidal anti-inflammatory drugs) and carbamazepine (anticonvulsants). In addition, erythromycin, sulfamethoxazole (antibiotics) and iopromide and iopamidol (contrast agents) have also been monitored since January 2010. These pharmaceuticals are registered by the State Institute for Drug Control and some of them are high on the Czech theoretical drug consumption list (www.sukl.cz, 2009). Drug determination at concentrations reaching the ambient pollution levels is relatively new to the chemical analysis of water. Expansion of liquid chromatography with tandem mass spectroscopy (LC-MS/MS) provided conditions for developing the methods of determination of drug levels in water. It is also important in this context that extremely sensitive mass detectors have been developed and are currently available at a reasonable price, affordable even to routine water management laboratories. Although currently drugs are not comprised in the Framework Monitoring Programme of the Czech Republic and in current national legislative documents, the above drugs are being monitored for already the second year at specific international sampling sites under the Elbe Monitoring Programme (IKSE-MKOL 2010). Povodí Vltavy, státní podnik (The Vltava Valley Authority) is responsible for the management of watercourses and for evaluation of surface water quality, and therefore it has been decided that this new group of drugs should be included in Povodí's programme of surface water operational monitoring to obtain basic information on pollution at selected sampling sites. The aim of this study was, first, to determine which of the monitored rivers were the most loaded with drugs, and then to try and identify the causes of high concentrations and, finally, to define the general nature of pollution; generally, the objective is to identify or at least suggest other areas with high drug concentrations.

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2 Analytical methods

A new analytical method was developed for the analysis of drugs in surface waters (Seitz et al. 2006; Chin-Kai 2006; Borton et al. 2007; EPA 2007; Kule et al. 2009). Liquid chromatography was used for separation, and tandem mass spectrometry was used for detection. In choosing the sample preparation, it was necessary to take into account the physical and chemical properties of analytes, especially their higher polarity and lower stability. Sample preservation from the time of sampling to the time of analysis (freezing) was therefore emphasised in the methodology. The technique uses a unique principle of detection, based on the determination of the characteristic MRM transmission between the precursor and product ion, and therefore the samples did not need to be cleaned. For liquid chromatographic analysis, a centrifuged water sample was injected directly, without any organic solvent extraction and without SPE or similar techniques. To achieve the required limit of determination, it was necessary to increase the sample injection volume to 1 ml. A combination of the standard addition method and internal standard method with isotope-marked standards is used to gain information on the elimination matrix interference and to ensure quality control. The limits of quantification, MRM transmissions and the RSD repeatability of the LC-MS/MS method with direct injection of large volumes of sample are given in Table 1.

Table 1. *Quantitative and qualitative MRM transmissions and statistical parameters: RSD of repeatability for a concentration of 0.05 µg/l and analytical limit of quantification (LOQ).*

Name	MRM QUANT.	MRM QUAL.	RSD (%)	LOQ (µg/L)
Ibuprofen	205.2 → 161.0		6.3	0.05
Diclofenac	294.1 → 250.1	294.1 → 213.9	6.4	0.05
Carbamazepin	237.1 → 194.0	237.1 → 192.1	5.3	0.02
Iopromide	792.0 → 573.0	792.0 → 558.8	22.9	0.1
Iopamidol	775.7 → 126.6		15[1]	0.1
Sulfamethoxazole	254.1 → 155.9	254.1 → 91.9	7.2	0.02
Erythromycin	734.4 → 158.1	734.4 → 576.4	12.2	0.02

[1] A qualified estimate

3 Preparation of monitoring

Sampling sites were selected with regard to the possible sources of waste water containing drugs: first, in the international profiles (Vltava at Zelčín and Berounka at Lahovice), followed by the final sites of backbone flows, where pollution is to be recorded from a larger area, such as a small river basin, which typically corresponds to an area of several water bodies.

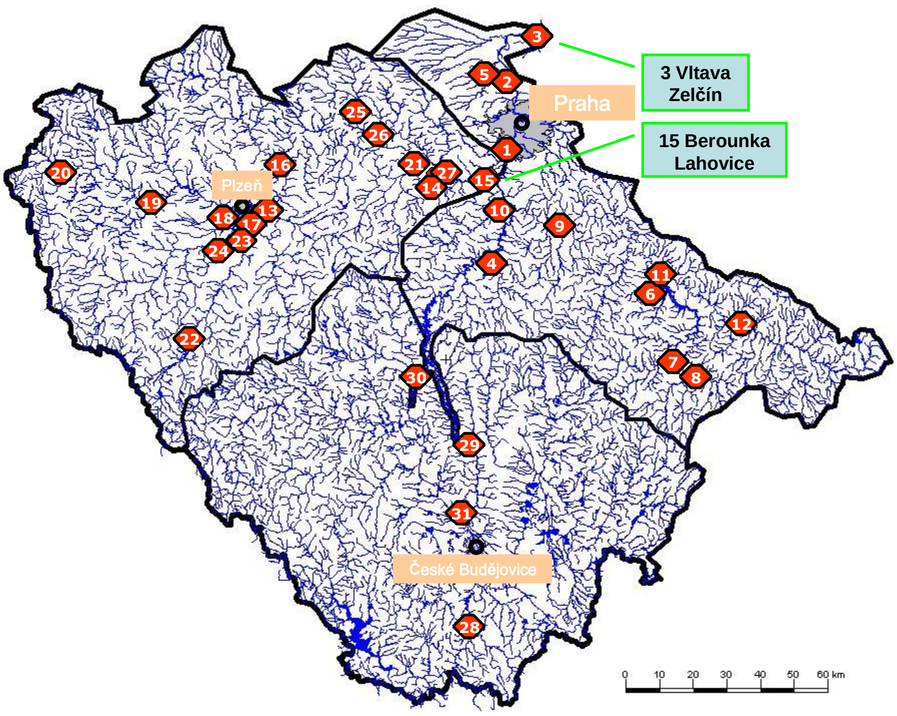


Figure 1. *Map of the Vltava river basin with a sampling sites list. Vltava at Zelčín and Berounka at Lahovice are the sites of the IKSE-MKOL international monitoring programme.*

1 Vltava Podolí
2 Vltava Libčice
3 Vltava Zelčín
4 Mastník Radíč
5 Zákolanský str. Kralupy
6 Želivka ÚV Hulice
7 Želivka Poříčí
8 Bělá Pelhřimov pod
9 Benešovský str. Benešov pod
10 Sázava Pikovice
11 Sázava Zruč nad Sázavou
12 Sázava Chlístov
13 Berounka Bukovec
14 Berounka Srbsko
15 Berounka Praha Lahovice
16 Střela Borek
17 Úslava Plzeň Doubravka
18 Mže Plzeň Roudná
19 Mže Stříbro pod
20 Mže Oldřichov
21 Litavka Beroun
22 Úhlava Svrčovec
23 Úhlava Plzeň Doudlevce
24 Radbuza Dobřany pod
25 Rakovnický str. Dolní Chlum
26 Rakovnický str. Křivoklát
27 Loděnice Hostim
28 Malše Pořešín
29 Lužnice Bechyně
30 Otava Topělec
31 Vltava Hluboká nad Vltavou

Simultaneously, monitoring was initiated at sites with a high population density where surface waters are affected by large amounts of treated municipal waste water discharged into a river, and also in areas where surface water is used as a source of drinking water. A total of 31 sites, whose locations are indicated in Figure 1, were selected for 2009. Sampling was carried out on a monthly basis. The initial set of 12 data items was thus generated, providing a first indication of pollution in the region.

4 Results

Figure 2 shows the average annual concentrations of ibuprofen, diclofenac and carbamazepine. Extremely high concentrations not recorded repeatedly, which did not reflect the standard conditions in the river, were excluded during data processing. As to concentrations below the limit of quantification, half the LOQ was used in the calculation (Nesměrák 2009). Table 2 shows the hydrological and population data from the sites where increased concentrations of drugs were regularly recorded. Monthly concentrations are shown in Figures 5-8.

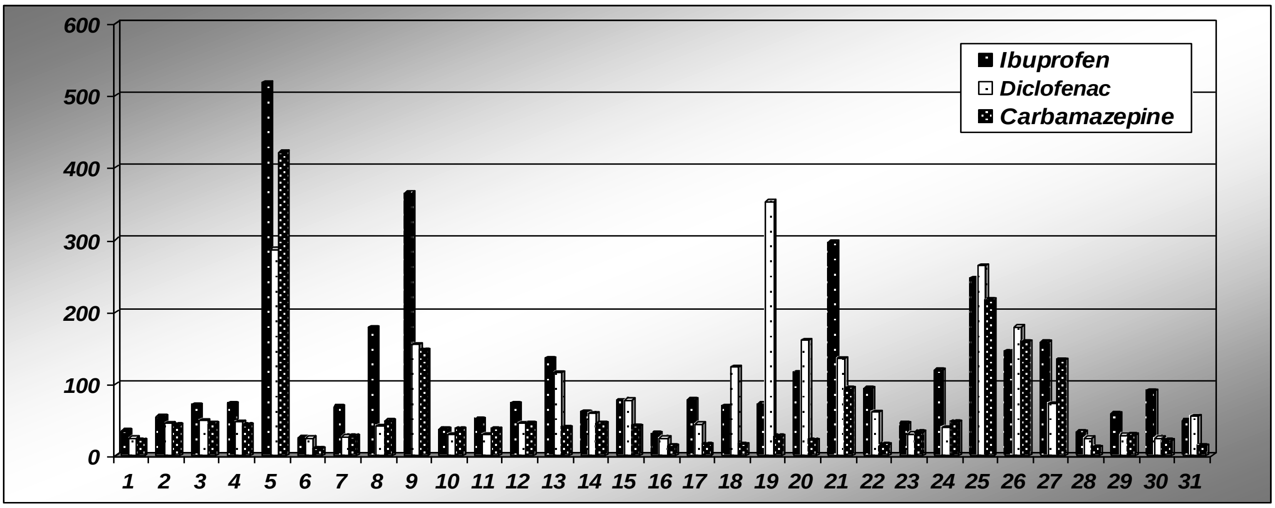
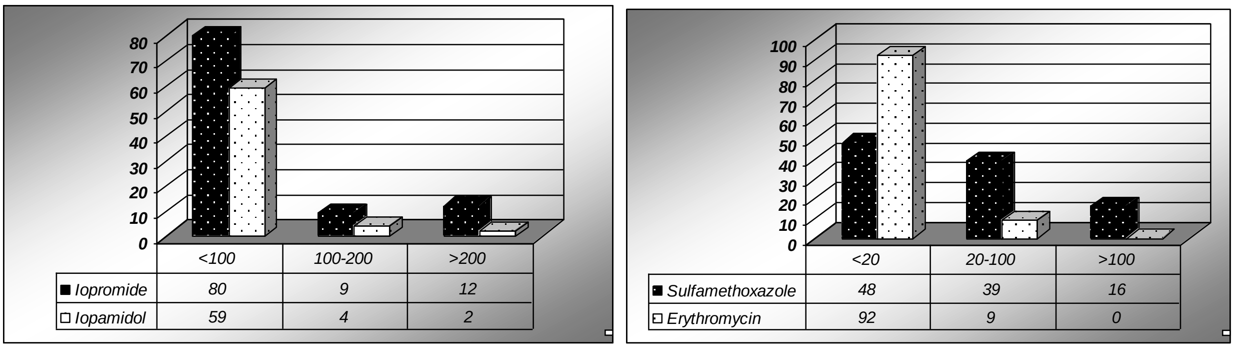


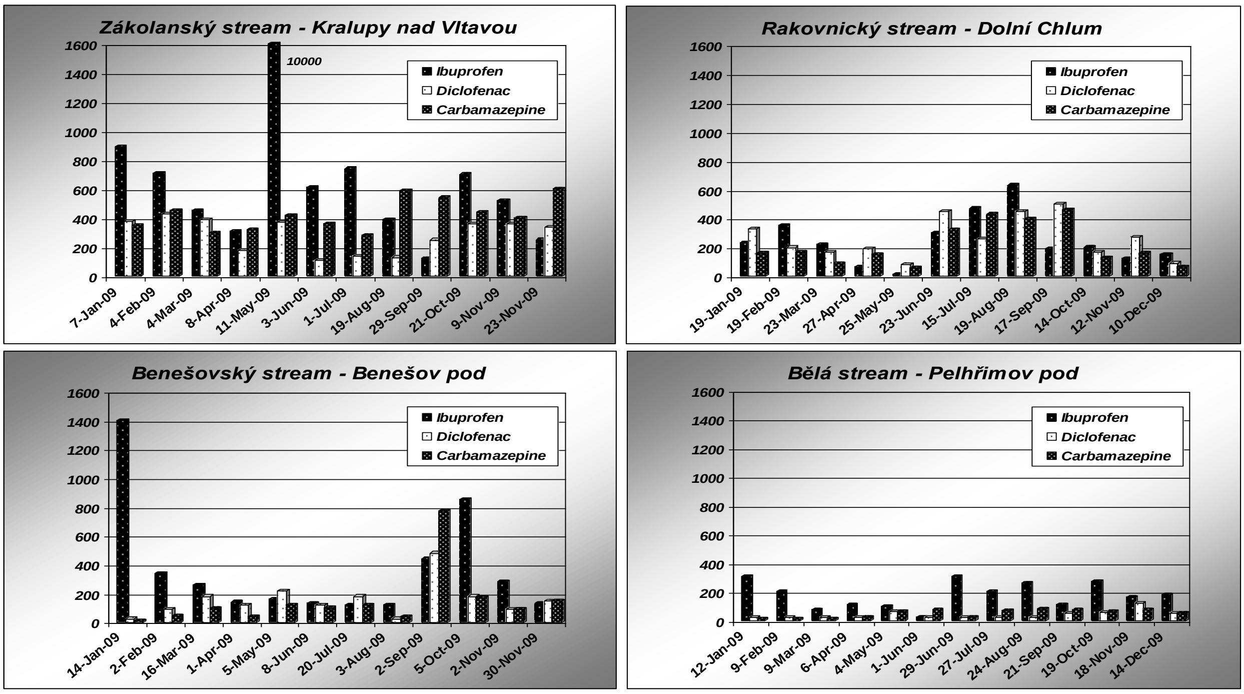
Figure 2. *Average concentrations (ng/l) of ibuprofen, diclofenac and carbamazepine (2009). Numbers on x axis identify the names of sampling sites (see sampling sites list in Figure 1).*

Table 2. *Hydrological and population data for the river basins with the highest drug levels.*

Name	Average discharge [m^3/s]	length [km]	drainage area [km^2]	population estimate
Rakovnický stream (Rakovník)	0.68	48.5	302.2	32,000
Zákolanský stream (Kralupy n/Vlt.)	0.63	28.2	265.6	107,000
Benešovský stream (Benešov)	0.33	17.2	80.7	17,000
Bělá stream (Pelhřimov)	0.87	22.7	94.2	20,000



Figures 3-4. *Distribution of values for iopromide, iopamidol, sulfamethoxazole and erythromycin (ng/l). Data was collected in November and December 2009.*



Figures 5-8. *Monthly concentrations (ng/l) of ibuprofen, diclofenac and carbamazepine. The sites with the highest concentrations in the Vltava River basin are small rivers (flow <1 m*^{3}*/s) to which a large quantity of wastewater is discharged from large cities (15-100 thousand inhabitants).*

Data for iopromide, iopamidol, sulfamethoxazole and erythromycin obtained in November and December 2009 represent only a small file, not allowing to calculate annual average concentrations. Distribution graphs for drug concentrations at all sampling sites were therefore created from all values (Figures 3-4).

5 Discussion

Figures 5-8 show rivers with a high frequency of concentrations above the limit of quantification for most of the drugs under review, often reaching hundreds of ng/l. What these sites have in common is a medium-sized city with a population of 15-100 thousand, whose municipal waste waters are discharged into a small watercourse with a flow rate of less than 1 m^3/s. Hence, an area where high concentrations of drugs are likely to occur can generally be characterised as “a large town on a small river”. Extreme drug concentrations as a rule disappear at the confluence of such a small stream with a large river. Therefore, the health risks caused by the toxic mixtures of drugs and their adverse impacts on the biological components of flowing surface waters can be expected to occur specifically in small watercourses. What can also be considered important is the fact that the ongoing monitoring is limited to only a few analytes, although as many as about 3000 active substances of medicinal products are known to be registered in the Czech Republic. Those used most widely include contraceptive pills, antibiotics, OTC drugs, etc. (Fuksa et al. 2010b). Summarising the following facts, we can obtain a detailed overview of the issues of drugs escaping into the environment, their impacts and the health risks to the ecosystem of surface waters in the Czech Republic:

- There is no balance monitoring of drugs in surface waters to provide information about the total amount of these substances in the aquatic environment.
- Research projects concerning the overall balance of drugs in waste waters (at inflow to treatment plants, in the treatment process, at the discharge from treatment plants) led to the conclusion that efficient removal is needed. The main reason is that with some of the drugs (carbamazepine) it will be impossible to find a consistent balance between the theoretical consumption and supply (Fuksa et al. 2010a).
- Technologies to remove pharmaceuticals from waste water are explored only marginally and specific applications are rare (WWTP Modřice: Vávrová et al. 2009; Jedličková at al. 2010).
- The range of the analytes being monitored is very narrow; for example, it does not include the active substances of hormonal contraceptives.

- Analysis of the impact of drugs on the biological components of rivers (fish, macrozoobenthos) in critical areas of the Czech Republic is not systematically documented.

To meet these challenges, state authorities (ministries, the Czech Hydrometeorological Institute, river valley authoritires), need to cooperate with the specialized departments of universities, with the T.G.Masaryk Water Research Institute p.r.i. Prague, etc. Sufficient funding must be provided (operational monitoring, research grants, etc.) in addition to the technical and scientific solutions.

6 Conclusions

Operational monitoring of selected drugs showed that these substances are present in surface waters at measurable concentrations, often in hundreds of ng/l. Municipal sewage treatment plants are the sources of the drugs. The concentrations are particularly high where the waste water dilution ratio is low (a big city on a small river). It is time now to fill the gaps in monitoring programs and research on ecological impact of the PPCPs.

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www.sukl.cz (2009) keywords Carbamazepine, Diclofenac, Ibuprofen, Iopromide, Iopamidol, Sulfamethoxazole, Erythromycin.

Contemporary geomorphological-sedimentary consequences of flooding - the Bratislava reach of the Danube River

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Keywords: Danube, flooding, geomorphology, sediments, landscape, evolution

1 Introduction

Increasing focus on the importance of the channel and floodplain physical habitats created by geomorphological processes, and concerns raised by recent flooding have served to highlight the importance of geomorphological processes in creating and sustaining biodiversity and flood conveyance. Monitoring change in the geomorphology of the river environment is, therefore and belatedly, becoming an important measure both of river management practice and system resilience to external environmental change. This paper outlines the recent geomorphic changes (1949-2008) in the suburban large river reach of the Danube River between dikes in Bratislava. The investigation of changes in landforms and floodplain roughness and rate of retreat of banks is based on the multi-temporal interpretation of aerial photographs. The sedimentological response of three flood events (24 March 2002 - Q_{50}, 16 August 2002 - Q_{100} and 8 September 2007 - Q_{10}) were investigated. The study reach represents a part of the tip of an extensive alluvial fan (inland delta) of the Danube River. The mean annual discharge is 2,045 m^3s^{-1} and the computed 100-year discharge Q_{100} = 11,000 m^3s^{-1} (Svoboda et al., 2000). The study river reach (Fig. 1) represents the right bank floodplain (inter-dike inundation area) of a unique tectonics-controlled bend of the Danube. It is approximately 5 km long with a radius of 1.5 km. The channel width is 350 m, the slope between 0.43 $^0/_{00}$ and 0.53 $^0/_{00}$ and the width of the floodplain between 300 – 600 m. Substrate deposits consist primarily of Pleistocene and Holocene gravels overlaid by sand to clay-sand sediments filling abandoned channels of the Danube (Hulman et al., 1974). The study area belongs to the suburban zone of Bratislava city. This area has been designated as the "flood way" and retains floodwaters under the flood protection measures of Bratislava. Upstream of the study reach in the urban area of Bratislava the Danube River today is a straight and canalized river. Downstream, the study reach ends in the impoundment area of the Čunovo dam. As far as fluvial processes are concerned, this reach represents the most active and also the most problematic (in terms of management) of the Slovak reaches of the Danube River.

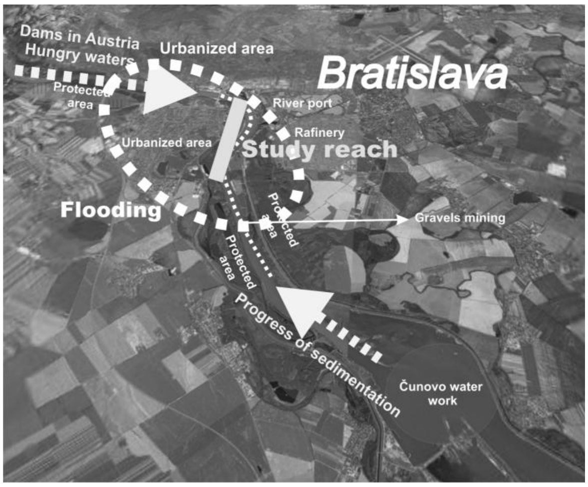

Figure 1. *Study river reach location*

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2 Methods

The basic data sources for this research were 1949, 1969, 1985 aerial photographs and ortho-photomaps for 1997 and 2004, and field work. Overbank deposits were identified by 10 borings, using handy soil driller and 20 pit exposures. Borings and pits served as sampling points to determine the processes and rates of the vertical accretion using an allostratigraphic approach classified on the basis of the fluvial style (Miall, 1996). Sediments were classified using established methods (Brierley 1991, Zwoliński, 1992). All data were processed using GIS ArcView 3.2. Bank retreat was documented by identifying the bank line from aerial photographs, and transferred to the respective ortho-photomaps for the above-mentioned time horizon. The method of Arcement & Schneider (1989) was used as the basis for characterizing floodplain roughness based on Manning coefficient (n) values.

3 Results

Overbank vertical accretion and levee formation processes during flood events dominate floodplain evolution of the study reach. According to Allen (1965), levees are best developed on the concave side of bends. Our study suggests that the development of levees proceeds, albeit unusually, in the convex part of the Danube's bend. Levee development can be explained by limited lateral migration due to the embankment of the concave left bank which strongly influenced flow direction during floods. Although the convex bankline was shifted (naturally and artificially) by 70 m into the floodplain after the 1997 flood (Q_{10}), an approximately 50 m wide strip of overbank sediments was deposited (new levee) in the vicinity of the new bankline after the flood of 2002. This is demonstrated by the profile of the new bankline which is 3 m above the average annual water level. The basal portion of the bankline consists of gravel horizons overlaid by fine sand fractions i.e. this is the new levee. The transition between the channel (gravel) and the floodplain (finer) facies is sharp. The thickness of sand sediments in the upper portion of the bank profile is about one metre, indicating the height of levee deposition. It is possible to observe the sedimentary records of the flood events of 2002 and 2007 in the overbank alluvia mainly in the neighbourhood of the riverbank. The structure of alluvia deposited on the levee by the 2007 flood as a lithofacial profile is shown in Fig. 2A. We recognised two three-unit sequences making up the record of three flood phases on this profile. They are deposited above a massive silt with isolated pebbles. The similar flood cyclothem of overbank deposits was found on the bank profile (Fig. 2B). It is possible to identify three units of different lithofacial features in each of these layersets:

(i) The lower unit represents an initial, rising phase of flood wave (Allen, 1965) that is "rising of water stage and bank modification" .The lithofacies representing this unit:

- the Massive Sandy Silt lithofacie (SFm) 5 cm thick (Fig. 2A),
- the roof part (2-3 cm thickness) of the Massive Sandy Silt lithofacie and the higher lying lithofacie of Massive Inversely Graded Fine Sands – Smi fragment 2-3 cm thick (Fig. 2A),
- the organic matter layer (C) with the Massive Silt admixture (C/Fm) of a few millimetres of thickness (Fig. 2B);

(ii) The middle unit is recording the phase of rising and distribution of flood water or "floodplain inundation and initial deposition" (the 2nd phase) The middle unit is represented by:

- the layer of 3-8 cm thickness of the Inversely Graded Massive Fine- and Coarse Sand lithofacie (Smi) and a layer of 4 cm thickness of the Inversely Graded Massive Coarse Sand lithofacie (Smi) associated in roof with the Matrix-Supported Gravel lithofacie (Gm) on the levee lithofacial profile (Fig. 2A),
- the layer of 15 cm thickness of the Semi-Horizontally and Low-Angle Cross Laminated Medium Sand lithofacie (Sh/Sl), in the bank lithofacial profile (Fig. 2B);

(iii) The top unit of flood cyclothem is recording the fall of flood wave and clearing of flood basins "falling of water stages and height intensity of deposition" and "cessation of overbank flow and final deposition". The top unit is represented by:

- a few centimetres thick layers of the Massive Mud lithofacies (Fm) occurred in two cyclothem on the natural levee profile (Fig. 2A),
- a few centimetres thick layers of the Massive Mud (Fm) lithofacies founded in the bank profile (Fig. 2B).

Taking into account the lithofacial features of the analysed layer sets and their position in profiles, the following correlation between them and flood events is assumed:

(i) The 2002 spring flood corresponds to the sequence of the three-unit flood cyclothem SFm - Smi - Fm affirmed in the levee profile (Fig. 2A) as well as the two-unit inversely graded sequence SFm - SFh in the bank profile (Fig. 2B).

(ii) During the 2002 summer flood, the three-unit flood cyclothem Fm – Smi (Gm) - Fm situated in the levee profile (Fig. 2A) as well as the three-unit layerset C/Fm - Sh/Sl - SFm in the bank profile (Fig. 2B) were deposited. It should be underlined that this sequence is the closest to the three-unit flood cyclothem described by Klimek (1974).

(iii) The Massive Mud (Fm) with organic matter (grass) was accumulated in the rising phase of the 2007 summer flood. Furthermore the Horizontally Laminated Sand and Low-Angle Laminated Sand (Sh/Sl) were deposited in the culmination phase of this flood in the bank profile (Fig. 2B). Moreover, during this flood a Massive Silty Sand (FSm) layer of a low thickness was accumulated on the natural levee (Fig. 2A).

The 2002 spring flood had less effect at the riverbank (up to 10 cm of mainly silt) and a bigger effect on the natural levee (up to 30 cm of silt and sand). The 2002 summer flood had a more balanced effect (up to 20 cm of sediments on both sides), on the bank mainly horizontally laminated sand, on the levee complete flood cyclothem (silt – sand – silt). On the bank the structure of sandy sediments is mainly semi-horizontally laminated and on the levee there is a complete 'flood cyclothem' (three-unit layerset, characterizing pensymmetrically graded sequence: silt – sand – silt). The last flood event (in 2007) induced sedimentation mostly in the close vicinity of the bank (up to 10 cm of sandy material), and only thin layers of finer sediment far away from the bank-line could be found.

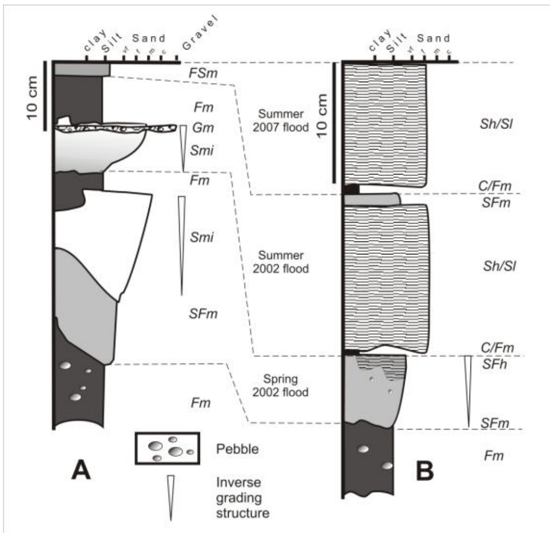

Figure 2. *Overbank alluvia lithofacial profile: A – natural levee lithofacial profile, B – channel bank lithofacial profile. Further explanations are given in the text.*

The flood of 2002 was also identified by dendrochronological analyses. Tree trunks silted by grey sand were found in four localities situated near the bank line. Beds of the same thickness were identified using estimates of the age of individual trees (read from growth rings) and the depth of their main root collar.

The military bunker at the southern tip of the Danube floodplain in the study area provides a long-term rate of vertical accretion of the floodplain. The bunker was erected by the Czechoslovak Army in 1937. At present, a 103 cm thick sedimentary deposit covers the entrance to the bunker. As the bunker was built in 1937, the rate of vertical accretion averages 1.4 cm per year. The estimated vertical accretion rate includes the alluvium deposited from approximately ten flood events in which floodwaters reached the bunker (Lehotský et al. 2010). Floodplain roughness was visually determined using aerial photographs and ortho-photomaps (1949, 1969, 1985, 1997 and 2004 respectively) for each land cover category (1. water bodies as special category; 2. grassland - very low roughness; 3. scarce shrubs - low roughness; 4. scarps covered by reed cover - medium roughness; 5. young forest with low shrub floor - high roughness; 6. mature forest with low and high shrub floors - very high roughness). Changes in floodplain roughness were classified for each time horizon by either the presence or absence of a given category (Fig. 3).

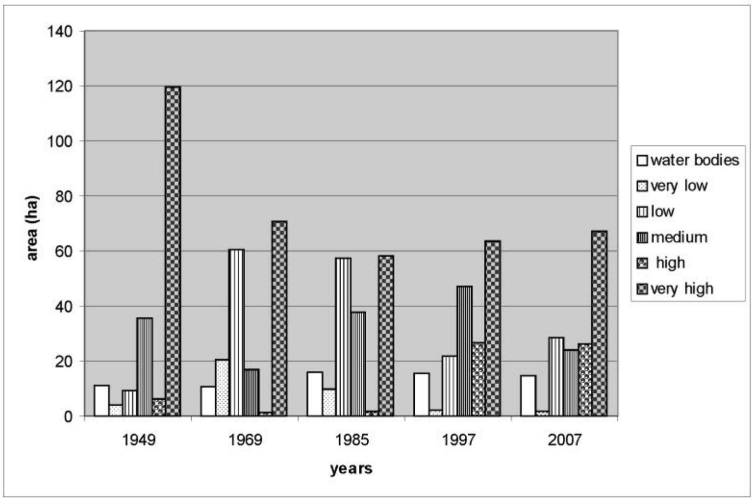

Figure 3. *Changes in floodplain roughness categories*

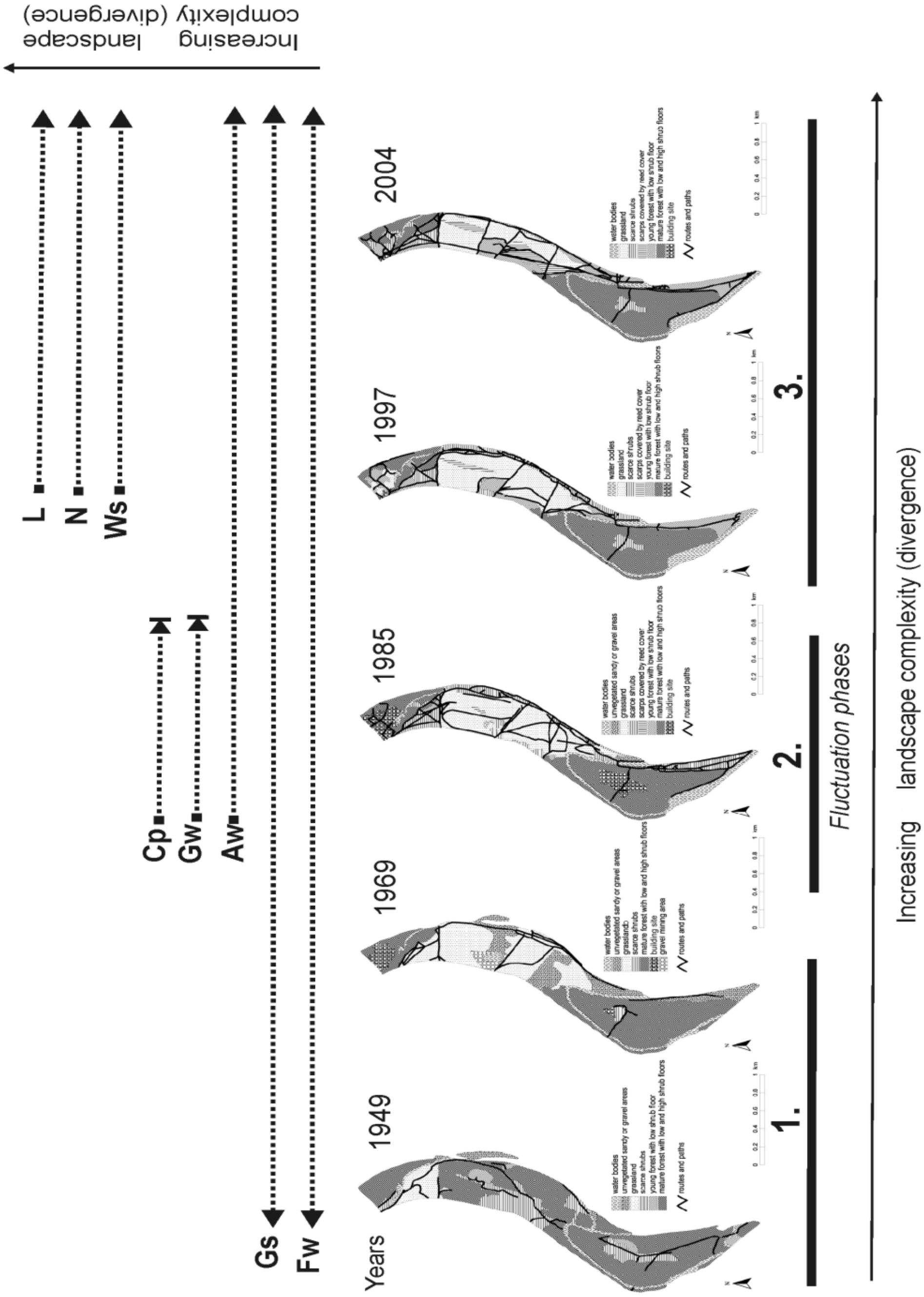

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Fig.ure 4. *Phases of contemporary evolution of the study area (Lehotský et. al 2008)*

4 Conclusions

Conflicts between urban development and flood regime of the Danube occur along the study reach. The evolutionary and qualitative "top-down" approach applied here to the problem of the current evolution of the study reach is based on the identification of a non-linear trajectory designated by changes in landform floodplain roughness categories and sedimentological response to flooding. The reach as a floodway represents a riverine environment in which a large river and its flood events conflict with the increasing urban development. The present geomorphic behaviour of the fluvial system reflects upstream measures such as dams in Austria, which have changed the suspended load regime leading to annual riverbed erosion of 2 to 3.5 cm near the Slovak-Austrian boundary (upstream of the study reach) and progressive aggradation of river bed along the study reach in Bratislava. The downstream Čunovo dam reinforces the upstream progression of sedimentation in the channel. Despite continuous gravel mining in the channel, its bottom has aggraded about 1 m. Bank retreat averaged nearly 100 m during 1949-2007 resulting in the formation of a new levee. The current deposits on the proximal part of the floodplain and of the natural levee differ in texture from the older ones. The old deposits are gravelly whereas the current sediment consists of fine-grained sands and sandy silts ranging in thickness between 0.5 m and 1 m. Thin overbank deposits of silt, silty sand and clay up to 0.2 m thick occur in flat floodplains and on the distal part of the levee. Gravel mining and flood control measures influenced changes in channel forms and biodiversity and sedimentation conditions. Three specific developmental phases have been identified in the recent geomorphological as well as land cover development of the river reach and eight factors related to the current changes. These are (Lehotský et al., 2008, Fig. 4):

1. flood control measures in the proximity of Bratislava - **FW**
2. gravel mining **- Gs**
3. construction of the Petržalka housing estate - **Cp**
4. construction and operation of the Čunovo dam - **Gw**
5. operation of upstream waterworks in Austria - **Aw**
6. woodland succession on the floodplain – **Ws**
7. leisure activities - **L**
8. operating of nature protection policies - **N**

Acknowledgements

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Sterlet (*Acipenser ruthenus* L.) as an object of research, fishery and aquaculture in Serbia

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Keywords: Danube, sturgeon, scientific research, commercial fishery

1 Introduction

Sterlet (*Acipenser ruthenus* L.) represents the smallest sturgeon species in the Danube River Basin, which exclusively inhabits freshwater habitats. While the other sturgeon species are present only on single continents, sterlet is the only sturgeon species that inhabits two continents, both Europe and Asia (Bemis & Kynard 1997).

Most of the sturgeon populations worldwide have experienced significant declines, mainly due to over-fishing, habitat destruction and pollution (Pikitch et al. 2005). At the same time, sturgeons have become popular species for aquaculture cultivation. Many countries have introduced exotic sturgeon species and hybrids in aquaculture facilities and, due to the proximity of fish ponds to natural water bodies, this has often led to unintentional introductions of exotic species and their hybridization with natural species and populations (Ludwig et al. 2009). Danube sterlet is known to hybridize with other sturgeon species, such as the introduced Siberian sturgeon (*Acipenser baerii*), which can lead to a rapid erosion of their autochthonous genetic diversity through the introduction of exotic genotypes (Ludwig et al. 2009).

Sterlet stocks in the Middle Danube have become dependent on stocking measures (Reinartz 2002). Major stocking activities are being conducted by Hungary (on average 100,000 fingerlings/year), and to a small extent by Slovakia, Bulgaria and Austria (Williot et al. 2002; Holčik et al. 2006; Guti & Gaebele 2009; Vassilev pers. comm.). However, stocking efforts are considered to be still insufficient to compensate the impact of unsustainable fishery and other negative factors (Vassilev 2006).

In Serbia and Hungary, sterlet is the only sturgeon species that is still a significant object of commercial and sport fishery (Guti & Gaebele 2009). Nevertheless, while the sterlet populations in Serbia represent an economically important resource, there are still unresolved problems of its unsustainable fishery, of catching the fish below the prescribed body length, as well as a lack of knowledge about its life history which diminishes possibilities for the development and implementation of efficient management measures. Furthermore, potential development of sterlet aquaculture in Serbia for both commercial and conservation purposes is hindered by the present economic problems. As a result, the aim of this study was to review the present status of sterlet in Serbia, primarily the research conducted on sterlet populations, its commercial exploitation and the possibilities of aquaculture development. Based on the presented information and the guidelines provided by both the Action Plan for the Conservation of Sturgeons (Acipenseridae) in the Danube River Basin (AP 2006) and the Action Plan for Sturgeon Species Management in Fishery Waters of Republic Serbia (Lenhardt et al. 2005), the authors present a number of suggestions for further research activities that would provide better understanding of the sterlet ecology and life history, as well as the key management and protection measures that would ensure sustainable use of their populations.

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2 Scientific research on sterlet in Serbia

The first thorough research activities on sterlet biology and ecology were initiated by Janković (1958), and conducted between 1951 and 1957 on the Danube River section between the towns Slankamen (rkm 1215) and Donji Milanovac (rkm 991). These research activities were mainly focused on morphological analyses, length-weight relationship, reproductive cycle, fecundity, nutrition and population age structure. Significant contribution was also provided by Ristić (1970) who, beside other findings, discovered that sterlet can migrate more than 300 km. Even today, this remains the only information on sterlet migrations, which may be surprising when bearing in mind the current wide use of telemetry and satellite tracking in ichthyological research. After these studies, there were only sporadic research activities, mostly focused on sterlet food composition, growth and length-weight relationship (Janković et al. 1994). More detailed analyses were initiated at the beginning of the 21st century. In 2002 and 2003, research conducted on specimens collected from the Danube near Belgrade involved analysis of morphological variability, sterlet growth and its parasites (Kolarević 2004; Lenhardt et al. 2009).

Research of sterlet diet (conducted on 585 specimens that belonged to 0^+ - 8^+ age groups) has revealed that Trichoptera, Chironomidae and Amphipoda were present in sterlet diet throughout the year and represented the main part of its diet (Janković 1958). In a study conducted in 1986, Trichoptera and Chironomidae were again found to be the main source of its food in the Danube River, while its main food in the Danube section between the two dams in the Djerdap gorge were Hirudinea (91%), which is probably due to the shift in benthic fauna composition caused by the impondment by the dam (Janković et al. 1994). The most recent studies of sterlet nutrition, conducted by Lapkina et al. (2005), have shown that Chironomidae were dominant sterlet food in July, while the leeches were dominant in August and September (representatives of six genera and three families). Leeches represented 100% of the sterlet diet during September, which has led to an increased sterlet growth (2.2 g/day), in comparison to its growth in July (1.8 g/day; Lapkina et al. 2005).

The 1990s were characterized by a significant development in the field of biomarkers, and the use of certain fish parameters as biomarkers to obtain early-warning signals of environmental risks (Van der Oost et al. 2003). As a bottom feeding species, sterlet is exposed to contaminants from both water and sediments, so it could represent a good indicator of water and sediment pollution (Poleksić et al. 2010). The main problem in utilization of sterlet as indicator species is its ability to migrate to great distances, so it can only indicate the state of a section of the river, and not of specific localities. Activity of antioxidant enzymes in sterlet liver, and aspartate and alanine aminotransferase in blood sera were used in sterlet from the Danube near Novi Sad (rkm 1253-1276) as biomarkers that respond to the presence of pollutants (Stanić et al. 2006). Heavy metal analysis of different sterlet tissues (liver, muscle tissue, gills and intestines) have revealed that the liver was the main heavy metal storage tissue, while the muscles accumulated the lowest levels of heavy metals. Sub-lethal histo-pathological changes were most pronounced in the liver and skin (Poleksić et al. 2010). Heavy metal concentrations in the sterlet muscle were below maximum threshold values and at acceptable levels for human consumption, except partly for cadmium.

The hypothesis of the existence of two different morphs of sterlet, one with a short, blunted snout, and the other with the long, pointed snout, was first introduced by Berg (1923), but it still remains unresolved. Based on 300 analysed sterlet specimens (both juvenile and adult male and female specimens), Janković (1958) concluded that it is difficult to confirm the hypothesis of two sterlet morphs. On the other hand, based on 5,137 analysed specimens, Ristić (1971) found some proof that might confirm the existence of two distinct sterlet morphs, but he avoided to make a final conclusion about this hypothesis. According to the data provided by Ristić (1971), short-snout sterlet was mostly present at spawning sites in the first half of the spawning season (11 March – 23 April), while the long-snout sterlet was present during the second part of the spawning season (28 April – 31 May). Results of a more recent study, conducted on juvenile sterlet specimens (Kolarević 2004) were not able to offer a conclusive answer to this question, while the study by Ognjanović et al. (2008) indicated a possible co-existence of two sterlet morphs in the middle stretch of the Danube River. However, all existing studies were so far mostly oriented on morphological analysis, so there is a need to combine morphological and genetic analysis in future research to provide a clear result.

Within the genetic analysis of sterlet in Serbia, primers for ten microsatellite loci were tested, in order to assess intraspecific and intrapopulation polymorphism (Cvijanović et al. 2009).

In a recent study by Jarić et al. (2009), population viability analysis in a Vortex simulation model has been conducted in order to assess the state of the six Danube sturgeon species, their future risk of extinction and to determine the most suitable conservation and management measures. Population viability analysis has revealed a large sensitivity of the sterlet populations to changes in natural mortality, age at maturity, fecundity and spawning frequency. It was also confirmed that the sterlet populations are highly susceptible to even moderate levels of commercial fishery. Population modeling was also used to assess the potential population growth rate of the Danube sterlet (Jarić et al. 2009).

3 Commercial sterlet fishery in Serbia

During 1951-1954, based on 2,000 studied specimens, Janković (1958) concluded that the sterlet catch was mostly comprised of 3^+ age specimens, as well as a significant portion of 1^+ and 2^+ specimens. Bearing in mind that the sterlet males and females can reach maturity in the second and third year of life, respectively, but mostly mature at age 3-4 (males) and 4-5 (females), observed fishery practices clearly seemed to be unsustainable (Janković 1958). Based on a study by Ristić (1969), sterlet catch in Serbia during 1948-1967 was mostly comprised of age 2^+-4^+ specimens, while the sterlet catch in the upper Danube section in Serbia was mostly comprised of specimens below 4^+ (99 %). Based on 467 sterlet specimens analyzed, collected from fishermen catch during 2002-2003, Kolarević (2004) has determined that the sterlet catch was mostly comprised of 0^+ and 1^+ age specimens. Construction of Djerdap I and II dams had significant impact on sterlet fishery, with notable increase of sterlet catch during that period, especially in the lower Danube section, with maximum catch in 1969 (23,615 kg) and 1984 (17,960 kg) (Lenhardt et al. 2004). Maximum annual sterlet catch in Serbia was in 1988 (79,978 kg). As a result of political and economic changes in Serbia during the end of 20th and the beginning of 21st century, data on sterlet catch for this period was fairly unreliable, due to untrustworthy official statistics and significant presence of illegal fishery. With the introduction of the new law on fishery (Anonymous 2009), quality of official catch statistics is expected to significantly improve in near future.

According to the national legislation, minimum prescribed standard body length of sterlet specimens in Serbia is 40 cm, while the temporary ban on sterlet catch lasts from 1 March to 31 May. Nevertheless, regardless of the existing national legislation, there is still a significant catch of specimens below the prescribed length, as well as fishing activities during the temporary ban on sterlet catch (according to the personal communication with commercial fishermen and the availability of sterlet on market). While most of the neighbouring countries have conducted regular supportive stocking activities, so far there was no such stocking of sterlet populations performed in Serbia.

4 Possibilities of sterlet aquaculture development in Serbia

After the construction of Djerdap I dam, a hatchery for artificial spawning of sturgeon was constructed few kilometres downstream of the dam, as a compensation for disrupted migration route of anadromous sturgeon species. Artificial spawning of Danube sturgeon species, among others of sterlet, was successfully performed at this facility. However, despite many favourable conditions, sturgeon aquaculture in Serbia has remained undeveloped until the present time. Nowadays, there is only one sturgeon aquaculture facility in Serbia, but unfortunately even that one close to be shut down, due to economic problems. With the aim to promote development of sturgeon aquaculture in Serbia, a cross-border Cooperation Programme between Serbia and Hungary was initiated in 2007 and financed by the EU – EAR. The Project ‘’Sustainable use of the sterlet and development of sterlet aquaculture in Serbia and Hungary’’ was conducted by the Institute for Multidisciplinary Research (Belgrade) and the Research Institute for Fisheries, Aquaculture and Irrigation (HAKI - Szarvas). One of the results of this project was the development of the Handbook for sterlet aquaculture. However, due to the present economic situation in Serbia, private aquaculture facilities are not motivated to introduce the cultivation of new species. The only possibility to develop sterlet aquaculture in Serbia seems to be a development of a project that would also involve private companies, and whose main goal would be artificial spawning and cultivation of sterlet.

5 Actions required for achieving sustainable use of sterlet populations in Serbia

In accordance with the guidelines provided by both Strugeon Action Plans (AP 2006, Lenhardt et al. 2005), and based on the state-of-the-art sterlet research in Serbia, as well as of the sterlet commercial fishery and sterlet aquaculture development possibilities, a number of activities required for achieving the sustainable use of sterlet in Serbia are presented in Figure 1.

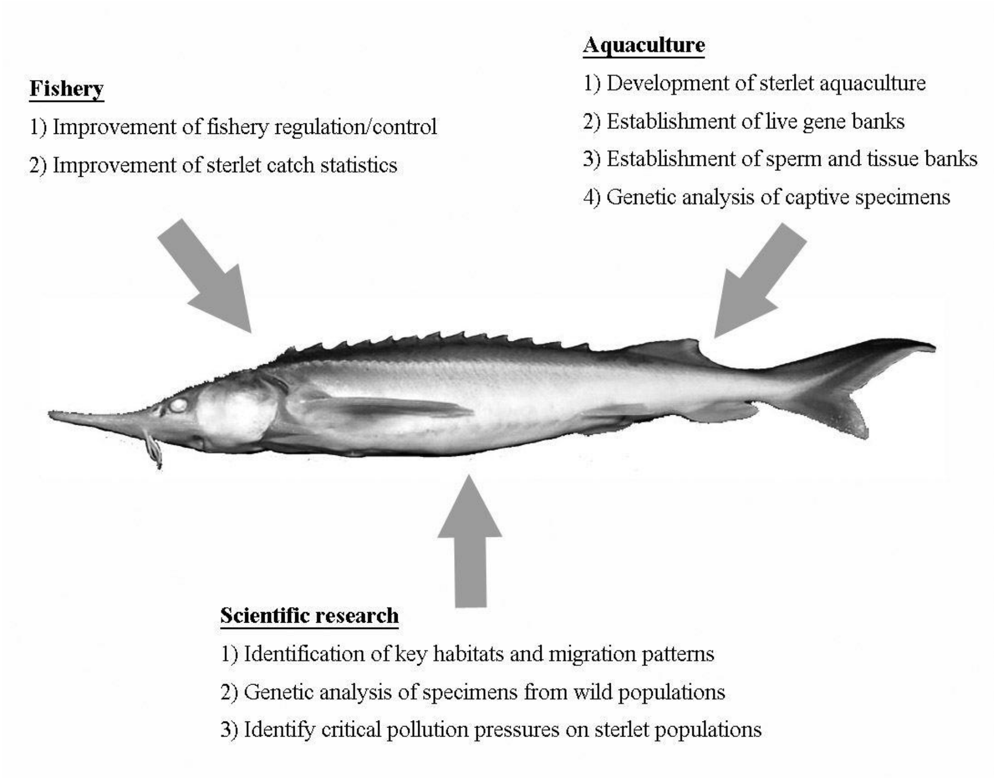

Figure 1. *Actions required in the field of scientific research, fishery management and aquaculture development for achieving sustainable use of sterlet populations in Serbia.*

6 Conclusions

While the sterlet is considered as an economically important species in Serbia, many issues that are related to its management and protection still remain unresolved, such as the unsatisfactory control of sterlet fishery, unreliable official catch statistics, undeveloped sterlet aquaculture and the lack of knowledge on its life history. In order to improve the present situation, it would be necessary to identify key sterlet habitats and to develop adequate measures of their protection, and to impose more efficient control of fishery, trade and more reliable official catch statistics. Cooperation between scientific institutions and private aquaculture enterprises, through the development of mutual projects, could be an important step towards the development of sterlet aquaculture in Serbia.

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The actual state of relict Pontic-Caspian invertebrate fauna of the Lower Danube within the area of Ukraine

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Keywords: fore delta, Pontic-Caspian fauna, macroinvertebrates.

1 Introduction

The close attention of biologists, zoologists dealing with faunistic research, hydrobiologists and hydroecologists to the study of the relict Pontic-Caspian invertebrate fauna is attributed to the uniqueness and the old history of this faunistic complex. Its species can be used as the reliable indicators of the ecological state of aquatic ecosystems taking into account their adaptability to the specific salinity and oxygenation (Zenkewitsch, 1947, Mordukhai-Boltovskoi, 1960). Although this faunistic complex has been studied for more than a century starting from the research of Sowinskyi (1902), the various authors do not assess unanimously the assignment of many invertebrate species of the lower reach of the Danube to the complex under study. While several species are in fact ubiquitous, other species seem to be included into the complex by mistake. The aim of the study consisted in the revision of the faunistic summaries for the lower reach of the Danube followed by the analysis of the changes in the composition of the Pontic-Caspian invertebrate fauna in the delta front of the Kyliya branch.

2 Materials and methods

The major faunistic summaries of the Pontic-Caspian invertebrate fauna for the lower reach of the Danube are contained in the works of Mordukhai-Boltovskoi (1960), Polischuk (1974) Polischuk & Shepa (1994) and Kharchenko (2004). These summaries upon the thorough analysis of the findings relevant to zoogeographic distribution and the origin were used as the reference sources for assigning the species studied to the Pontic-Caspian complex. Furthermore, we have also used the works of Markovskyi (1955), Moroz (1993) as well as the results of our own study of invertebrate macrofauna in the Kyliya branch in 1988-2009.

3 Results

First, the following species were excluded as being non-related to the Pontic-Caspian complex: 1) cosmopolites – *Plumatella emarginata* Allman (Braiko, 1983), *Paranais litoralis* Muller (Chekanovskaia 1962), *Nais elinguis* Muller, *Isochaetides michaelseni* Lastockin (Chekanovskaia, 1962); 2) disputable species if their origin was doubted – *Victorella pavida* S.Kent (Polischuk 1974; Vinogradov, 2008), *Manayunkia caspia* Annenkova (Mordukhai-Boltovskoi 1960), *Tubifex svirenkoi* (Lastochkin) (Phinogenova 1968); 3) species that were included into the complex by mistake – the freshwater Danube endemic species *Theodoxus danubialis* (G. Pfeiffer) (Mordukhai-Boltovskoi 1960), the Mediterranean Amphipoda *Corophium volutator* (Pallas) (Mordukhai-Boltovskoi 1978).

The gastropod *Theodoxus euxcinus* (Clessin) should be particularly noted. Such a species is given in the summaries of Polischuk (1974) Polischuk & Shepa (1994) and Kharchenko (2004). Nevertheless, as it has been recently shown, only two species of the genus inhabit the delta front of the Kyliya branch, namely *Th. fluviatilis* and *Th. danubialis* (Zhalay et al. 2008). As to *Th. euxcinus*, it was attributed to the delta front by mistake.

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We have also supplemented the faunistic lists of the lower reach of the Danube with the species, which were omitted earlier and discovered in the branches of the delta in the 1980s (Hydroecology 1993; Biodiversity 1999): *Cystobranchus fasciatus* Kollar, *Pontogammarus subnudus* (G. Sars) and *Amathillina cristata* Grim.

The final revised list of invertebrate Pontic-Caspian macrofauna for the lower reach of the Danube comprises 94 species (Table 1). According to Mordukhai-Boltovskoi (1960), 66 species inhabited this region. Polischuk (1974) has extended the list by including the species of Bivalvia, Gastropoda and Oligochaeta. Further revisions (Polischuk & Shepa 1994, Kharchenko 2004) were insignificant.

Table 1. *The species list of relict invertebrate Pontic-Caspian macrofauna in the lower reach of the Danube and in the delta front of the Kyliya branch in different periods of study.*

NN	Taxa	The Lower Danube (summary data)*				Dynamic of species richness within the fore delta of the Kilia arm**				
		1960	1974	1994	2004	1948-1950	1963-1969	1972-1977	1987-1998	2003–2009
1	2	3	4	5	6	7	8	9	10	11
	Hydrozoa									
1.	Cordylophora caspia (Pallas)	+	+	+	+		+		+	+
2.	Polypedium hydriforme Uss.	+	+	+	+					
3.	Moerisia maeotica (Ostr.)	+	+	+	+		+			
	Polychaeta									
4.	Hypania invalida (Grube)	+	+	+	+	+	+	+	+	+
5.	Hypaniola kowalewskii (Grimm)	+	+	+	+	+	+	+	+	+
	Oligochaeta									
6.	Paranais simplex Hrabe		+	+	+	+				+
7.	Paranais frici Hrabe		+	+	+	+		+		
8.	Potamothrix bavaricus Stephenson		+	+	+	+		+		
9.	Potamothrix vejdovskyi (Vejdovsky)		+	+	+	+		+		
10.	Potamothrix caspicus Lastockin			+	+					
11.	Potamothrix mrazeki (Mrazek)		+	+	+	+		+		
12.	Potamothrix danubialis (Mrazek)		+	+	+	+		+		
	Hirudinea									
13.	Caspiobdella fadejewi (Epstein)		+	+	+				+	+
14.	Archaeobdella esmonti Gr.				+					+
15.	Cystobranchus fasciatus Kollar.								+	
	Bivalvia									
16.	Dreissena polymorpha (Pallas)	+	+	+	+	+	+	+	+	+
17.	Dreissena bugensis Andr.		+				+			+
18.	Hypanis caspia grossui Scarlat et Starob.		+	+	+			+		
19.	Hypanis pontica (Eichw)	+	+	+	+	+		+	+	

*1960 – (Mordukhai-Boltovskoi, 1960), 1974 – (Polischuk, 1974), 1994 – (Polischuk, 1994), 2004 – (Kharchenko, 2004);
**1948-1950 – (Markovskyi, 1955; Phinogenova, 1970), 1963-69 – (Polischuk, 1974), 1972-1977 – (Moroz, 1993), 1987-1998 – (Hydroecology…, 1993; Biodiversity…, 1999; own data), 2003-2009 – own data.

20.	Hypanis anguisticosta (Borcea)		+	+	+			+		
21.	Hypanis yalpugensis (Borcea)		+	+	+			+		
22.	Hypanis colorata (Eichw.)		+	+	+		+	+	+	
23.	Hypanis luciae (Borcea)		+	+	+					
24.	Hypanis laeviscula fragilis (Milachavitch)	+	+	+	+	+			+	+
25.	Hypanis plicata relicta (Milachavitch)	+	+	+	+					
26.	Hypanis dolosmiana (Borcea)		+	+	+					
	Gastropoda									
27.	Theodoxus pallasi Lidh.	+	+	+	+		+			
28.	Caspiohydrobia eishcwaldiana (Golic. et Starob.)		+	+	+					
29.	Caspiohydrobia convexa (Golic. et Starob.)		+	+	+		+	+		
30.	Turricaspia triton (Eichw.)		+	+	+					
31.	Turricaspia ismailensis (Golic. et Starob.) [***]		+	+	+	+				
32.	Turricaspia lindcholmiana (Golic. et Starob.)[***]		+	+	+	+		+		
33.	Turricaspia caspia lincta (Milachevitch)[***]	+	+	+	+	+				
34.	Turricaspia ostroumovi (Golic. et Starob)[***]		+	+	+	+		+		
35.	Caspia logvinenkoi (Golic. et Starob.)			+	+					
36.	Caspia macarovi (Golic. et Starob.)		+	+	+			+		
	Isopoda									
37.	Jaera sarsi (Volkanov)	+	+	+	+	+		+	+	+
1	2	3	4	5	6	7	8	9	10	11
	Corophiidae									
38.	Corophium curvispinum Sars	+	+	+	+	+	+	+	+	+
39.	Corophium robustum Sars	+	+	+	+	+			+	+
40.	Corophium nobile (G.O. Sars)	+	+	+	+		+	+	+	+
41.	Corophium chelicorne Sars	+		+	+	+				+
42.	Corophium sowinskyi Martynov	+	+	+	+					+
43.	Corophium maeoticum Sow.	+	+	+	+	+		+	+	
44.	Corophium mucronatum G.O.Sars				+				+	
	Gammaridae									
45.	Amathillina cristata Grim.						+	+		
46.	Cargiophilus baeri G.Sars	+	+	+	+	+				
47.	Chaetogammarus bechningi (Bechningi)	+	+	+	+	+				+
48.	Chaetogammarus ischnus (Stebbing)	+	+	+	+		+	+	+	+
49.	Chaetogammarus warpachowskyi (Sars)	+	+	+		+		+	+	+
50.	Chaetogammarus placidus (Gr.)	+	+	+	+	+	+	+		
51.	Gmelina costata Sars, 1894	+	+	+	+	+	+	+	+	+

[***] p. Micromelania.

52.	Gmelina pussila Sars	+	+	+	+	+	+	+		+
53.	Niphargoides compactus G.O.Sars.	+	+	+	+					
54.	Niphargoides corpulentus G.O.Sars.	+	+	+	+	+		+		+
55.	Niphargoides spinicaudatus Car.	+	+	+	+	+	+	+		+
56.	Niphargoides motasi Car.	+	+	+	+	+				
57.	Niphargoides borodini intermedius (G.O. Sars)	+	+	+	+	+	+	+		
58.	Iphiginella shablensis Car.	+	+	+	+	+		+		
59.	Iphiginella andrussowi Car.	+	+	+	+	+		+	+	
60.	Iphiginella acanthopoda Gr.	+	+		+				+	
61.	Dikerogammarus haemobaphes (Ehrenberg)	+	+	+	+	+	+	+	+	+
62.	Dikerogammarus villosus (Sowinsky)	+	+	+	+	+	+	+	+	+
63.	Pontogammarus crassus (Sars)	+	+	+	+	+	+	+	+	+
64.	Pontogammarus robustoides (Sars)	+	+	+	+	+	+	+	+	+
65.	Pontogammarus sarsi (Sowinskyi)	+	+	+	+	+	+	+	+	+
66.	Pontogammarus obesus (G.O. Sars)	+	+	+	+	+	+	+	+	+
67.	Pontogammarus maeoticus (Sowinskyi)	+	+	+	+	+	+	+	+	+
68.	Pontogammarus subnudus (G. Sars)								+	
69.	Pontogammarus weidemanni (G.O. Sars)	+	+	+	+	+	+	+		
70.	Pontogammarus abbreviatus (G.O. Sars)	+	+	+	+	+		+		
71.	Stenogammarus macrurus (G.O. Sars)	+	+	+	+	+		+		+
72.	Stenogammarus compresus (G.O. Sars)	+	+	+	+	+		+		+
73.	Stenogammarus carausui (Derzhavin et Pjat.)	+	+	+	+			+		+
74.	Stenogammarus similis (G.O. Sars)	+	+	+	+	+	+	+		+
75.	Stenogammarus deminutus (Stebbig)	+	+	+	+	+		+	+	
	Mysidacea									
76.	Hemimysis serrata Bac.	+	+	+	+					
77.	Hemimysis anomala G.O.Sars	+	+	+	+			+		
78.	Limnomysis benedeni Czerniavsky	+	+	+	+	+	+	+	+	+
79.	Katamysis warpachowskyi G.O.Sars	+	+	+	+		+	+		
80.	Paramysis ulskyi (Czerniavskyi)	+	+	+	+	+		+		
81.	Paramysis intermedia (Czerniavskyi)	+	+	+	+	+	+	+		+
82.	Paramysis baeri bispinosa Martynov	+	+	+	+	+		+	+	+
83.	Paramysis kessleri sarsi (Derjavin)	+	+	+	+	+		+		
84.	Paramysis lacustris (Czerniavskyi)	+	+	+	+	+	+	+	+	+
	Cumacea									
85.	Schizorhynchus eudorelloides (G.O.Sars)	+	+	+	+	+	+	+	+	
86.	Schizorhynchus scabriusculus (G.O.Sars)	+	+	+	+	+	+	+	+	+
87.	Pterocuma rostrata G.O.Sars	+	+	+	+	+		+	+	+

88.	Pterocuma pectinata Sowiskyi	+	+	+	+	+	+	+	+	+
89.	Caspiocuma campilastoides (G.O.Sars)	+	+	+	+		+			
90.	Pseudocuma cercaroides G.O.Sars	+	+	+	+	+		+	+	
1	2	3	4	5	6	7	8	9	10	11
91.	Pseudocuma laevis G.O.Sars	+	+	+	+		+	+		
92.	Pseudocuma graciloides G.O.Sars	+	+	+	+	+	+	+	+	+
93.	Pseudocuma tenuicauda G.O.Sars	+	+	+	+	+		+		
Decapoda										
94.	Astacus leptodactilus (Echsholtz)	+	+	+	+	+	+	+		+
In total		66	88	87	89	59	38	63	38	42

Taking into account the revised list of the species, we have analyzed the literature data on the species composition of invertebrate Pontic-Caspian macrofauna in the delta front of the Kyliya branch since 1948 until the present (Table 1). The fauna under study was most abundant in the 1948-1950 and 1972-1977 (59 and 63 species, respectively).

The analysis of the dynamics of the particular groups of invertebrate Pontic-Caspian macrofauna in the delta front of the Kyliya branch of the Danube (Table 1) has demonstrated the absence of several taxons according to the findings of recent research. For example, only one of seven species of Oligochaeta, namely *Paranais simplex* was found in the samples of recent years. Until 1972, several species of Gastropoda were identified in the samples of invertebrate Pontic-Caspian macrofauna (*Theodoxus pallasi*, *Caspiohydrobia convexa, Turricaspia lindcholmiana*, *T. ostroumovi*, *Caspia macarovi*). Meanwhile, more recent summaries of the Pontic-Caspian invertebrate fauna do not mention such species. It should be noted that the shells of *Turricaspia* genus representing the typical psammophilous species are highly susceptible to the organic contamination of the water preferring oligo-β-mesosaprobic waters (Moroz 1993).

The Pontic-Caspian Bivalvia fauna has also changed substantially. Three species of Hypanis genus (*H. caspia grossui*, *H. anguisticosta* and *H. yalpugensis*) have been lacking in the waters of the delta front of the Kyliya branch since 1972, *H. pontica* and *H. colorata* – since 1992. *Dreissena bugensis*, recorded by Polischuk (1974) had not been mentioned in faunistic summaries until 2004 when it has been found in the Romanian part of the Delta (Micu & Telembici 2004). Since 2008, this species is found systematically in the delta front of the Kyliya branch (Lyashenko et al. 2009).

Gammaridae are quite abundant, while only 8 of 31 species, namely *Gmelina costata, Dikerogammarus haemobaphes*, *D. villosus*, *Pontogammarus crassus*, *P. robustoides*, *P. sarsi*, *P. obesus*, *P. maeoticus* are encountered consistently for the last 50 years. Since 1948, *Cargiophilus baeri* and *Niphargoides motasi* have not been reported in the delta front of the Kyliya branch. Only in the period of 1987-1992, *Iphiginella acanthopoda* and *Pontogammarus subnudus* were found.

The maximal number of Misidacea species (7) was recorded in the delta front of the Kyliya branch in the period of 1972-1977. In our studies, only four species were found in the period of 2003-2009, with two species *Limnomysis benedeni* and *Paramysis lacustris* being encountered over the whole study period. Among Cumacea, four species *Schizorhynchus scabriusculus*, *Pterocuma rostrata*, *P. pectinata* and *Pseudocuma graciloides* were sampled consistently over the whole study period. *Pseudocuma laevis* and *P. tenuicauda* have not been found since the beginning of in the period of 1972-1977. *Caspiocuma campilastoides* has not been sampled since 1969.

The comparison of the taxonomic composition of Pontic-Caspian fauna in the waters of the delta front of the Kyliya branch (Table 2) has demonstrated the similarity of the overall species richness in the different study periods. Nevertheless, at present the number of Gammaridae, Misidacea and Cumacea species in the branches has been reduced. The reduction of the Crustacea species is much more pronounced in the waters of the Delta (from 6 to 1 species for Misidacea and from 7 to 3 species for Cumacea. Meanwhile, the overall number of Gammaridae species has been increased.

Table 2. *Taxonomic composition of invertebrate Pontic-Caspian macrofauna complex in different aquatic systems in the delta front of the Kyliya branch in the various study periods.*

Water bodies type	Period of investigation	Polychaeta	Hirudinea	Bivalvia	Isopoda	Corophiidae	Gammaridae	Mysidacea	Cumacea	Decapoda	In total
Water courses	1948-1950 (Markovskyi 1955)	2	–	3	1	4	24	6	4	1	45
	2003-2009	2	2	3	1	5	18	4	3	1	39
Water reservoirs	1948-1950 (Markovskyi 1955)	1	–	–	–	2	12	6	7	1	29
	2003-2009	2	1	2	1	4	14	1	3	–	28

4 Conclusions

The revised species list of invertebrate Pontic-Caspian macrofauna complex in the lower reach of the Danube comprises 94 species. This list is rather exhaustive with 28 species being added to the first list given in Mordukhai-Boltovskoi (1960). Meanwhile, the findings of more than 60 years of systematic observations in the delta front of the Kyliya branch of the Danube are indicative of the serious changes in the patterns of invertebrate Pontic-Caspian macrofauna. At present, no species representing the entire Gastropoda class are found; several species of Cumacea, Misidacea and Bivalvia have not been sampled for several decades. The populations susceptible to anthropogenic impacts are reduced. The exploitation of the Delta and its resources as well as the increasing eutrophication of the water and increasing content of the toxic pollutants, especially within the 80s of previous centaury (Romanenko et al., 2008) affected negatively the richness of the invertebrate macrofauna. Nevertheless, one should not consider such losses as irreversible. The Delta served as the refuge of species for thousands of years. At present, the diversity of the landscape and terrestric-aquatic habitats of the Delta provides a good environment to preserve the resident populations. However, the increase of species richness and frequency of occurrence depend largely on human activities. To sum up, the invertebrate Pontic-Caspian macrofauna complex in the lower reach of the Danube is still an abundant faunistic complex.

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The actual state and fish capacity of Sasyk reservoir (the comparison 1986-1987 and 2008-2009)

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Keywords: Sasyk reservoir, ecological state, fish capacity.

1 Introduction

Until the end of the 1970s, the salty Sasyk estuary in the Black Sea was one of the most productive reservoirs in the Ukrainian Danube region (Bragynskyi, 1990; Mironov, 1990). According to projects on the large-scale diversion of Danube water to the Dnieper, a dam was erected separating the Sasyk estuary from the sea, and a canal was dug to fill the Sasyk reservoir with Danube water. From the 1980s, the Sasyk reservoir was used for water management purposes, initially, for irrigation. However, due to faulty design, the planned water quality parameters have never been attained. With the collapse of the Soviet Union, the pumping stations stopped working, irrigation was terminated, and the quality of water deteriorated. During 1983-1987, the fish capacity of the reservoir was rather high (about 100 kg per hectare) (Bragynskyi, 1990), but, bioproductivity has been reduced because of the lack of scientific management of the fishery and fish stocking programs. Recently, the public organizations as well as the scientific community addressed the matter of restoring the original state of the reservoir, namely connecting it with the sea to increase salinity.

The aim of the research was to characterize the up-to-date state of Sasyk reservoir and to document changes from the 1980s. The patterns of macrozoobenthos and the trophic relations were taken into account.

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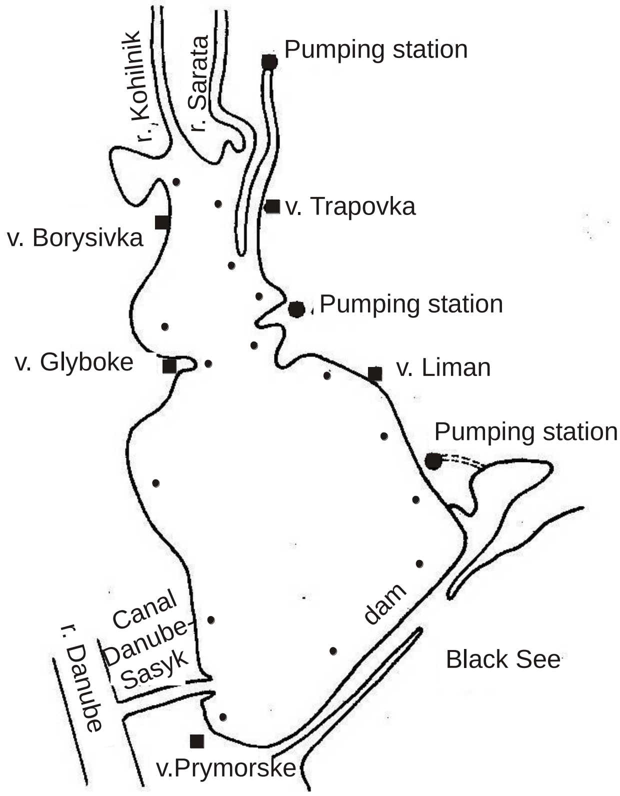

Figure 1. *Scheme of Sasyk reservoir (• - sample stations)*

2 Materials and methods

The samples were taken in 2008-2009 using the traditional network of stations (Braginskyi, 1990, Fig. 1). Several hydrochemical parameters were measured such as pH, oxygen content, and salinity according to standard methods (Romanenko, 2006). Water quality was assessed by macrozoobenthos indicator species by using the indices of Pantle & Buck (1955) and Woodiwiss (1964). The production of dominant macrozoobenthos groups was assessed for the vegetation period 2009 using the physiologic method (Alimov, 1989). The potential fish capacity was calculated from macrozoobenthos production using the corresponding coefficients (Polischuk & Bortkevich, 2006).

3 Results and discussion

Sasyk reservoir was and still is characterized by high alkalinity, reflected by maximum pH values (Table 1). By flushing with freshwater the salt concentration was decreased to the range of oligohaline – beta-mesohaline waters. The reduced salinity (0.7–1.6 mg/l) was confirmed by Smirnov & Tkachenko (2007). The oxygen patterns were rather variable, indicating periods of depletion and oversaturation.

We have recorded 64 species of macrozoobenthos. The insects were characterized by the largest species richness with Chironomidae larvae being represented by 20 species; further, we found 3 species of Odonata, 2 species of Ephemeroptera and 1 species each of Trichoptera and Chaoboridae. Among Annelida, Oligochaeta were represented by 11 species, Polychaeta by 2 species. Among Crustacea, the largest species richness was found in Gammaridae (9 species); we also found 3 species of Corophiidae 2 species of Cumacea and 1 species each of Misidacea and Decapoda. Mollusca, Gastropoda and Bivalvia were represented by three species each. One species each of Nematoda and Hydrozoa was also registered. Except of Gammaridae, in all major macrozoobenthos groups the species richness decreased slightly during the last 20 years. As a result, the total species number decreased 1.5-fold (Table 1).

Table 1. *Patterns of macrozoobenthos and productivity of Sasyk reservoir.*

Characteristics	1986-1987[a]	2008-2009
Hydrochemistry characteristics		
pH	7.8-9.2	7.8-9.0
O_2, mg/l	7.0-15.4	6.6-13.5
Salinity, mg/l	0.7-2.5	0.7-1.6
Species richness		
Chironomidae	28	20
Oligochaeta	15	11
Cumacea	5	2
Gammaridae	7	9
Corophiidae	3	3
Total[d]	99	65
Ponto-Caspian fauna	27	19
Intruders	1	3
Biotic indices		
Shannon index, bit/ind	-	1.87−2.23
Saprobity index P&B	2.30-3.60[b]	1.90–3.48
Woodiwiss index	-	4-5
Catches fishes, t (%)[c]		
Benthos feeders	486.52 (66%)	357.83 (91%)
Plankton feeders	16.96 (2%)	20.20 (5%)
Predators	231.20 (31%)	6.06 (1%)
Others	8.56 (1%)	10.57 (3%)
Total	744.34 (100%)	395.47 (100%)

Characteristics	1986-1987[a]	2008-2009
Abundance, thousand ind/m^2		
Chironomidae	1.05-7.77	0.96-3.60
Oligochaeta	11.28-23.20	4.63-11.62
Cumacea		0.07-5.39
Gammaridae	2.27-6.03	0.21-0.35
Corophiidae		0.001-15.38
Total[4]	22.01-35.81	6.44−19.44
Biomass, g/m^2		
Chironomidae	28.30-31.90	1.25-1.72
Oligochaeta	13.30-31.60	2.78-11.80
Cumacea		0.001-14.26
Gammaridae	2.10-4.10	1.29-5.20
Corophiidae		0.001-0.03
Total[d]	174.20-210.26	13.98−113.94
Production, kJ/m^2 of the vegetation season		
Chironomidae	846.03	43.50
Oligochaeta	167.91	82.78
Dreissenidae	179.37	60.97
Cumacea		124.60
Gammaridae	44.39	27.74
Corophiidae		0.25
Total production	1237.70	339.84
Fish capacity, kJ/m^2 (kg/ha)	61.86 (148.02)	30.94 (74.01)

Note: [a] – by Bragynskyi (1990), [b] – by Lyashenko & Metelezkaja (1997), [c] – by Smirnov & Tkachenko (2007), [d] – including smaller macrozoobenthos groups not given in the table.

19 macrozoobenthos species belong to the relict Ponto-Caspian fauna (14 species of Crustacea, 3 species of Bivalvia, and 2 species of Polychaeta). Such species native to the Danube Delta may indicate whether the natural ecosystems are unimpaired (Mordukhai-Boltovskoi, 1978). Earlier, the Ponto-Caspian species in the benthos of Sasyk reservoir were more abundant (27 species, (Bragynskyi, 1990)). The following species have not been found in our recent samples: Hirudinea – *Caspiobdella fadejewi* (Epstein), Bivalvia – *Hypanis pontica* (Eichw), *H. yalpugensis* (Borcea), *H. laeviscula fragilis* (Milachavitch), Crustacea – *Pseudocuma graciloides* G.O.Sars, *P. cercaroides* G.O.Sars, *Schizorhynchus eudorelloides* (G.O.Sars), *Paramysis baeri bispinosa* Martynov, *P. kessleri sarsi* (Derjavin) and *P. lacustris* (Czerniavskyi).

The ability to resist the invasion of new species is one of the parameters characterizing the state of the ecosystems (Alimov & Bogutzkaia, 2004). Shortly after filling the reservoir with fresh water, *Rhithropanopeus harrisii tridentata* Maitland, which inhabited the Sasyk estuary before, was recorded as invasive species (Yenaki et al., 1973). In 2008/9, we have found two more invasive species. The North American Hydrozoa *Bougainvillia megas* Kinne, which intruded the Black Sea in 1932 (Paspalev, 1933), was present in various regions of Sasyk reservoir in benthos, in biofouling, and in the weed bed. Bivalvia *Dreissena bugensis* Andr., which has not inhabited the Delta until the beginning of the 21st century (Lyashenko et al., 2009; Micu & Telembici, 2004), recently became the abundant representative of macrozoobenthos in Sasyk reservoir.

The inter-seasonal variations of Shannon species diversity index (MacArthur, 1955) in macrozoobenthos were insignificant. Saprobity changed within β–α-mesosaprobic state, slightly decreasing from the 1980s. The maximum values of Woodiwiss index in recent times did not exceed 4–5 points corresponding to «poor» – «moderately polluted» grades (Afanasiev & Grodzinskyi, 2004).

The abundance and biomass of invertebrates changed significantly from 1986/7 to 2008/9 (Fig. 2). Oligochaeta showed maximum abundance (64%), while Bivalvia contributed maximum biomass (71%; predominantly *Dreissena*). The structure of macrozoobenthos changed significantly from the 1980s. The abundance and biomass of Oligochaeta and Chironomidae larvae decreased (15-fold for Chironomidae biomass). The amount of predatory Chironomidae diminished from 60% to <5%. However, the abundance and the biomass of Gammaridae, especially Cumacea, have increased substantially. Mollusca remain the dominant group with regard to biomass (Fig.2).

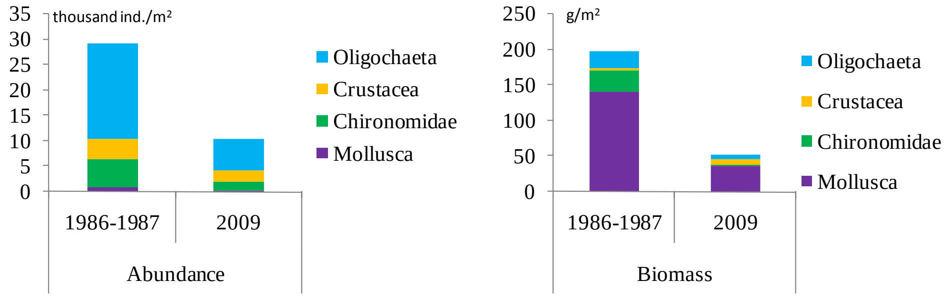

Figure 2. *Macrozoobenthos patters of Sasyk reservoir: abundance and biomass of main groups of invertebrate*

Macrozoobenthos production in the vegetation period of 2009 amounted to 339.84 kJ/m^2 (3.7 times less than in the 1980s, Table 1). The largest contribution to the overall production is recorded for Cumacea (Cructacea). The production of Oligochaeta and Dreissenidae is also high. Nevertheless, earlier Chironomidae larvae contributed most of all in terms of the production. Now the contribution of Chironomidae larvae has been reduced from 68% to 13% (Fig. 3). In contrast, the proportion of Crustacea has increased from 4% to 45%.

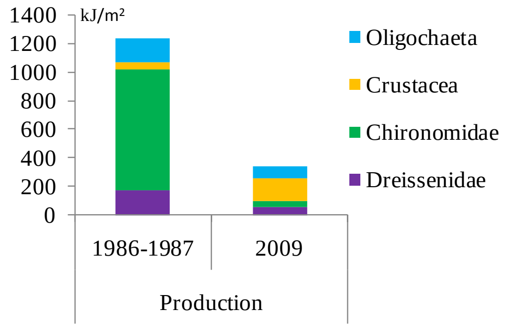

Figure 3. *Production of dominant groups of macrozoobenthos in various periods*

The fish capacity calculated according to macrozoo-benthos production in 1986–1987 amounted to 61.68 kJ/m^2 or 148.02 kg/ha (Bragynskyi, 1990) which is twice as much as nowadays (30.94 kJ/m^2 or 74.01 kg/ha, respectively). In fact, the official fish yields were substantially less: 25.5 kg/ha in 1981–1985 (Smirnov & Tkachenko 2007) and 43.9 kg/ha in 1986–1987 (Braginskyi, 1990). In the first half of the 1990s, the value decreased further to 22.5 kg/ha. The minimum fish catches were recorded late in the 1990s, namely, 17.9 kg/ha, with slight increase in the following years to 19.8 kg/ha (Smirnov & Tkachenko, 2007). Benthophagous fish have increased from 66% in 1986–1990 to 91% in 2000–2001 (Smirnov & Tkachenko, 2007). Earlier, the bream *Abramis brama* Linnaeus (36%) (benthos feeder), the pike-perch *Sander lucioperca* Linnaeus (24%) (predator), and the carp *Cyprinus carpio carpio* Linnaeus (benthos feeder) (20%) dominated in the catch. Now, the crucian carp *Carassius auratus gibelio* Bloch (benthos feeder), is the dominant species (80%). The overall fish catch now has been reduced 1.88-fold as compared to the mid 1980s. While the relative contribution of benthophages increased the catch decreased 1.36-fold (Table 1).

4 Conclusion

The study has demonstrated certain shifts in the Sasyk reservoir ecosystem. The water salinity has been stabilized, pH and oxygenation state have remained the same, and the saprobity has slightly improved. At the same time, the patterns of macrozoobenthos have changed significantly. Within the first ten years after water diversion, Sasyk reservoir was at the "chironomidae" high-productive stage because with Danube’s freshwater were provided additional energy (Bragynskyi, 1990; Kharchenko, 1991, 1998). Later on, when the pumping stations stopped working, species richness and productivity diminished substantially with the changes in the dominating species. Macroozoobenthos now is dominated by Crustacea. The top-down control of predator fish has decreased sharply, with the crucian carp (benthos feeder) being the dominant species now. Overall, we observed the transition from a high-productive pulse-stabilized mode (Bragynskyi, 1990; Kharchenko, 1991, 1998) to a more stable but less productive lake-type reservoir. In principle, there are several ways for increasing productivity, including the reversion to the initial succession stage of the salty estuary. Or else, the connection with the Danube should be restored by resuming the operation of the pumping stations. In any way, such water managment measures will require a lot of money. If no measures are taken, the natural succession from aquatic to terrestrial ecosystems including rampant weeds and marsh formation will continue.

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Bioindication and biotesting of water and sediments of water bodies of the Danube biosphere reserve

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Keywords: Danube, bioindication, biotesting

1 Introduction

Large amounts of toxic substances penetrate into the lower part of the river (Sheliah-Sosonko 1999; Aleksandrov 2001) demanding the continuous ecological monitoring of the Danube delta, especially in the area of the Danube biosphere reserve. Taking into account that sediments are the main sink of contaminants and can be a source of secondary pollution in aquatic ecosystems, the development of methods for rapid and cost-effective screening of bottom fauna status and sediment toxicity are urgently needed.

The tasks of the current study included: 1) characterization of benthic invertebrates of the Danube Delta and bioindication of the state of water bodies; 2) investigation of toxicity of the Danube Delta water and sediments (biotests); 3) comparison of bioindication and biotesting data.

2 Materials and methods

In June 2007 water and sediment samples were taken 3 m from the river bank at five monitoring stations in the Kilia part of the Danube Delta (see Figure 1): station 1 – the origin of Ochakivskiy arm, 17 km from the Black Sea (gray clayey silt, depth 0.8 m); station 2 – the end of Ochakivskiy arm, 6 km from the Black Sea (silty sand; depth 1.5 m); station 3 – the origin of Bistriy arm, 10 km from the Black Sea (gray clayey silt, depth 1.0 m); station 4 – the end of Bistriy arm, Danube outflow (sand, depth 0.5 m); station 5 – the origin of Vostochniy arm, 8 km from the Black Sea (gray clayey silt, depth 2.0 m). For sampling the sediments, a bottom-grab was used with the working surface of 100 cm^2. The samples were collected in triplicate.

Taxonomic diversity and abundance of benthic invertebrates were used for calculating biotic indices (Goodnight-Whitley, Mayer and Woodiwiss: Goodnight 1961; Woodiwiss 1977; Afanasiev 2004; Arsan et al. 2006).

Water samples were passed through a plankton net (mesh-size 320 μm) for separating small aquatic organisms. Water and sediment samples used for biotests were transported to the laboratory of the Institute of Hydrobiology in a portable refrigerated chamber (+4ºC).

For investigation of sediments toxicity water elutriates were prepared (Scherban' 1994). The procedure included 1-hour shaking of sediments with water (1:4 by mass), settling of suspended particles and further use of supernatant. The samples of water and elutriates of sediments were used for toxicity tests with water flea *Daphnia magna* and onion *Allium cepa* with end-points survival (48, 96 h) and root growth inhibition (120 h), respectively (Fiskesjo 1985; ISO 6341:1996).

We used a multimetric biological assessment system comparable to that developed by AQEM (Hering et al. 2004). To compare data on bioindication and toxicity we unified multi-metric indices and used 5-classes categorization, which was recommended by the European Water Framework Directive. It should be noted that only the way of presenting the results is in line with WFD, because this approach is not widely elaborated in Ukraine. Classes of categorization are known only for biomass and abundance indices (Oksiiuk et al. 1994), and for toxicity of waste waters. Therefore we based as well on our

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experience and recommendations of our colleagues (Romanenko et al. 2008). The five classes are presented in Table 1.

Table 1. *The scale for unification of bioindication and toxicity data and assessment of the ecological state of water body.*

State / Average mark	**High** **1.0–1.5**	**Good** **1.5–2.5**	**Moderate** **2.5–3.5**	**Poor** **3.5–4.5**	**Bad** **4.5–5.0**
Survival (96 h), %	>90	90–80	80–67	67–50	<50
Growth inhibition or stimulation, %	<10	10–25	25–50	50–75	>75
Total abundance, ind/m^2	<500	600–2100	2100–10000	10100–40000	>40000
Total biomass, g/m^2	<5.0	5.1–50.0	50.1–300	300.1–1000	>3000
Woodiwiss index	10–9	8–7	6–5	4–3	2–1
Mayer index	>22	21–17	16–11	10–5	<5
Goodnight–Whitley index	1–45	46–70	71–80	81–90	91–100

2.1 Characterization of macrofauna

In total 24 taxa of benthic invertebrates were recorded (Table 2).

Table 2. *Taxonomic composition and the abundance of bottom invertebrates.*

№	Groups of bottom invertebrates	Abundance, ind/m^2				
		Station 1	Station 2	Station 3	Station 4	Station 5
1	***Oligochaeta***	**1400**	**4900**	**2400**	**6300**	**2100**
	Limnodrilus sp.	800	2800	1300	3200	
	Limnodrilus hoffmeisteri (Claparede)	100	300	400		
	Isochaetides newaensis (Michaelsen)		300		400	300
	Isochaetides michaelseni (Lastockin)	500		300	2700	1400
	Potamothrix moldaviensis (Vejdovsky et Mrazek)		500			400
	Tubifex tubifex (O. F. Muller)		800	400		
	Branchiura sowerbyi (Beddard)		200			
2	***Corophiidae***					**600**
	Corophium curvispinum (Sars)					500
	Corophium robustum(Sars)					100
3	***Gammaridae***			**100**	**100**	
	Dikerogammarus haemobaphes (Ehrenberg)			100		
	Pontogammarus robustoides (Sars)				100	
4	***Coleoptera***	**100**				

	Hydrophilus flavipes (Steven)	100				
5	***Chironomidae***	**100**	**400**		**600**	**200**
	Cricotopus silvestris (Fabricius)	100			500	
	Fleuria lacustris (Kiffer)					200
	Psectrotanypus varius (Fabricius)		200			
	Polypedilum convictum (Walker)		200		100	
6	***Bivalvia:***	**100**		**100**		**100**
	Spheriidae sp.	100				
	Dreissena polymorpha (Pallas)			100		100
7	***Gastropoda:***	**1700**		**600**		**800**
	Fagotia esperi (Ferussae)	300				500
	Bithynia tentaculata (Linne)					200
	Physa fontinalis (Linne)			100		
	Lithogliphus naticoides (Pfeiffer)	1400		200		
	Theodoxux fluviatilis(Linne)			200		100
	Valvata pulhella (Studer)			100		
	Total taxa	**8**	**8**	**10**	**6**	**10**
	Total abundance, ind/m^2	**3400**	**5300**	**3200**	**7000**	**3800**
	Total biomass, g/m^2	**74.35±7.4**	**6.19±0.28**	**101.35±2.8**	**2.30±0.46**	**152.03±7.46**

Obtained values of Mayer and Woodiwiss indices are consistent in general, while the Goodnight-Whitley index deviated (Table 3). The reason for this disagreement may be the following: Goodnight-Whitley index takes into account only *Oligochaeta* that are not very sensitive to pollution, while Mayer and Woodiwiss indices are based on the diversity of indicator taxa. Moreover, some difficulties arose from transferring the original number of quality classes proposed by Goodnight-Whitley and Mayer (3 and 4, respectively) to the 5-class-system recommended by the European Water Framework Directive.

According to average marks determined from biotic characteristics (abundance; biomass; Woodiwiss, Mayer and Goodnight–Whitley indices) the ecological state at stations 1, 4 and 5 could be rated as “moderate” (class 3), while stations 2 and 3 were “poor” (class 4).

Table 3. *The values of biotic indices.*

Place of sampling	Goodnight–Whitley index, %	Woodiwiss index	Mayer index
Station 1	41	3	5
Station 2	92	2	4
Station 3	75	2	3
Station 4	90	4	5
Station 5	55	2	7

2.2 The toxicity assessment of water and sediments

According to the Daphnia test the water was not or weakly toxic (Table 4). High pollution was registered at station 1, where the sediment samples indicated acute toxicity.

Table 4. *Survival of Daphnia magna in water and water elutriates of sediments.*

Sampling stations		Survival, %	
		48 hours	96 hours
1	water	96.7	83.3
	sediments	66.7	45.4
2	water	100.0	93.3
	sediments	93.3	83.3
3	water	90.0	76.7
	sediments	90.0	83.3
4	water	93.3	80.0
	sediments	86.7	66.7
5	water	96.7	93.3
	sediments	93.3	89.7

Table 5. *Allium cepa roots growth inhibition in water and water elutriates of sediments.*

Sampling stations		Average length of roots, mm	Growth inhibition, %
1	water	47.8±0.2	0.4
	sediments	27.6±0.3	42.5
2	water	47.7±0.5	0.8
	sediments	30.1±0.4	37.4
3	water	32.6±0.2	32.2
	sediments	29.6±0.4	38.3
4	water	32.4±0.3	32.6
	sediments	39.9±0.2	17.0
5	water	40.1±0.5	16.6
	sediments	32.8±0.6	31.8
Control		48.0±0.3	

Sediments from most of the stations (except station 4) demonstrated statistically significant adverse effect to *Allium cepa* (Table 5). The toxicity of sediments is higher than the toxicity of water samples suggesting the accumulation of toxic substances in sediments. However, water in stations 3 and 4 (Bistriy arm) was more toxic than sediments, may be due to dredging.

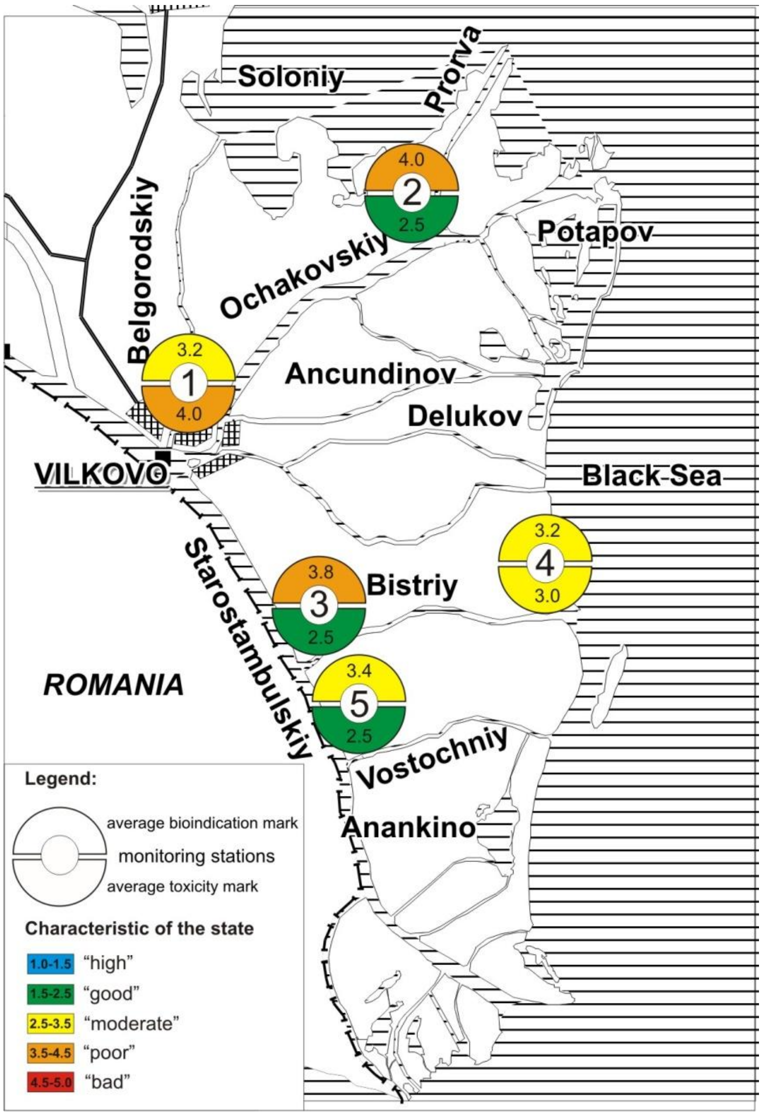

Figure 1. *Mapping of ecological state of investigated water bodies according to bioindication of benthic communities and sediments toxicity testing.*

The toxicity and bioindication data have no close correlation (Figure 1). Possible explanation of this phenomenon is that biotic indices characterize the general ecological state of water bodies that depends on many environmental factors; however, contamination of water bodies by toxic substances is only one of these factors. The poor state of benthic communities at sampling stations 2 and 3 may not be caused by sediment contamination and additional investigations are required.

3 Conclusion

Our data are indicative of moderate state of benthic communities of water bodies of the Danube biosphere reserve. The toxicity data suggest that the sediments of Ochakivskiy arm were most toxic (station 1), most likely caused by anthropogenic impact of Vilkovo city (Kharchenko et al. 1993). Sediments from the Bystriy arm were less toxic; those from Vostochniy arm (station 5) did not show statistically significant adverse effect. As expected, the toxicity of sediments was higher than the toxicity of water samples, and *Allium cepa* was more susceptible than *Daphnia magna*. This could indicate that sediments were contaminated by agricultural chemical substances, but supplementary investigations are required.

In Ukraine there is a need for developing methods allowing for the rapid and cost-effective screening of bottom fauna status and sediment toxicity. Moreover, improvement of the approach for assessment of ecological state is required taking into account peculiarities and individuality of water bodies.

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Flood risk management service in support of the implementation of the EU Flood Directive – First results for test sites in Romania and Bulgaria

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Keywords: Flooding, hydrological modelling, assets mapping, EU flood directive, GMES, SAFER

1 Introduction

Floods are considered worldwide as one of the major natural disasters. Changes occurred in climate patterns and land cover, altered river hydromorphology, loss of adjacent floodplains converted in dry land for agriculture or constructions, urbanization, etc. enhance their destructive potential.

In Europe, a rising number of flood disasters had been noticed in the last years and major flood events occur more frequently (Barredo, 2007). Also, the damages they produce have increased in the last few decades: 155 lives were lost and costs of over 35 billion euro were recorded between 2000 and 2005 (Barredo et al., 2007, quoted in Glaser et al., 2010).

As a consequence of the climatic changes, a major shift of the precipitation level occurred across Europe (IPCC, 2008), increasing up to 10-40 % in the Northern and Central part of Europe and decreasing by 20 % in South Europe; moreover, projections for the future, based on climate change models, indicate increasing frequency of extreme hydrological events, increasing the risk of river floods, flash floods, landslides, groundwater rise and storm drainage overflow (Kundzewicz et al., 2010).

In response to these alarm signals and projections, the European Union (EU) adopted recently the Flood Directive (2007/60/EC), according to which flood-protective measures should be coordinated at river basin scale, considering the solidarity principle (measures taken in one state must not increase the risk of flooding in neighbouring countries); each EU Member State shall prepare flood risk management plans, using the best available techniques and taking into consideration the area specificity. These plans should be based on flood hazard maps designed for three scenarios: low (extreme event), medium (≥ 100 years) and high probability, emphasizing the flood extent, water depths and flow velocity. The flood risk maps should emphasize the potential impact on inhabitants and economic and environmental damages in the affected area.

Within the framework of the European Commission's (EC) and European Space Agency's (ESA) joint initiative "Global Monitoring for Environment and Security" (GMES) several flood related geo-information services have been developed during the past few years. The project "Services and Applications For Emergency Response" (SAFER, www.emergencyresponse.eu) contributes to this initiative by providing rapid, reference and thematic mapping services relevant to an effective support for natural disaster management. In this contribution, the focus is put on thematic services addressing flood risk management and assets mapping.

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2 Materials and methods

The objective of the work performed by the authors within the SAFER project is to focus on the further development of a flood risk management service portfolio which is intended to provide up-to-date flood relevant products for test sites in Romania (Timis river catchment) and Bulgaria (Rousse and Sofia regions) and which can be transferred to other river catchment areas of different geography and topography. The products are derived from Earth Observation data, in-situ and ancillary data. The applied methodologies comprise hydrodynamic modelling, assets mapping (mapping of monetary values) and the application of damage functions. Altogether the portfolio comprises four products offering a solution for an integrated flood risk management approach: Past flood event maps, flood hazard maps, flood risk maps and the online information system www.floodserver.eu.

As there is a high demand for quantitative and qualitative risk maps in Romania and especially in Bulgaria – where no national flood maps are available (Moel et al., 2009) – we will focus here on the production of countrywide assets maps which can serve – in combination with the flood extent maps – as a basis for the generation of flood risk maps on a national level as well.

The workflow of the model applied here can be summarised as follows: In a first step to generate asset maps, socio-economic statistics that describe the valuables / assets are grouped to classes and assigned to one or more thematically fitting land use categories (e.g. household goods assets are assigned to urban areas). In a next step the assets maps serve as input data for the damage modelling. The rate of flood-related damage to a valuable class is determined by a number of factors, the most prominent ones being flooding depth and flow velocity. This hazard layer is calculated using a hydrodynamic 2D-modelling approach and the software FloodArea. The expected damage of each assets class can be shown as a function of each of these factors and reveals the damages in percent of the affected assets. The damage functions are applied separately to each class of assets. In a last step, the potential damages from each asset-class are summed up for each land use category resulting in a potential damage map (quantitative risk map) displaying values in € per m² or km². The work flow diagram for the damage assessment modelling is shown in Figure 1. For more details on the remainder of the flood risk management portfolio we refer to Holzhauer et al. (2009) and Mueller et al. (2009).

It is worth mentioning that the approach outlined here requires the making of several assumptions and neglects. Among them is for example the assumption that the assets value related to livestock splits evenly into two land use classes (here: pasture and rural built-up area). Among the neglects are the non-considerations of currency fluctuations or statements on the derived damage figures in relation to the respective national purchase powers. As to the accuracies and validations of the assets and damage assessment models and maps, there are still only few references and detailed enough on-site data available. Also, the indication of uncertainties in the final products is not yet implemented either but would definitely add further value to the maps. These facts in combination with the approach of assumptions and neglects sketched before demonstrate the need for more research and operational testing in this domain. Both will be subject during the remaining project run-time of SAFER until the end of 2011.

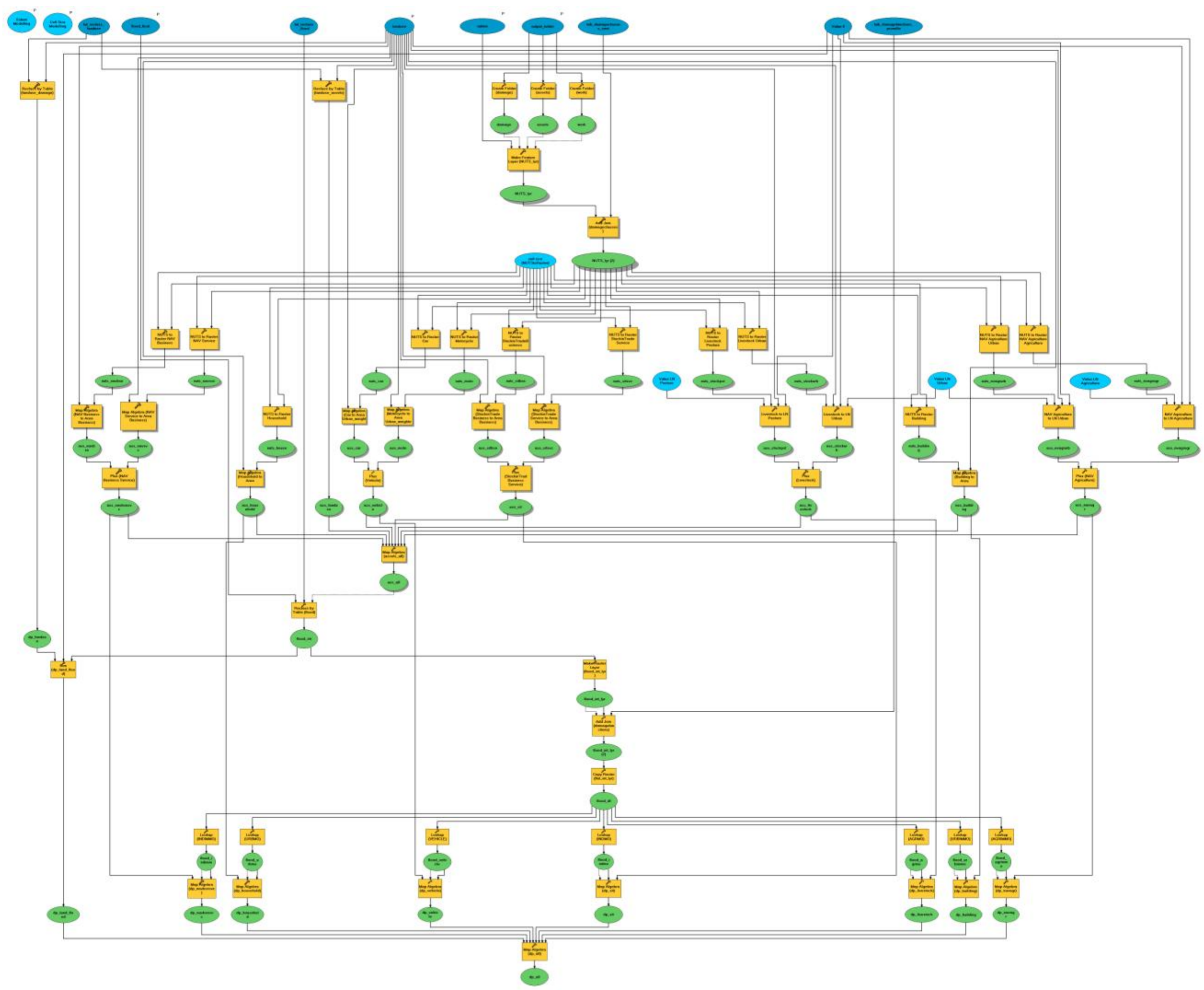

Figure 1. *Work flow diagram of the damage assessment model, implemented as ArcGIS model builder script. Land cover / use data and various (official) socio-economic statistical data in combination with flood inundation information serve as input data for the modelling procedure (Explanation: blue = input files and given constants; yellow = calculation processes; green = output files).*

3 Results and discussion

By providing past flood event maps, flood hazard / risk maps and a flood information system (see www.floodrisk.eu) the service portfolio contributes to the implementation of the EU Flood Directive (2007):

Article 4

2. (...) The assessment shall include at least the following:

(b) a description of the ***floods which have occurred in the past*** *and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent and conveyance routes and an assessment of the adverse impacts they have entailed;*

(c) a description of the ***significant floods which have occurred in the past****, where significant adverse consequences of similar future events might be envisaged;*

Article 6

*1. Member States shall, at the level of the river basin district, or unit of management referred to in Article 3(2)(b), prepare **flood hazard maps and flood risk maps**, at the most appropriate scale for the areas identified under Article 5(1).*

Article 10

*1. In accordance with applicable Community legislation, Member States **shall make available to the public** the preliminary flood risk assessment, the flood hazard maps, the flood risk maps and the flood risk management plans.*

The substantial benefit of this service portfolio results from the combination of Earth observation data with regional/local data and enhanced modelling techniques. The former enables a European-wide harmonised and cross-border approach, the latter contributes to the provision of custom-tailored solutions considering also e.g., specific geographical/hydrological circumstances of the river basin.

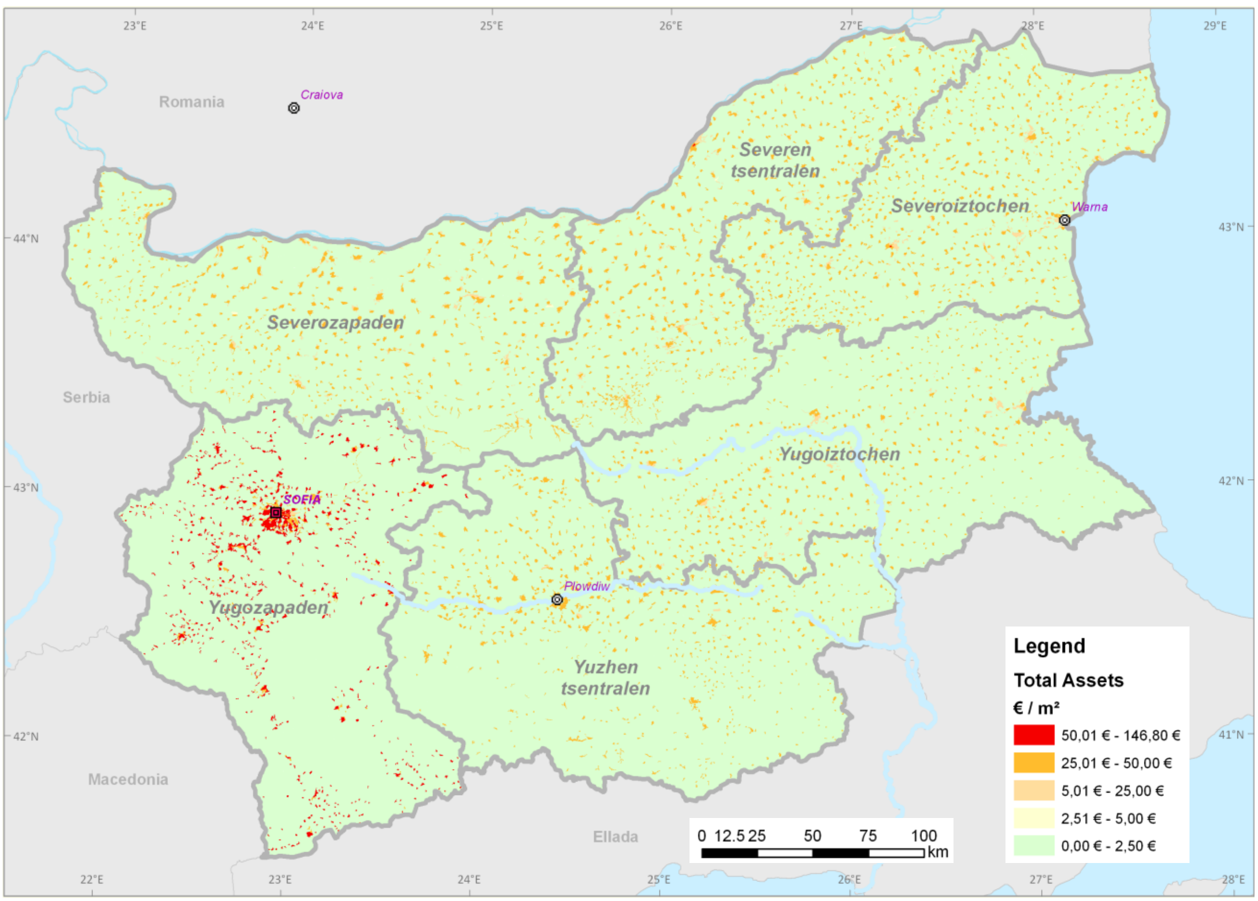

***Figure 2.** Basic European Assets Map (BEAM) for Bulgaria.*

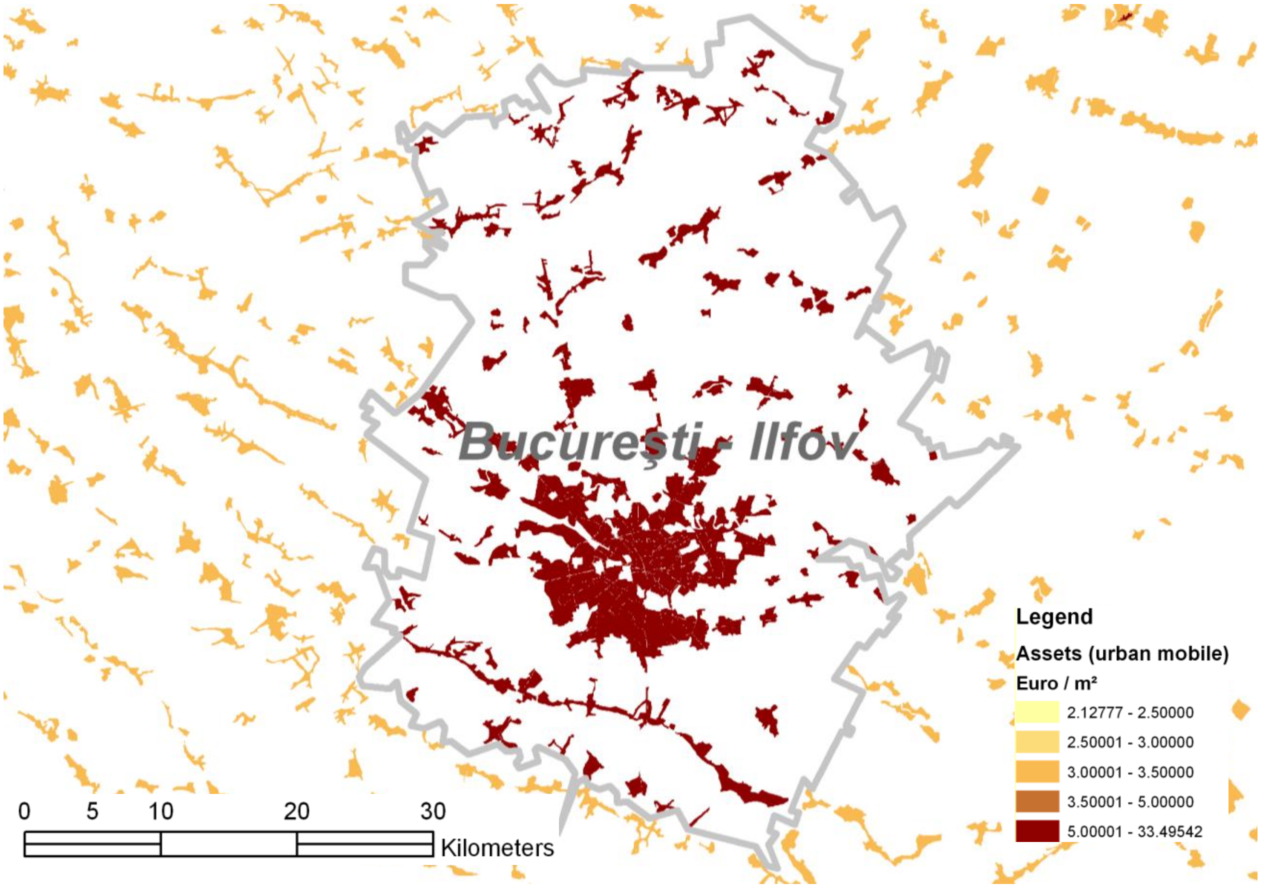

Figure 3. *Basic European Assets Map (BEAM) for Romania: Map section Bucharest region – displaying the assets class "household".*

Main results of the first project year (2009) are the data collection, preparation and production of the Basic European Assets Map (BEAM) for the complete territories of Romania and Bulgaria. Figure 2 shows the BEAM product for Bulgaria, figure 3 gives a detail from Romania (Bucharest). This is also an example for a single class representation (here: household goods). The bottom line of the methodology developed here is that BEAM can relatively easy be transferred to other European countries. The data sets used here as inputs are European-wide available land cover data sets and socio-economical statistics obtained from the European Commissions statistics database.

4 Outlook

Within the project's run-time the further development of BEAM to a sort of European core service is currently ongoing - including the production for additional selected countries in Europe. Furthermore, the diversification of the service portfolio will be advanced, i.e. generating assets map products of higher level of details for regions (but less transferable, in terms of GMES so called downstream services). The same applies to the service portfolio for the flood products, i.e. following a double tracked approach - comprising both core and downstream products as elements of an integrated solution for an effective flood risk management. From this it follows that the service presented here offers a suited portfolio to contribute to the implementation of the EU Flood directive and is thus of special relevance to the persons responsible – in order to take the right actions in policy, water management and civil protection.

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Sediment Management in the Elbe from the Perspective of the Port of Hamburg

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Keywords: Elbe, sediments, navigation, maintenance dredging, River Basin Sediment Management

1 Introduction

Continuous maintenance dredging is necessary in the Port of Hamburg to safeguard water depths for navigation. Since the 1990s the annual amount of dredged sediments has increased from about 2 million to about 6 million cubic meters today. The challenges for sediment management are manifold. Contamination of Elbe sediments decreased over the last decades; nevertheless, sediment quality still needs to be improved. Nature protection regulations and marine policy requirements demand management plans and limit placement of dredged sediments in open water. Although Hamburg safely disposes annually 1 million cubic meters of contaminated Elbe sediments on land, most dredged sediments have to be brought back to the aquatic system.

2 Sediment transport in the river and in the estuary

The Port of Hamburg is situated some 1,000 km downstream of the Elbe source and 100 km upstream of the Elbe mouth at the North Sea. Natural erosion processes lead to a fine-grained suspended matter load of more than 500,000 tons per year from the upstream region. The so called tidal pumping processes transport coarser material from the North Sea into the estuary. In the estuary these two fluxes mix.

In former times, many centuries ago, during flood events these sediments could settle in the low lying coastal plains, thus forming the fertile marsh lands. Due to embankment for flood protection this is not possible any more since centuries. Also river deepening and hydraulic engineering changed hydro-morphology and sediment transport patterns in the estuary. Today, the river and remaining inundation areas cover only a small percentage of the original area.

Sediments tend to settle where flow velocity decreases, both is true in shallow waters and in harbor basins. This is the reason why especially in the Port large volumes have to be dredged regularly to maintain safe water depths for navigation. But also shallow areas like side branches tend to silt up. If no counter-measures are taken the river will become more and more a canal, thus even accelerating the process by increasing the tidal pumping. Another effect is that natural habitats will become more and more uniform, and biodiversity will decrease.

Suspended matter, especially fine grained material, also functions as a carrier for contaminants. For decades prior to the fall of the "iron curtain" the Elbe had been the recipient of insufficiently treated wastewater. For example, the chemical complex at Bitterfeld used to release 200,000 m³ of untreated industrial sewage into the Elbe each day. After the collapse of the communist regimes, the remaining and the newly built industries became generally equipped with modern pollution-control technologies. However, the concentrations of several contaminants in sediments are still not satisfying. Dredged material criteria are exceeded, fish consumption has to be restricted.

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3 Dredged material management in the Port of Hamburg

Recurring maintenance dredging is necessary in the Port of Hamburg as in most other ports world-wide. This activity is ongoing since centuries, although the equipment has certainly changed over times. In addition to the sediments dredged in Hamburg in the downstream part of the Elbe estuary the Federal Waterways administration has to dredge about another 15 million cubic meters per year. In other big estuaries in the North Sea region, like the Scheldt, the Rhine, or the Humber about the same overall amount has to be dredged.

In former times the dredged sediments were brought onto land in Hamburg. They were used for agricultural purposes, land reclamation, etc. Some 30 years ago the contamination of the sediments was detected. Research was undertaken to develop technologies to deal with large amounts of contaminated sediments. At the same time old disposal sites had to be remediated in order to minimize their ecological impacts.

As a result the Hamburg Dredged Material Management Concept was developed in the 1980s. It consists of mechanical treatment of the sediments and subsequent safe disposal of the contaminated fine sediments, following European and German technical landfill standards (Figure 1). These disposal facilities are in operation since then. Annually 1 million cubic meters of sediments is treated and disposed on land, annual expenditure is ca. 35 million Euros. With this treatment Hamburg is mitigating the contaminant load of the Elbe and subsequently the North Sea by some 30-50 %.

Figure 1. *METHA Treatment plant and Francop dispsosal site*

After German reunification in 1990 measures could be taken to control emissions at the source. As a result sediment contamination decreased. Therefore commonly used open water disposal was introduced in Hamburg. A management framework was agreed with the environmental administration to limit sediment contamination and to reduce ecological effects by introducing time restrictions for operation.

Today, most dredged sediments remain in the aquatic system. In the last four years some 2 or 3 million cubic meters were relocated into the river near Hamburg, while more than 1 million cubic meters were brought to the North Sea (Figure 2). This sediment removal based on a temporary permit by the federal state of Schleswig-Holstein should break the sediment loops which recently occurred caused by tidal pumping: sediments were not sufficiently transported to the sea and accumulate in the upper part of the estuary. Due to this fact the German Federal Waterways Administration and the Hamburg Port Authority have developed a common river engineering and sediment management concept for the tidal Elbe (HPA / WSV 2008).

Figure 2: Elbe estuary with Wadden Sea. Tonne E3 is a temporary placement for dredged sediments from Hamburg in the North Sea.

4 Sediment Management Concept for the Tidal Elbe

The concept considers first the historical development of the tidal Elbe. Like any estuary the one of the Elbe is very dynamic by nature. At the same time human interventions, like the ones described above, have changed this environment. Any future development has to keep these dynamics in mind. Most parts of the estuary are designated Nature 2000 habitats, and environmental protection is a key issue.

The requirements of EU directives get increasingly important also for sediment management. The CIS-Document "Water Framework Directive (WFD) and Hydro-morphological pressures / Focus on hydropower, navigation and flood defence activities / Recommendations for better policy integration" (2006) states: "Given the impacts of sediment on water uses and/or aquatic habitats, supplementary measures dealing with sediment transport management could be part of the (sub) basin river management plans to support the achievement of the WFD objectives." In a letter the EU Commission stated that "… for dredging works in the tidally influenced part of the Elbe that have been designated as Natura 2000 sites the directive applies … Regular dredging works as maintenance measures - not intending to deepen the shipping lane – can be included in the management plan for the respective Natura 2000 site and would in this case not be considered to be a plan or project according article 6 of the directive."

Therefore, the sediment management concept is aiming at win-win solutions, following the Working with Nature concept of PIANC (2008) with three main purposes.

(1) River engineering measures shall reverse the negative developments of tidal characteristics, which intensified the tidal pumping. These are long-term measures. The first will be implemented soon in Hamburg by creating a new tidal volume and a tidal habitat. A first so called silt trap has been built downstream of the port. Its purpose is to keep marine sediments from entering the port area, thus reducing the amounts to be dredged. It has been in operation for nearly two years now, but final results cannot be given yet. There are first ideas to construct artificial, near natural structures in the river mouth to dampen the tidal force. This would also lead to protect the estuary against storm surges.

(2) Modified dredging strategies aim to break sediment loops by transporting the dredged sediments to sites from where they do not return with the tide. Hence, fewer sediments should be dredged and less

sedimentation should occur in nearby shallow waters. The consequence are longer transport distances and higher costs for sediment disposal.

(3) River remediation as a long-term task for the whole Elbe community is a key element in remediation of sediment quality and to secure open water placement of dredged sediments. In this context land treatment of contaminated sediments in Hamburg plays an important role.

As many EU directives affecting sediment management came and will soon come into force, HPA commissioned a legal study to review the Sediment Management Concept for the Tidal Elbe on the background of EU legislation. The study came to the conclusion that the concept fulfils all these requirements in a holistic way and all measures have to be evaluated in this context (Breuer 2009).

5 Elbe River Basin Sediment Management

By the end of 2009 River Basin Management Plans were published in Europe as requested by the Water Framework Directive. Contamination was identified as an important issue in water-resources management in the Elbe catchment. Two research studies identified substances of concern for the Elbe catchment, based on existing data (Heise et al. 2008). The studies provide details about the so called risk areas where these substances originate. Sources of pollution are abandoned sites or legacies of the past "in or near the river". New emissions are not relevant.

In 2009 the German Elbe River Board published a background paper to identify supra-regional management objectives in respect to contamination (FGG Elbe 2009). In this context a supra-regional risk is given when concentration of a contaminant at a measuring station

- Can endanger the integrity of aquatic ecosystems,
- Can have adverse effects on human health,
- Can compromise the quality of land ecosystems,
- Affects efficient sediment management for navigation or flood control.

The paper identifies management targets for sub-catchments, given in percentage of contamination reduction of existing concentrations. These targets are derived from several specific uses or subjects of protection, reflected in concentrations.

The states belonging to the international river-basin district of the Elbe developed a common management plan consisting of two parts. Part A is being compiled under the umbrella of the International Commission for the Protection of the River Elbe. The Elbe management plan highlights sediments as an essential and integrated part of the river. Qualitative and quantitative aspects of the sediment regime are taken into account with regard to the assessment of the ecological status and to supra-regional management objectives. First measures for improving the sediment budget and the quality of sediments have been planned. Important statements of the first plan are:

- Measures for an improved bed load balance and sediment management are envisaged to reduce hydro-morphological stress. Principles of bed load and sediment management should be implemented at the river basin scale. Such a comprehensive approach has never been taken before.
- Significant contaminant loads belong to the most important supra-regional issues in water-resources management and are one of the major reasons of this dissatisfying situation. Accordingly, one of the main objectives is to establish a management concept for particle-bound contaminants at river-basin scale.
- Sediment quality was crucial for the definition of supra-regional environmental objectives regarding the contaminant issue.

6 Conclusions

Sediment management is of great importance both for quantity and for quality issues (SedNet2007). This is true in the estuary and for the Port of Hamburg and also in the entire river basin. Although contamination of sediments has improved significantly over the last decades, this trend has to continue. Sources are mainly in the upstream part of the catchment with an effect into the marine environment. Quantity issues, or hydro-morphological changes, are important in parts of the river, like the Middle Elbe or the estuary.

Nowadays tools exist to tackle this task. An overarching sediment management concept has been developed for the tidal Elbe and is being implemented step-by-step. Over-regional issues are being discussed in both national and international working groups under the umbrella of the national and international Elbe protection commissions and will lead to remediation of existing contamination sources in the whole catchment.

EU legislation, especially the WFD, together with other requirements have led to holistic reflection and action. This will help not only the environment, but also the Port, and the Port of Hamburg will play its role to support these common tasks.

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Room for the river in Cat's Bend: Application of the SketchMatch method in Romania

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Keywords: interactive planning method, spatial design, SketchMatch

1 Introduction

The project *"Room for the River in Cat's Bend, Romania"* is a pilot-project, initiated by the Romanian Ministry of Environment and financed by the Dutch Government. In an interactive process together with regional partners (i.e. policymakers and other stakeholders), this project aimed to draw up integrated regional plans for the Cat's Bend region in the Lower Danube near Galati (Figure 1), based on the flood protection strategy as defined in the project *"Ecological and economical restoration of the lower Danube floodplain – Romanian sector"* (REELD) and an economic feasibility study carried out by the Danube Delta National Institute in 2007 and 2008 - and using the Dutch "Room for the Rivers" approach.

The Cat's Bend was chosen as project area, in consultation with the Romanian Ministry of Environment. In the past, this region was developed at the expense of natural areas. Many former river forelands are now being used for agriculture. Thus the area had to struggle repeated large flooding and severe water management problems, which had created much damage, particularly in the last few years (Groot & Termes 2009).

The actual national strategy for flood risk management supposes to combine flood mitigation with ecological restoration of former wetlands and socio-economical development. This project tries to implement the strategy by developing integrated regional spatial plans in an interactive process with stakeholders from the area. Creating interaction and communication between stakeholders with diverging perceptions contributes to learning processes (Hommes et al. 2009).

2 Project objective

This project works out spatial concepts, i.e., the space needed by the Danube River in the Cat's Bend region by combining diverse methods: socio-anthropological research (stakeholder interviews), SketchMatch (interactive design) workshop, hydraulic modeling and 3-D GIS visualizations. One of the main goals of this project was to stimulate support and involvement from stakeholders for the implementation of flood protection measures in the Cat's Bend region by consulting and involving these people in the design process and making use of a coherent package of interactive methods.

Regional plans are spatial designs that let one see how the integrated flood management approach could be implemented on a local level. These spatial designs form the basis for the future flood protection policy in the Galați Cat's Bend region (Figure 1).

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3 Methods

The method used to support the interactive process is the so-called '**Sketch Match'**. The SketchMatch is developed by Dutch Government Service for Land and Water Management (DLG) and works as a 'creative pressure cooker'. During a minimum of one to a maximum of three days, a group of stakeholders such as citizens, policymakers, farmers and others came together to analyze, define and work out solutions to a spatial problem. All this is done collectively, in a group. A SketchMatch is facilitated by a process supervisor and one or more spatial designers, who visualize problems and solutions by sketching them out on maps.

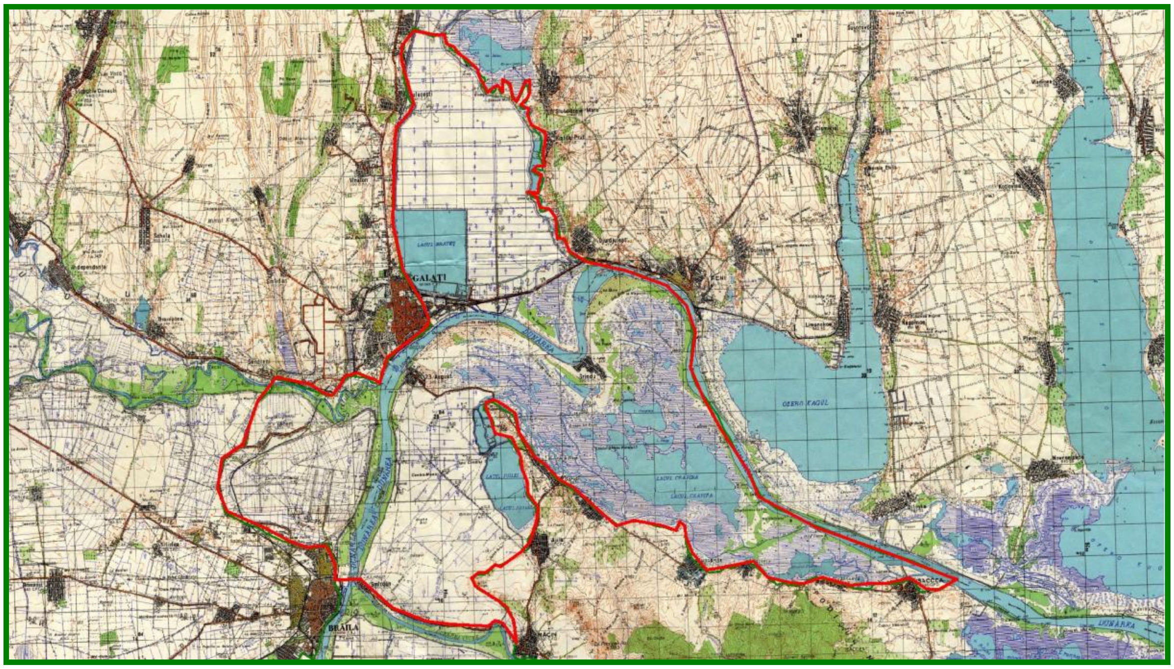

Figure 1. *The project region Cat's Bend, near Galați*

Various disciplines come together in a SketchMatch: spatial design, GIS, ecology, hydrology, hydraulics, economy, depending of the nature of the project and issues involved. The result of a SketchMatch is a spatial design, in the form of a ground plan, map, book, visual story, model, or whatever form suits the project best.

Often a SketchMatch creates a lot of enthusiasm and accelerates the decision making process. Participants begin to understand each other's interests and try to find jointly supported solutions. It increases support for a spatial plan or policy, because participants have been involved in the creation of it (Dienst Landelijk Gebied 2009).

A thorough preparation, including a clear picture of the design assignment and the players involved, is very important. If the right people with the right expectations sit down at the design table, they increase the chance of success (Figure 2).

Initial aims of the SketchMatch in Cat's Bend were, in short:

- Introduce participants to this method of interactive design
- Explore suitable solutions to water management problems in Cat's Bend area. Suitable solutions are:
  - Support by the local, regional and national stakeholders
  - Fit to the usage and characteristics of the local landscape
  - Preferably in accordance with existing policy

Figure 2. *Work in progress in one group*

4 Results

SketchMatch session took place in Măcin town between 22 and 24 June 2009. In the first and second day two workshops were organized. These workshops consisted in forming four groups that all paid attention to water and the river, but they also had a focus on: "*Agriculture, fishery and horticulture*", "*Tourism, nature and nature development*", "*Living, working and infrastructure*", "*Development of qualities of the area*", "*Irrigation*", *"Channel at the foot of Măcin Mountains*", "*Prut and Vădeni* ", "*Grindu area and Danube itself* ". The groups were divided randomly over the rooms (every room had a spatial planner). Each group focused on three aspects: problems, qualities and potentials of the area. All groups had two different participant categories: project team participants and project participants. The role of the first category of participants was to lead the discussions on the proposed themes. The working time for each group was approximately two hours. In every evening, the results of the groups were presented in plenary in short way by a member of each group. The presentation used the draft sketches resulted in the group.

On the third day there was a resumé of the first two days in the sense of presenting all the sketches resulted from all the working groups. Also it was presented in plenary the general conclusions of the entire SketchMatch session. Furthermore, three sketches were made that include all three categories of issues that were followed in the SketchMatch session: q*ualities* (Figure 3*), problems* (Figure 4) and *potentials* (Figure 5). Also on the last day, the project team's designers had the task to integrate these separate building blocks into one final, integrated design-map. They took the three concepts and combined them into an integrated sketch: the Schita Integrata (Figure 6). This Schita Integrata can be seen as the endproduct of the SketchMatch workshop, in which all the efforts and ideas of three days hard work come together.

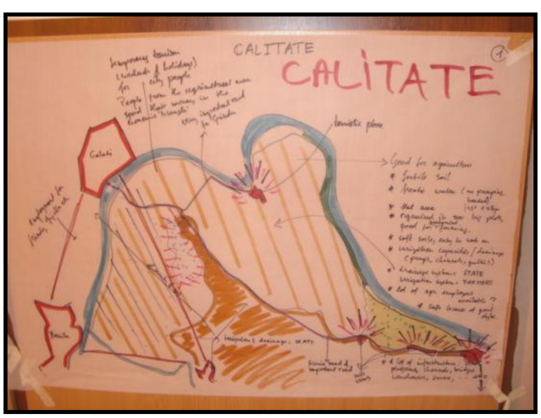

Figure 3. *Qualities of the Cat's Bend area*

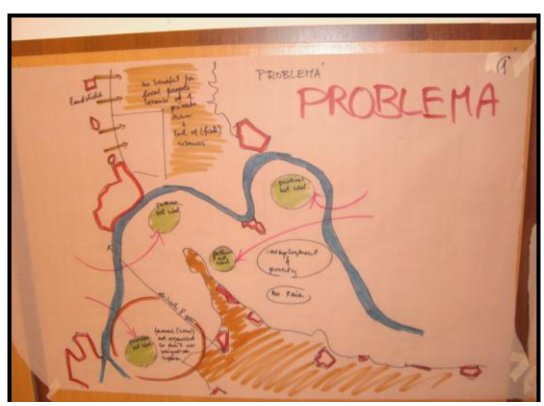

Figure 4. *Problems of the Cat's Bend area*

It is a regional perspective as an answer to:

- Regional climate issues like droughts and floods
- Regional socio-economic issues like sustainable land use in connection with economic development

Figure 5. *Potentials of the Cat's Bend area*

Figure 6. *Integrated sketch*

The three different design concepts, which compose the Schita Integrata are:

1. Connecting and restoring the old Danube branch and wetlands by a new west-east connecting channel along the Macin mountains. This new navigable canal will stimulate microclimate and economic development in the villages and will serve as flood channel at high water.
2. System of infiltration and drainage channels based on the existing system – to reinforce the potential for agricultural production and to improve microclimate.
3. Application of "Room for the River" measures: a dike-displacement north of Grindu locality and a flood channel south of Grindu, contributing to flood protection by reducing water levels of the Danube.

This cooperation between different stakeholders and experts had certain very clear results and advantages for the project and planning process:

- One result is ‘raised awareness’ among participants. In Cat’s Bend, participants became aware of the nature of the region’s water system and its interrelationship with other spatial functions (nature, agriculture) and other aspects (economic viability and microclimate). Participants also realized that integrated solutions are needed to solve such complex problems.
- Another aspect of this raised awareness can be called ‘empowerment’: stakeholders become aware of their own power to create solutions together and of the importance and benefits to cooperate with other stakeholders to reach these solutions.
- Conceptual flexibility is another advantage of the SketchMatch method, which ensures that problems and solutions are defined in such a way that participants support them. This adds up to the feasibility and stakeholders’ support for measures once they are implemented. In Cat’s Bend, the design assignment was changed so that it could accommodate stakeholders’ views. This flexibility is an inherent strength of the SketchMatch, but also implies that end results cannot be predicted beforehand.
- The combination of spatial design and hydraulic modeling brings together facts and vision. In Cat’s Bend, design concepts could be screened right away for their rough (hydraulic) effects. This gave participants a better insight into the probable effects of their proposals and discussions (Dienst Landelijk Gebied 2009).

5 Follow-up for the SketchMatch results

The SketchMatch for the Cat’s Bend area resulted in an extensive dialogue and shared awareness of problems and solutions. It is important to consolidate and extend this awareness in the near future. Regional and national authorities have to make clear witch elements of the proposals they will or will not adopt, based on clear argumentation. At the same time it is important that they state how they will continue to include local stakeholders in the following stages of planning and implementation of measures in the area. This is an important prerequisite to create and maintain generated local support in the near future. If authorities adopt local stakeholders’ ideas and anchor these in new policies, this may create a driving force for a successful and sustainable development of Cat’s Bend area. Such a development will safeguard the area from future floods, while at the same time stimulating economy, ecology, the resilience of the water system and the living conditions in the Cat’s Bend villages.

The SketchMatch can connect top-down thinking (policies or studies like REELD) with bottom-up acting (like the solutions defined by stakeholders in a SketchMatch session). A SketchMatch can generate usable concepts on both the (inter)national level of policy, focusing on the whole Danube Basin, as well as on a local level, focusing on a particular project area. Using this method in national, regional and local planning processes and equipping staff with the required skills is therefore advisable (Dienst Landelijk Gebied 2009).

6 Sketchmatch session conclusions

The Cat’s Bend SketchMatch must be seen as a first step in a long process; as the start of a (renewed) dialogue between policymakers and inhabitants, laymen and experts. The SketchMatch’s outcomes need to be worked out in more detail, so that they can be incorporated into new policies and be implemented in the future. Local, regional and national administrators must take the lead in this process and continue to work together with local inhabitants, farmers, entrepreneurs and other stakeholder parties (Dienst Landelijk Gebied 2009).

The following main issues were identified: ecology versus economy; use current values and investments; take future management into account; create combinations.

During the SketchMatch session the following principles were developed: “Room for the River Danube”; agriculture and improvement; the old Danube and gradient.

One strategic note is that the project area is only a very small part of the Danube Basin; this implies that it can only provide a small contribution to the catchment approach or river basin management.

The SketchMatch integrated several aspects (technical, social, economic).

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New methods in estimating biodiversity: a case study on aquatic and semi-aquatic Heteroptera in the Arieş River Basin (Romania)

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Keywords: Arieş River Basin, biodiversity, number equivalent

1 Introduction

Biodiversity is an important indicator of wildlife quality. It can be measured by different techniques; most commonly used are indices that reflect particular aspects of the flora and fauna in study. Comparing several methods may reveal with greater precision the way the target community has adapted to the habitats in the study area; moreover, new techniques facilitating the evaluation are always welcome.

Our target group, aquatic and semi-aquatic Heteroptera belong, according to the latest classifications, to Infrasuborder *Nepomorpha* Popov 1968 and *Gerromorpha* Popov 1971, respectively (Gaby Viskens, 2005, on www.earthlife.net). They are insects associated, more or less, with water surfaces, forming a part of the nekton and epineuston. They inhabit a large variety of micro-biotopes, from those lacking vegetation, to those completely covered (Andersen, 1982; Davideanu, 1999). The typical habitats of Heteroptera are ponds, lakes, slow flowing creeks or little bays formed at the banks of rivers. Most species are not sensitive to moderate human impact on the habitat and to the presence of vegetation.

We investigated the quality of specific Heteroptera habitats in the Arieş River Basin that drains the central part of Apuseni Mountains in western Romania, being one of the largest tributaries of Mureş River. The upper basin is formed by two separate rivers (Arieşul Mare and Arieşul Mic) wich unite near the city of Câmpeni to the main river. In the upper basin crystalline rocks prevail, while the lower basin is characterized by sedimentary rocks (especially limestone).

2 Material and methods

The study took place in June 2009 encompassing 16 sampling stations in the upper and lower basin of Arieş River (Fig. 1). They covered the entire diversity of habitats preferred by Heteroptera and an altitudinal gradient for β-biodiversity (S 1 at highest, S 16 at lowest altitude). One sample from each station was taken, 8 to 15 meters in lenght, covering the entire habitat (water surface and body, aquatic vegetation if present, bottom); the samples were collected with an entomological net (mesh-size 60 cm^2).

Species were identified under a stereo binocular by the morphological features or, where necessary, by genitalia, using data from other specialists (Jansson, 1986; Davideanu, 1999). Larvae could not be identified at species level except those of *Nepa cinerea* Lineé 1758; therefore, they were not considered in the biodiversity analysis. In this respect, two of the sampling stations, S 2 and S 8, are not included in the analysis, since only larvae were sampled. At station S 10, one female *Dichaetonecta sp.* Hutchinson, 1940 was found, impossible to identify at species level in the absence of the male (Jansson, 1986).

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However, because it is the only *Dichaetonecta* individual found in the entire area, it was considered as one species in the biodiversity analysis.

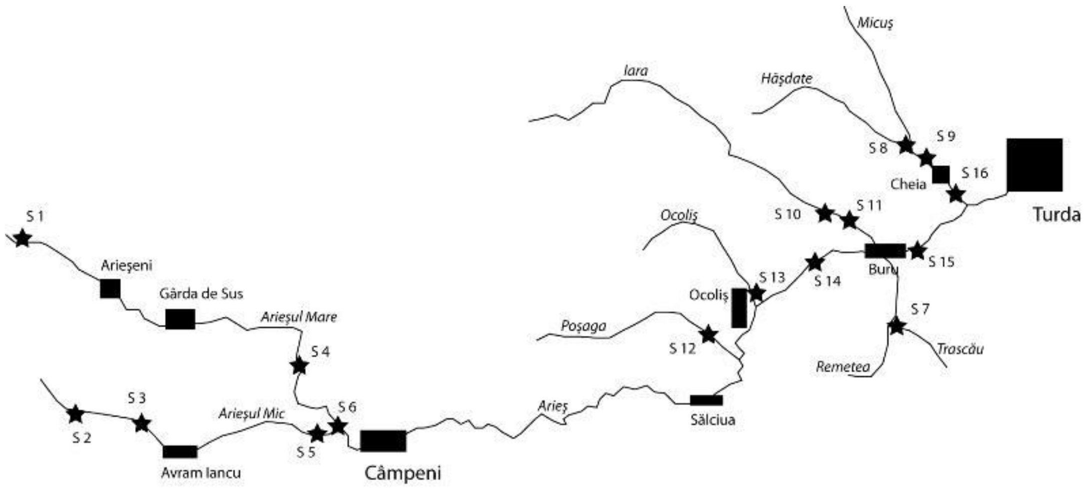

***Figure 1**. The location of sampling stations (stars) in the Arieş River and its tributaries. Rectangles represent cities and villages.*

We used two different approaches to calculate biodiversity: (1) The classic approach of areal biodiversity (γ biodiversity) obtained by multiplying medium α values by β values (Sîrbu & Benedek, 2004). For α biodiversity of each sampling station we used the Menhinick Index; the Whittaker Index indicated β biodiversity, using altitude as a gradient. (2) Jost (2006, 2007) proposed a new type of calculation, based on what he believes is the confusion made by biologists between the value of the biodiversity index and the true value of biodiversity. He proposed a number equivalent for entropy-like indices (Shannon, Renyi, Gini-Simpson etc.), number equivalent that will reflect the true value of biodiversity. The methodology is appliable for the calculation of α and γ (total) biodiversity, β values being obtained from the previous two (each index has its own formula for the number equivalent and for β diversity calculation). Where community weights are different, the use of Shannon Entropy ($-\Sigma p_i * \ln(p_i)$) is recommended, with the number equivalent of $\exp(-\Sigma p_i * \ln(p_i))$, for which the β value is obtained by dividing γ by α (Jost, 2007).

3 Results and discussions

The specific Heteroptera habitats are scarce in the area for two reasons: (1) prevailing crystalline rocks in the upper Arieş Basin cause fast run-off and unfavorable lotic habitats; (2) intense human impacts in the middle basins of Arieş and Arieşul Mare Rivers on the hydromorphology (enbankments) and terrain levelling destroyed favorable habitats such as still waters, puddles and lentic river stretches.

We found 17 species of Heteroptera, ten belonging to Infrasubordo *Gerromorpha* (semi-aquatic Heteroptera) and seven to Infrasubordo *Nepomorpha* (aquatic Heteroptera) (Table 1).

All species are first time mentions in the area (Paina, 1975), but only the lack of studies made in the area can be the reason for that, because they were all sampled in the nearby regions (between Aiud and Cluj-Napoca).

Considering *Dichaetonecta* and *Velia*, the Arieş River Basin encompasses 19 out of 67 species found so far in Romania (Davideanu, 1999, Ilie, 2008). This is about 29% of the aquatic and semi-aquatic Heteroptera species sampled in the entire country found on only 14 sampling stations covering a very small area along a medium size river. The 71 adults sampled result in an individual/species ratio of 3.94, not considering *Velia*, and they belong to a high number of 9 Heteroptera families, which means nearly 8 individuals per family. The genus *Gerris* Fabricius 1794 is represented by six out of nine species present in Europe (Viskens, 1995, on earthlife.net), a comparatively large portion if we consider the relatively poor conditions of the area and the gathering of only one sample from each station.

***Table 1**. List of aquatic and semi-aquatic Heteroptera sampled in the Arieş River Basin*

Nr	**TAXONS (families, species)**	**STATIONS (S)**															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
	Infrasuborder Gerromorpha																
	Fam. Gerridae																
1	*A. paludum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
2	*G. lacustris*	-	-	-	1	4	5	4	-	3	-	8	-	4	-	-	-
3	*G. costae*	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*G. argentatus*	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
5	*G. gibbifer*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*G. odontogaster*	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
7	*G. thoracicus*	-	-	-	-	-	-	-	-	-	-	-	-	2	4	-	-
8	*Gerris sp. larvae*	5	-	20	1	12	34	5	-	-	-	15	-	-	-	-	-
	Fam. Veliidae																
9	*Velia sp. larvae*	7	3	-	-	-	-	-	5	-	-	-	-	-	-	-	-
	Fam. Microveliidae																
10	*M. reticulata*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	Fam. Hebridae																
11	*H. pusillus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	Fam. Hydrometridae																
12	*H. stagnorum*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
	Infrasuborder Nepomorpha																
	Fam. Corixidae																
13	*S. nigrolineata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
14	*S. lateralis*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
15	*S. striata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
16	*H. sahlbergi*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
17	*Dichaetonecta sp.*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
	Fam. Nepidae																
18	*N. cinerea*	-	-	-	-	-	-	-	-	-	1	4	2	-	-	-	-
19	*N. cinerea larvae*	1	-	-	-	-	-	-	-	1	-	10	-	-	-	-	4
	Fam. Notonectidae																
20	*N. glauca*	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-

Fam. Pleidae																	
21	*P. minutissima*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
TOTAL (imago)		**3**	**-**	**5**	**1**	**8**	**5**	**4**	**-**	**3**	**2**	**18**	**2**	**6**	**4**	**1**	**9**

Biodiversity analysis (Table 2) using the two methods described above is showing remarkably similar results: low α values and relatively high β values, leading to a high γ for the lower basin and for the entire area; in the upper basin five out of six stations comprise only Gerridae, resulting in a lower β component and in overall diversity. The similarity of results obtained with two different methods confirms the practical applicability of Jost's method that, however, is much easier to use.

Low α values may be due to the poor quality of habitats and the small amount of samplings. Being well adapted to specific habitat conditions, particular aquatic and semi-aquatic Heteroptera species are in need of a suitable bottom, flow, presence of vegetation etc., difficult to be found in small sampling stations we studied. Therefore, the only stations with high α values are relatively large, for example S1 or S11, where different habitat conditions allow different species to coexist. This is explained best by the high number of stations with only one species found (9 out of 16, particularly the smallest and the most homogenous ones).

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

Station	***α 1***	***average α 1***	***β 1***	***γ 1***	***α 2***	***average α 2***	***β 2***	***γ 2***
S 1	*3.32*	*Upper basin: 1.11*	*Upper basin: 2.22*	*Upper basin: 2.45*	*2.00*	*Upper basin: 1.53*	*Upper basin: 2.32*	*Upper basin: 3.55*
S 2	*-*				*-*			
S 3	*0*				*1.00*			
S 4	*0*				*1.00*			
S 5	*2.22*	***Total: 1.31***	***Total: 7.50***	***Total: 9.82***	*2.65*	***Total: 1.61***	***Total: 5.32***	***Total: 8.58***
S 6	*0*				*1.00*			
S 7	*0*				*1.00*			
S 8	*-*				*-*			
S 9	*0*				*1.00*			
S 10	*3.32*				*2.00*			
S 11	*3.98*				*4.86*			
S 12	*0*				*1.00*			
S 13	*1.29*	*Lower basin: 1.42*	*Lower basin: 5.00*	*Lower basin: 7.10*	*1.89*	*Lower basin: 1.66*	*Lower basin: 4.71*	*Lower basin: 7.80*
S 14	*0*				*1.00*			
S 15	*0*				*1.00*			
S 16	*4.19*				*4.17*			

The relatively high variation of β diversity is due to the fact that most aquatic and semi-aquatic Heteroptera species are well adapted to particular habitat conditions, so different types of habitats are occupied with different species (Andersen, 1982). Due to the small dimension of the sampling stations, almost each station offered few ecological niches for Heteroptera species, reflected by the α diversity results described above. The change of geographical conditions along the altitudinal gradient influences habitat type and Heteroptera species composition. The low β values of the upper basin are in consistence with the relatively homogenous geological conditions.

4 Conclusions

The species sampled are new to the area, as far as we know, probably because of the lack of research made on the group. The results of this study can be improved by further research in the area.

Nevertheless, the results are important for the overall picture of Romanian aquatic and semi-aquatic Heteroptera, because it is proved by earlier work of the authors that most species can be found in montane regions (Ilie, 2008; Olosutean & Ilie, 2008, 2010). Some species have key roles in pioneering semi-aquatic habitats; therefore, research on Heteroptera is important and needs further studies.

As for the biodiversity analysis, Jost's number equivalent method proved to be useful, easy to apply and reliable, recommending further use.

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Inventory of Macrophytes and habitats along the river Danube in Croatia

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Keywords: Macrophytes, Habitats, Danube, Croatia

1 Introduction

The length of the Danube course in Croatia is 137.5 km; it enters from Hungary (river km 1433), and stretches as a bordering river between Croatia and Serbia downstream to rkm 1295.5 (Figure 1). Main Danube tributaries in Croatia are: the Karašica River in Baranja (mouth at rkm 1425), the Drava River (confluence with the Danube at rkm 1382.5), and the Vuka River (mouth at rkm 1333).

In the Baranja section, between rkm 1433-1380, the Danube flows through a vast floodplain area, where a specific relief with oxbows, side arms, islands and sandbanks is formed due to meandering activity. The Danube course has been intensively modified due to regulation works in the past (Bognar 1990). Several wide meanders were cut: Šarkanj (1814-1820), Blaževica (1894), Siga (1894) and Srebrnica (1894). Since then, the former main channel and large side-channels became oxbows or semi-separated side-arms, called "Dunavci". Part of the Danube course between rkm 1412-1382 belongs to the protected area of Kopački rit Nature Park, which is also protected by the Ramsar Convention as a wetland area of world wide importance.

Figure 1. *The Danube course through Croatia.*

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Between Erdut (rkm 1367) and Dalj (rkm 1354), the Danube performs a large curve, thus avoiding the relief barrier of Erdut hill, a horst (190 m a.s.l.) stretching for 15 km in W-E direction. Steep loess cliffs (20-40 m high) have been formed at the northern side of the hill as the result of fluvial erosion. Due to tectonic movements in the recent geological past, in the sector between Šarengrad (rkm 1306) and Ilok (rkm 1300) the Danube flows almost in a straight line (Bognar 1994). A strong asymmetry is evident between floodplain formed on the left riverside, and vertical loess cliffs on the right riverside. The Danube continuously cuts its main channel into the Vukovar loess plateau on the right riverside during high flow, while characteristic mean flow mechanisms such as meandering activities, erosion and sediment deposition, formation of side-arms, islets and sandbanks were not present in this sector.

An exceptionaly dry and warm period from February to early October 2003 resulted in drought in the Danube River. The mean water level at water gauging station in Batina (rkm 1425) in July 2003 was 41 cm, which is 285 cm lower compared to average water level of 326 cm for the period 1961-1998.

2 Material and methods

The inventarisation of aquatic macrophytes and assessment of habitat parameters along the Danube course were carried out during 2003-2004, comprising the right riverside which belongs to the Croatian territory. These tasks were part of the implementation of the international project “Multifunctional Integrated Study Danube: Corridor and Catchment –MIDCC” (Janauer 2002).

The distribution and abundance of macrophytes were assessed from the bank or using a boat in survey units of one river km length. In each survey unit, the following habitat parameters were assessed, using the methodology of Kohler & Janauer (1995): bank structure in the upper littoral, extending over the water level during mean discharges; sediment type in the littoral of the river where the aquatic plants are growing; flow class indicating the water velocity; Secchi depth transparency and land use type. The conservation status is determined according to the Red data book of Croatian vascular plants (Nikolić & Topić 2005), Annex I of the Bern Convention, and national legislation adopted under the Nature Protection Act (Anonymous 2009).

3 Results and discussion

The aquatic flora of the River Danube in Croatia is influenced by the bank structure along the main channel, sediment type, flow velocity, water transparency, and the land use type.

In the bank structure, steep slopes of fine inorganic material dominate, and make up 42% of the investigated river km. Other recorded types of bank structure are: riprap used for bank stabilization and river regulation (30%), flat slopes of fine inorganic material (21%), artificial material for the embankment (5%), and sand (2%). Urbanisation and industrialisation strongly influenced the bank structure between rkm 1353-1333, where 30% of the bank is made of concrete. An industrial centre with fabrics was built in Borovo. The centre of the Croatian Danube Region is Vukovar, situated at the mouth of the Vuka River (rkm 1333), hosting a large port.

The river bottom near the banks consists of fine inorganic material as dominant sediment type (64%), sand (29%), gravel (5%), and solid rock (2%). Medium flow velocity (35-65 cm/s) is most frequent and was recorded at 78% of investigated river km. Lower velocity (<30 cm/s) occurred in only 14%, and high velocity (>70 cm/s) in 8 % of the whole stretch. Secchi depth transparency ranged from 55-90 cm, with an average value of 70 cm.

Considering land use type, the most frequent are broad-leaved forests (86%), classified according to National Habitat Classification (Topić & Vukelić 2009) into habitat types: E.1.1 floodplain willow forests (Alliance *Salicion albae*), E.1.2 floodplain poplar forests (Alliance *Populion albae*), and E.9.3 plantations of allochthonous poplars. Scrub and open spaces with little or no vegetation make up 3%, agricultural area covers 3%, and industrial and urban areas were 4% each in the surveyed area.

In total 34 plant species were recorded, eleven of which: *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Myriophyllum spicatum, Potamogeton crispus, Potamogeton pectinatus, Ranunculus circinatus, Salvinia natans, Spirodela polyrhiza, Trapa natans* and *Wolffia arrhiza*, were restricted to the Danube main channel (Table 1). This indicates a low macrophyte diversity, similar to that confirmed in the adjacent reaches of the Danube course in Hungary (Szalma 2004) and Serbia (Vukov et al. 2006).

Table 1. *List of the macrophytes recorded on the right bank of the Danube in Croatia (rkm 1433-1295.5) and their conservation status*

Species	**Conservation status**		
	Croatian Red Data Book	**Croatian Nature Protection Act**	**Bern Convention Annex I**
Bidens tripartita L.			
Butomus umbellatus L.	Near threatened	Protected	
Carex pseudocyperus L.			
Carex vulpina L.			
Ceratophyllum demersum L.			
Cyperus fuscus L.	Vulnerable	Strictly protected	
Cyperus glomeratus L.	Vulnerable	Strictly protected	
Cyperus michelianus (L.) Link.		Strictly protected	
Echinochloa crus-galli (L.) Beauv.			
Elodea canadensis Michx.			
Galeobdolon luteum Huds.			
Gnaphalium uliginosum L.			
Iris pseudacorus L.			
Lemna minor L.			
Limosella aquatica L.	Critically endangered	Strictly protected	
Lycopus europaeus L.		Strictly protected	
Lythrum salicaria L.			
Myriophyllum spicatum L.			
Phragmites australis (Cav.) Trin.ex Steudel			
Persicaria amphibia (L.) Gray			
Persicaria hydropiper (L.) Spach			
Persicaria lapathifolia (L.) Delarbre			
Potamogeton crispus L.			
Potamogeton pectinatus L.			
Ranunculus circinatus Sibthorp			
Rorippa amphibian (L.) Besser			

Rorippa palustris (L.) Besser			
Sagittaria sagitifolia L.			
Salvinia natans (L.) All.		Protected	■
Spirodela polyrhiza (L.) Schleiden			
Stachys palustris L.			
Trapa natans L.	Near threatened	Protected	■
Veronica peregrina L.			
Wolffia arrhiza (L.) Horkel ex Wimmer	Vulnerable	Strictly protected	

In the Hungarian part of the Danube, between rkm 1468-1433 (bordering point to Croatia), four aquatic species were recorded on the right, and five on the left riverside. Recorded types of bank structure on both riverside are riprap used for bank stabilization and sand, while the most frequent sediment type is fine inorganic material. The flow is low, and Secchi transparency ranged between 40 and 50 cm.

On the left riverside in Serbia, between rkm 1410-1359, eleven aquatic plants were recorded in the Danube main channel. Compared to the investigated sector on the right riverside, sand is prevailing in bank structure (44%) and as sediment (58%), flow is medium, and Secchi transparency was 40-70 cm. This part of the Danube is characterized by medium to high flow, due to straitening the river after cut-off of a wide meanders in the past (Bognar 1990). Meandering activity of the Danube is evident even nowadays. The right (Croatian) bank is elevated and exposed to fluvial erosion, so the bank is more stabilized with riprap than left (Serbian) bank, which is more flat and suitable for deposition of eroded material.

The absence of favourable conditions for the reduction of the Danube flow velocity disables the occurrence of aquatic plants along the Danube course in Croatia. Significant increase in species diversity is recorded in Serbia, downstream of rkm 1155 (Vukov et al. 2008). The construction of the power plant and the dam Đerdap I altered hydrological conditions in a way that flow velocity was reduced, sedimentation rate was higher, and banks were enlarged. In the impoundment of Đerdap I, 37 plant species were recorded.

Our survey contributed to the enlargement of the Croatian flora, since *Veronica peregrina* discovered on the sandbank of a Danube oxbow at Zeleni otok (rkm 1423), was reported as new species (Topić & Ilijanić 2003).

Nine species of value for conservation were found in the area (Table 1). Depending on the degree of their vulnerability, six of the recorded aquatic plants (18 %) are included in different categories of the Red data book of Croatian vascular plants: *Limosella aquatica* as critically endangered; *Cyperus fuscus*, *Cyperus glomeratus*, and *Wolffia arrhiza* as vulnerable; *Butomus umbellatus* and *Trapa natans* as near threatened. According to the Croatian Nature Protection Act, six species have been protected under the category “Strictly protected native taxon”, and three as “Protected native taxon”. Two of the recorded species: *Salvinia natans* and *Trapa natans* are internationally protected under the Annex I of the Bern Convention.

4 Conclusions

Diversity of the aquatic macrophytes along the Danube course in Croatia is low, and it is similar to that recorded for the left and right riverside in the adjacent reaches in Hungary and Serbia. Medium to high flow velocity of the Danube, caused by meandering activity, is the main factor that disables the growth of the aquatic plants. However, the number of macrophytes is significantly larger in the Danube backwaters and area of Kopački rit Nature Park, with pronounced diversity of wetland habitats.

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Investigation of the isotopic composition of Danube water as indicator for hydroclimatic changes in the Danube basin. Establishment of a representative isotope monitoring near the mouth of the river

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Keywords: Danube, isotope hydrology, climatic change, deuterium (^{2}H), oxygen 18 (^{18}O)

1 Introduction

Isotopes of particular interest for hydrological studies generally include the stable isotopes ^{2}H and ^{18}O. They are incorporated within the water molecule and exhibit systematic variations in the water cycle as a result of isotope fractionation linked with phase changes and diffusion. Precipitation variability is related mainly to air-mass source and evolution including temperature-dependant equilibrium fractionation effects (e.g. Mook 2000). River discharge signatures provide insight into the basin-integrated hydroclimate forcings on water cycling such as precipitation variability (e.g. changes in condensation temperature, latitude/altitude of precipitation, air mass mixing and recycling, distance from ocean source, and seasonality) and evaporation from the catchment by rivers, soil water, wetlands, lakes, and reservoirs. Since evaporation has little effects on the isotopic composition of river water within the Danube Basin, the isotopic composition in Danube water reflects mainly the isotopic composition of precipitation in the whole basin and so provides an integrated isotope signal for climatic/hydrological conditions and changes in the catchment (Rank et al. 2009).

Rivers are an important part of the global hydrological cycle, returning about 35 % of continental precipitation to the oceans. For sustainable management of water supply, agriculture, flood-drought cycles, and ecosystem and human health, there is a basic need for improving the scientific understanding of water cycling processes in river basins and the ability to detect and predict impacts of climate change and water resources development. In 2002 the International Atomic Energy Agency (IAEA) launched a coordinated research project on "Isotope tracing of hydrological processes in large river basins" aimed at developing and testing isotope methods for quantitative analysis of water balance and related processes, tracing environmental changes, and ultimately establishing an operational "Global Network for Isotopes in Rivers" (http://isohis.iaea.org). This network builds on complementary monitoring of the IAEA/WMO Global Network of Isotopes in Precipitation (GNIP), a cooperative program for analysis of monthly isotope composition of precipitation at over 500 stations worldwide, operated since 1961. In recent years many international and national hydrology research programs have focused on the basin, continental and even global scale. Examples of tracer-based studies at the small scale are numerous, however their application in the study of water cycling processes in large river basins remains a virtual scientific frontier (Gibson et al. 2002).

The worldwide longest isotope record of a large river exists for the Upper Danube at Vienna (drainage area 102,000 km^2, average discharge 1915 m^3/s). The results suggest that isotope signals in river discharge can provide additional insight into seasonal to decadal hydrological processes in large river basins and reflect hydroclimatic changes (Figure 1, Rozanski & Gonfiantini 1990, Rank et al. 1998, Kaiser et al. 2001, Rank &

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Papesch 2005). Isotope records from some other river stations of the Austrian isotope network on Danube tributaries (Figure 2) show the same trend (Rank & Papesch 1996). No similar records exist for the Lower Danube. Therefore a representative isotope monitoring near the Danube Delta should be established to achieve isotope-hydrological information about the entire Danube Basin (drainage area ca 800,000 km^2, average discharge ca 6.500 m^3/s, Lászlóffy 1967). A simple extrapolation from the Upper Danube data to the whole catchment is not possible because of different morphologic, hydrological and climatic conditions within the catchment.

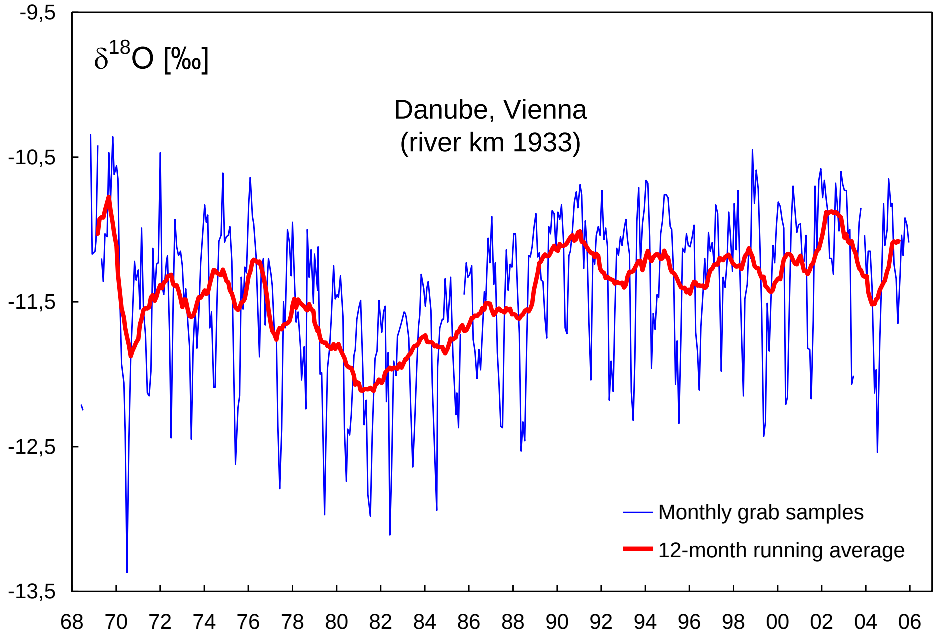

Figure 1. *δ^{18}O time series of the Danube at Vienna (monthly grab samples, 12-month running average) (Rank & Papesch 1996, updated). The δ^{18}O pattern reflects the general δ^{18}O trend of precipitation in Central Europe (Rank & Papesch 2010).*

Figure 2. *The Danube Basin river system with indication of the two proposed sampling points at the Iron Gate and Tulcea as well as the sampling points of the Austrian network for isotopes in river water, where long-term isotope records are available (based on ESRI ArcGIS 9.3).*

2 Preliminary isotope survey on the Lower Danube (Iron Gate, Delta) in order to find suitable sampling points for a long-term isotope monitoring of river water

Representative isotope monitoring on a river requires a careful selection of sampling site(s) and sampling frequency. The sample(s) should be representative for the entire cross-section of the river and thus for the whole catchment and not be influenced by side effects (e.g. inflow of tributaries, channels, municipal wastewater outlets etc.). In case of totally mixed rivers, one single sampling location would be enough for a routine sampling program.

The spatial isotopic variation of Danube water in the pre-delta region was investigated in two cross-sections at the bifurcations of the Danube Delta arms in October 2009 (Figure 3) within a bilateral Austrian-Romanian cooperation between Austrian Institute of Technology - AIT, Seibersdorf and National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca. A few samples were taken also in the Iron Gate section of the Danube and at Braila.

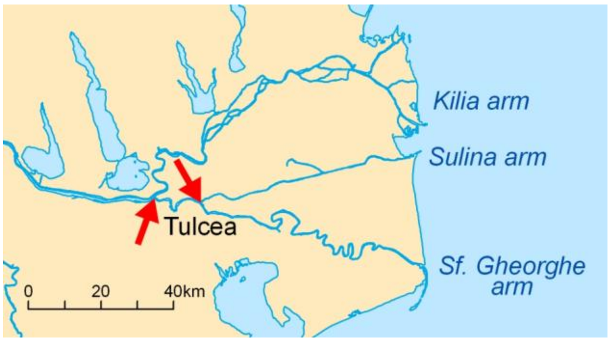

Figure 3. Sampling sites for stable isotope cross-sections at the bifurcations of Kilia/Tulcea arm and Sulina/Sf. Gheorghe arm, respectively.

Table 1. Results of a preliminary isotope survey of the Lower Danube (Iron Gate, Braila, Danube Delta) in October 2009 (d = deuterium excess, calculated from d = δ^2H - 8.$\delta^{18}O$).

Sampling point	River km	Date of sampling	δ^2H [‰]	$\delta^{18}O$ [‰]	d [‰]
Dubova, left bank	969	2009-10-06 09:00	-68.2	-9.71	9.5
Iron Gate 1, downstream of dam, left bank	943	2009-10-06 10:30	-67.6	-9.61	9.3
Drobeta, left bank	927	2009-10-06 11:00	-68.1	-9.65	9.1
Braila, ferry, right bank	167	2009-10-08 10:00	-68.1	-9.65	9.1
Cross section bifurcation Kilia/Tulcea arm					
1 Middle of the river		2009-10-07 10:30	-68.2	-9.62	8.8
2 10 m from right bank		2009-10-07 10:45	-68.7	-9.68	8.7
Cross section bifurcation Sulina/Sf. Gh. arm					
1 15 m from left bank		2009-10-07 10:00	-68.8	-9.65	8.4
2		2009-10-07	-67.5	-9.67	9.9
3		2009-10-07	-69.0	-9.68	8.4
4		2009-10-07	-68.2	-9.68	9.2
5		2009-10-07	-67.9	-9.64	9.2
6		2009-10-07	-68.0	-9.66	9.3

7	2009-10-07	-68.9	-9.67	8.5
8	2009-10-07	-67.5	-9.67	9.9
9 15 m from right bank	2009-10-07	-67.6	-9.67	9.8

Uncertainty of measurement: below ± 1.0 ‰ and ± 0.1 ‰ for δ^2H and δ^{18}O, respectively. Samples 1-9 were taken in equal distances.

The results (Table 1) do not show any significant isotopic variations within the cross-sections in the pre-delta region. So the Danube River was isotopically totally mixed at the time of sampling (the flow rate was near mean discharge). Also the isotope values of the samples from the Iron Gate section and Braila did not exhibit variations exceeding the uncertainty of measurement.

As a result from this preliminary investigation we can conclude that it will be possible to achieve a representative long-term isotope record of the whole Danube Basin by sampling at only one suitable location.

3 Conclusions and outlook

Since evaporation has only little effects on the isotopic composition of river water within the Danube Basin, the isotopic composition of Danube water near the mouth in the Black Sea reflects mainly the isotopic composition of precipitation in the whole basin and so provides an integrated isotope signal for climatic/hydrological conditions and changes in the whole catchment.

A preliminary investigation of the isotopic composition of Danube water in cross-sections in the Tulcea region showed that the Danube River is isotopically totally mixed at the bifurcation of the Danube Delta arms. Therefore routine sampling at only one location in the pre-delta region seems to be sufficient to get a representative isotope record for the whole Danube Basin. This result should be checked by repeating the investigation at different hydrological conditions to elucidate seasonal and inter-annual variation.

Routine sampling at Tulcea twice a month was started in November 2009. A sampling program at the Iron Gate (rkm 944) is in preparation.

The Danube water isotope time series will serve as a basic data set for hydrological investigations as well as for assessing future impacts within the Danube Basin. This includes climatic/hydrological changes (e.g. temperature changes, change of precipitation distribution) as well as anthropogenic impacts on the hydrological regime (e.g. reservoirs, change in land use).

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Long-term prognosis of discharge in selected rivers of the Danube and Elbe basins

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Keywords: discharge prediction, time series analysis, spectral analysis, stochastic models

1 Introduction

Since the very inception of hydrology as a scientific discipline, hydrologists and climatologists around the world have been trying to make science-based prediction of future development in the hydrosphere. Generally it is expected that the increase of temperature will increase evapotranspiration in summer and decrease the runoff. Consecutively the oxygen regime and stream water quality will worsen.

There are two main approaches to stream runoff prognosis in the next decades:

1. Statistical analysis of long-term discharge series followed by prognosis using stochastic auto-regressive models;
2. Application of hydrological rainfall-runoff models based on precipitation-temperature-stream runoff relations. The precipitation and temperature data are modified according to selected climate scenarios for future time horizons (most frequently 2025, 2050 or 2075).

We used the first method and identified the changes in statistical characteristics of the discharge using detailed statistical analysis of the daily, monthly and annual time series. The second part of this study is devoted to the long-term prediction of the monthly discharge of the Danube and Elbe Rivers by applying stochastic methods.

2 Description of the basins and data

The Danube and Elbe are among the largest rivers of Europe. The basin area upstream of the Bratislava, and the Wittenberge gauge is 131 338 km^2, and 123 532 km^2, respectively (Table 1, Fig.1). The Elbe Basin is one of the driest river basins in Europe according to the specific yield. The mean annual runoff of the Elbe River at Wittenberge is only one third of the Danube runoff at Bratislava (495 mm to 173 mm) (Table 1).

The increase in air temperature has not affected the annual mean discharge rate observed in the Upper Danube at Bratislava station during 1876–2005 (Fig.2), while the seasonal pattern has been significantly changed by increasing discharge rates in December–April and decreasing rates for June–August.

The mean annual discharge of the Elbe River is slightly increasing in 1875–2005. The increase is mainly due to increase of discharge in the winter period.

On the other side, in Slovak Danube tributaries Morava and Vah decreasing rates of the discharge were observed.

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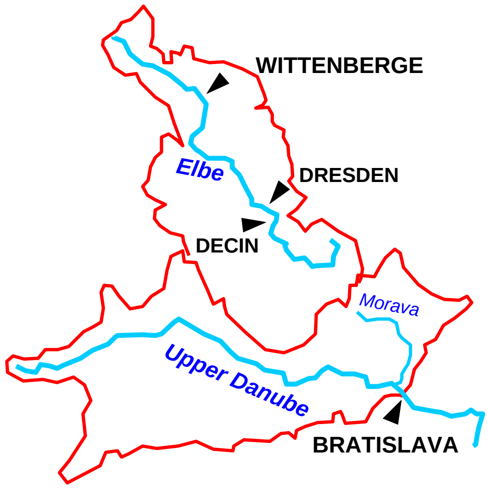
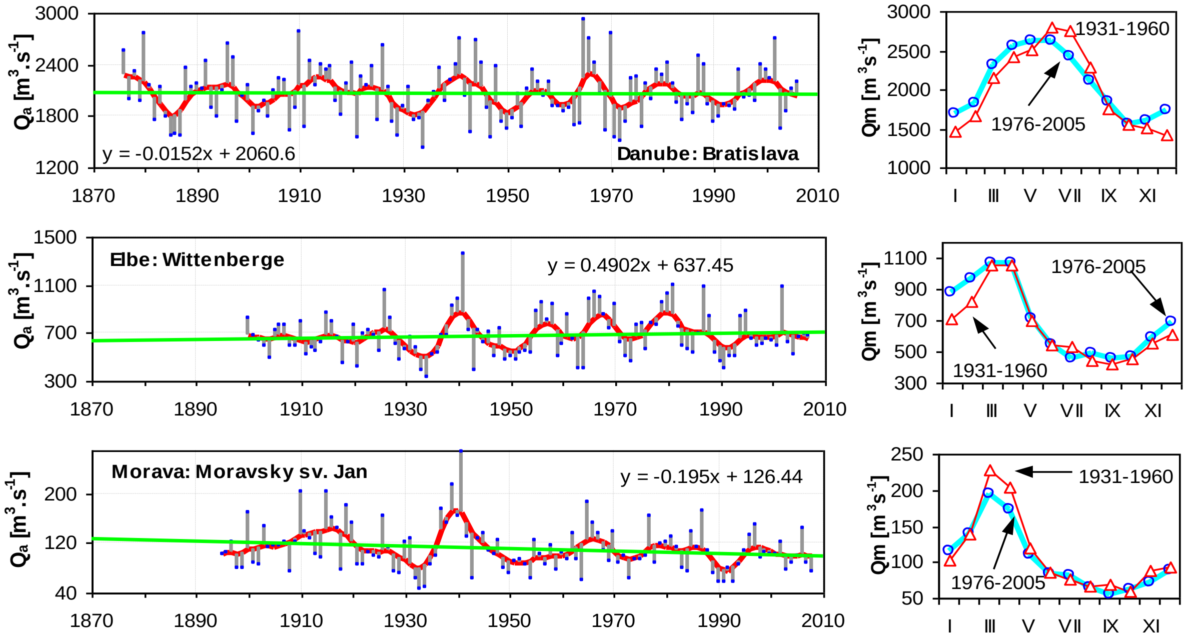


Figure 1. *Scheme of the Elbe and the Upper Danube River Basins*

Table 1. *Long-term mean annual and daily discharge characteristics of the Danube at Bratislava and Labe at Wittenberge. A – basin area; Q/q/R – long-term average annual discharge/specific yield/runoff depth; $Q_{d,min}$/Q_{dmax}- minimal/maximal daily discharge [m^3s^{-1}]; $Q_{m,nim}$/$Q_{m,max}$ - minimal/maximal monthly discharge [m^3s^{-1}]*

	A [km^{2}]	*Q* [m^3s^{-1}]	*q* [$l.s^{-1}km^{-2}$]	*R* [mm]	3 $Q_{d,min}$	4 $Q_{d,max}$	$Q_{m,min}$	$Q_{m,max}$
Danube: Bratislava	131338	2060	15.68	494.5	580	10810	633	7324
Elbe: Wittenberge	123532	678	5.49	173.1	120	3690	132	2345



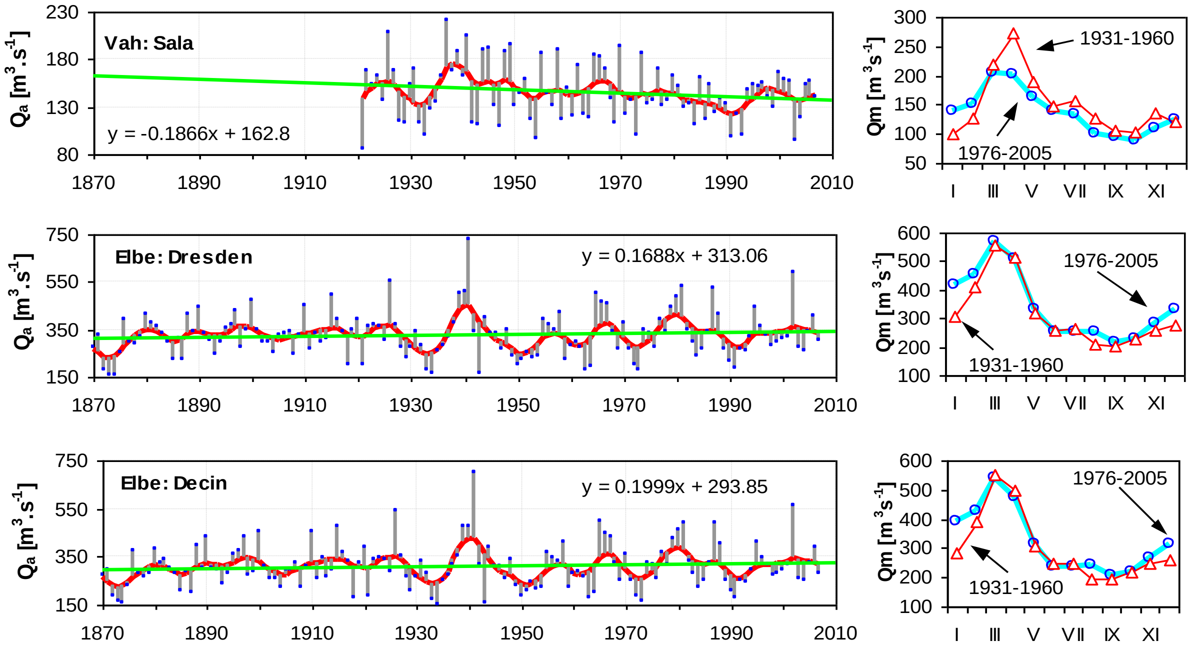


Figure 2. *Mean annual discharge at selected stations of the Danube and Elbe Basins during the whole observation periods (left panel) and comparison of the mean monthly runoff regime in two different 30-year periods (right panel).*

5 Multi-annual variability of runoff – Hurst phenomenon

More than 50 years ago, by the studies of long-term storage requirements on the Nile River, Hurst (1951) discovered a special behavior of the hydrological and other geophysical time series, which has become known as the “Hurst phenomenon”. This behavior is essentially the tendency of the wet years to cluster into wet periods, or of the dry years to cluster into drought periods (Lin & Lye, 1994).

The basic mathematical expression of this phenomenon can be written as: $R_n/S_n = (n/2)^h$; where R_n and S_n are the sample-adjusted range of cumulative departures from the arithmetical sample mean and the sample standard deviation, respectively, for a given time series of length n. Coefficient h denotes the Hurst coefficient. The Hurst parameter is commonly used as an indicator of the time-series' long-range memory, i.e. persistence (Markovic & Koch, 2006). A value $0<h<0.5$ corresponds to antipersistent, $h=0.5$ to white, and $0.5<h<1$ to correlated or persistent noise. Moreover, a time-series of $h=1$ is called pink noise, of $h=1.5$ brown noise, and of $h>1.5$ black noise. For precipitation and river discharge time series $0.5<h<1$ are most likely encountered. Hurst observed, that on average h = 0.73. The Hurst coefficient h of the average annual Danube discharge at Bratislava (1876–2005) is 0.59, of the Elbe River at Dresden 0.64.

In this part of the study, we focused on dry and wet multi-annual cycles identification of the annual runoff characteristics for the Danube River at Bratislava, Morava River at Moravsky sv. Jan, and Elbe River at Dresden and Decin. The multi-annual cyclic component of the average annual discharges was identified by auto-correlograms (Fig. 3) and spectral analysis. Figure 4 depicts combined periodograms (Pekárová, 2009) of average annual discharges. The spectral analysis confirmed that the occurrence of multi-annual cycles within dry and wet periods (in both basins) is of the following durations: 2.4; 3.6; 5-6; 7; 7.8; 10-11; 12-14; 20-22; and 28-30 years.

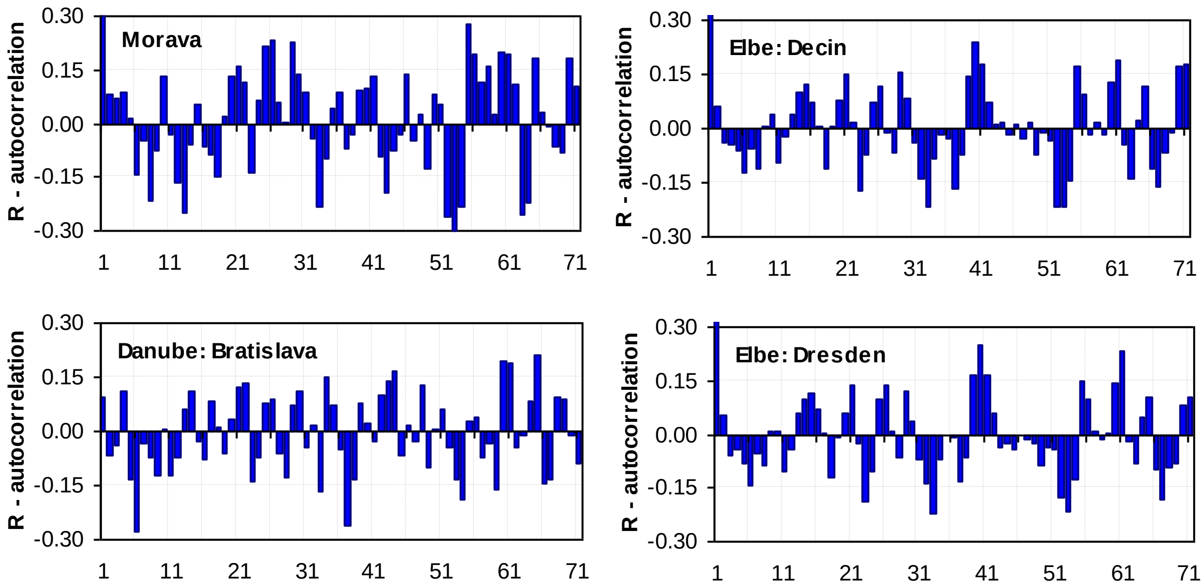


Figure 3. *The auto-correlograms of the average annual discharges of the Morava River at M. Jan; the Danube River at Bratislava; the Elbe River at Decin and at Dresden (time lag in years).*

6 Long-term discharge prognosis

To model the discharge time series, several linear autoregressive models were tested (Komornik et al., 2006; Mares et al., 2007; Pekarova et. al, 2008).

In Figure 5 is the example of the simulated mean monthly discharge of the Danube at Bratislava 15 years ahead using models PYTHIA and SARIMA (Pekarova & Pekar, 2006).

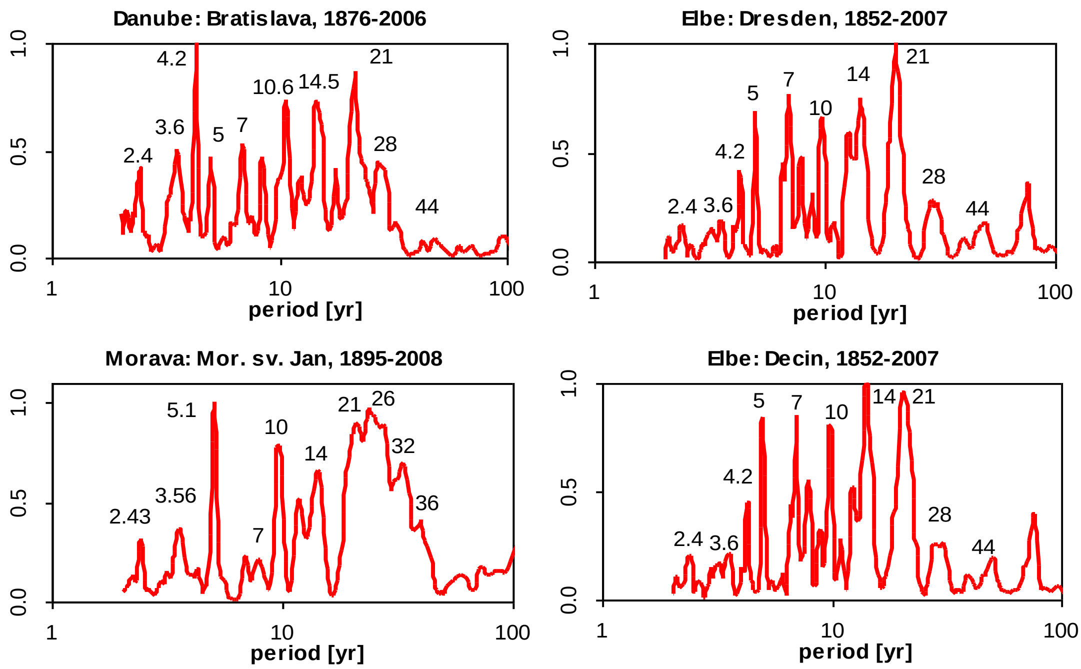


Figure 4. *The combined periodograms of the average annual discharges of the Morava River at M. Jan; the Danube River at Bratislava; the Elbe River at Decin and at Dresden.*

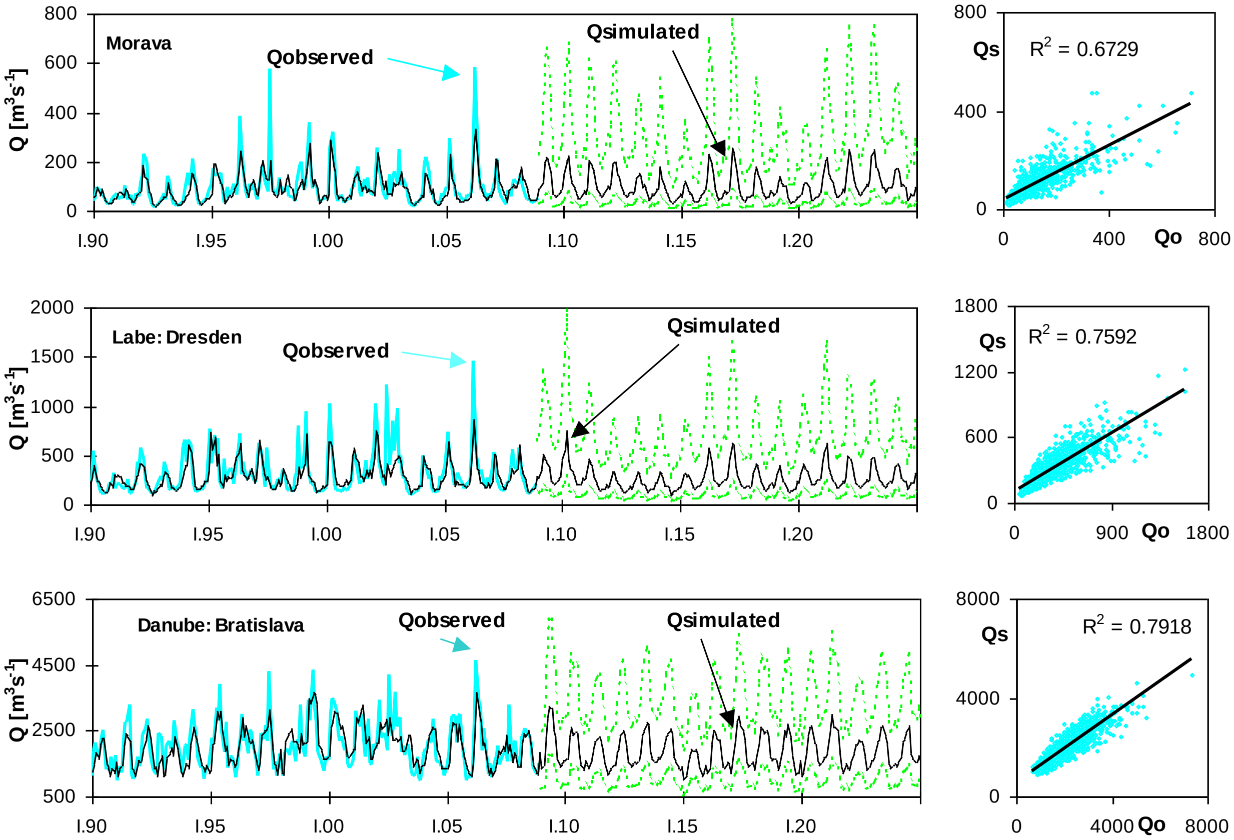


Figure 5. *Prediction of the mean monthly discharge of the Morava, Elbe, and Danube rivers, period 1990–2008 observed, period 2009–2025 simulation, model PYTHIA and SARIMA, Upper and lover 95% confidence interval. (left), observed Qo versus simulated Qs discharges (right).*

7 Conclusion

The mean annual discharge of the Danube at Bratislava is almost three times higher than the Elbe discharge at Wittenberge. The difference in low flows is even bigger. Therefore the Elbe Basin is much more sensitive to water pollution and water irrigation impacts than is the Upper Danube Basin.

In the long run, the annual discharges of the Danube at the Bratislava station do not change over time. The long-term trend in the annual discharges over the period of observations is near zero.

The occurrence of the dry and wet periods is the same in both basins. These cycles are related to global atmospheric oscillations such as NAO and AO phenomena, to the Solar activity, and to the thermohaline circulation (Pekarova, 2009). The most important component of a stochastic model is the identification of the correct cycle length.

The final part of the study presented some results of the long-term prediction of average monthly discharges 15 years ahead by applying stochastic models. The results of this study suggest that in 2010 increased discharge is likely to be observed. Beyond 2012 a dry period is expected to come in the Elbe.

We are fully aware of the high uncertainty that arises from the use of such stochastic predictive models. Efficiency of predictions decreases considerably with the extent of prediction. Further analysis of several more European rivers will, however, enable to explain the long-term discharge variability which nowadays remains unknown and thus it is considered a random variable in stochastic models. Efficiency of predictions is likely to improve in the future, thus models such as these presented in this study will be widely used in hydrological practice for monthly discharge series generation, design discharge determination, etc.

Acknowledgements

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The long daily discharge data series of Elbe River were obtained from the Global Runoff Data Center in Koblenz, Germany. The daily discharge series of the Danube River were obtained from the database of the UNESCO project No.9 “Flood Regime of Rivers in the Danube River Basin”.

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1D hydrological model as a predictive tool for the assessment of aquatic habitat changes in floodplain rivers

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Keywords: eco-hydrology, restoration ecology, ecological benchmarking, GIS habitat mapping, Danube, Szigetköz

1 Introduction

Activities that directly affected the natural system of the large floodplain rivers were usually associated with river regulations. The related problems are increasingly recognised in society and interest has grown in restoring of regulated rivers. This recognition is emphasized in the EU Water Framework Directive (EC 2000) in which the improvement of the “ecological status” of river systems is one of the central considerations.

The Szigetköz section of the Danube (rkm 1850-1794) is one of Europe’s last extensive inundated floodplains. River regulations have altered its natural geomorphologic processes and landscape dynamics since the end of the 19th century. The rehabilitation of river section is in the interest of several stakeholders, but the harmonisation of the stakes of hydropower utilization and nature conservation was difficult in the last decades. One of the main environmental objectives of rehabilitation is the re-modification of habitat structure for the revitalization of ecological functions of the river-floodplain ecosystem.

Predictions of changes of aquatic habitat structure in floodplains are essential for planners and decision-makers of river restoration programmes. In the frame of a preliminary ecological benchmark system developed for the evaluation of habitat changes in the Szigetköz (Guti et al. 2010), an assessment method was worked out to prognosticate the aquatic habitat structure according to the scenarios of rehabilitation measures. The present paper describes a method of habitat identification using results of a one dimensional (1D) hydrological model.

2 The study area

The Szigetköz floodplain is the right side of the extensive alluvial cone in the upper part of the Hungarian-Slovak section of the Danube, within the Kisalföld region (Little Danube Plain). Under undisturbed conditions the Danube changed its course on a broad scale forming a delta-like ana-branching channel pattern characterized by multiple channels, bars and unstable islands.

At the end of the 19th century, the modern time river regulations formed a unified and straitened main riverbed to ensure the navigation route. The wandering of the riverbed was stopped and the floodplain inundations were restricted with the construction of flood protection dikes. Further significant changes in the river section occurred by the construction of the Gabčikovo hydropower dam. Its operation started in 1992, and nearly 85 % of the river discharge was diverted to the hydropower bypass canal and the water level dropped 2-3 m in the floodplain branch-system. For mitigating the draining, a water replenishment system with the capacity of 40-180 $m^3 s^{-1}$ was created to provide a seasonally variable discharge supply

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for the branch-system, but the major connections between the main arm and the branches were blocked by weirs (Guti 2002).

Despite of mitigation measures environmental degradation was significant due to change in discharge regime and disconnection between the main arm and branch-system. Several scenarios were worked out for rehabilitation of the river-floodplain connectivity from the middle of the 1990s, for instance:

- *“3 weirs” variant*: water level elevation by construction of 3 weirs in the main channel, dredging of point bars, clearing defined floodplain areas, additional check dams in side branches, removal of some side-arm closures;
- *“narrowing” variant*: raising level of existing vegetated point bars by 2 m comprising 1/3 of the channel area, side-arm closures left;
- *“optimum filling” variant*: raising the bed level by 3-4 m in order to obtain average water levels of the 1950s at a discharge of 350 m^3s^{-1} in the main channel plus 80 m^3s^{-1} in side branches.

3 Methods

The ‘functional sets’ concept (Amoros et al. 1987) is one of the most extensive classification systems of the floodplain water bodies. It based on hydrological, hydro-morphological and ecological analysis and subdivides the floodplain water bodies into four main types called functional sets. In this study, the habitat typology follows the ‘functional sets’ concept and the definitions are used for the Austrian section of the Danube (Hohensinner et al. 2005) with minor modifications.

Table 1. *Definitions of the aquatic habitat types in the Szigetköz floodplain*

Habitat type	Definition
Eupotamon-A	Main stream
Eupotamon-B	Always connected side channels, with permanent flow
Parapotamon-A	Highly dynamic side arms, intact downstream connection, blocked upstream by bare gravel/sand deposits
Parapotamon-B	Less dynamic side arms, intact downstream connections, blocked upstream by vegetated deposits
Plesiopotamon	Isolated water bodies, close to the main channel, often connected
Paleopotamon	Isolated water bodies (oxbows in the meandering sector), seldom connected

The recent distribution of the aquatic habitats was analyzed using areal photographs and direct field observations. The future changes in structure and areal extent were predicted using results of 1D hydrological models produced by the MIKE 11 software according to the scenarios of the floodplain rehabilitation. Discharge, flow velocity and water depth data were used for habitat typology in the floodplain branch system. The habitat type (Table 1) of channel segments or individual beds were determined using the following key:

1) When the discharge input to the floodplain branch system is 40 $m^3\ s^{-1}$ (low water level),
   – The flow velocity in the bed is > 0 (flowing), the habitat type is *eupotamon-B*.
   – The flow velocity in the bed is = 0 (stagnant), …………………………………..... (skip 2)
2) The bed is stagnant, when the discharge input to the branch system is 40 $m^3\ s^{-1}$.
   – The minimum depth at the upstream or downstream end of the bed is > 0.…………(skip 3)
   – The minimum depth at the upstream and downstream ends of the bed is = 0 (disconnected), ……………………………………………………………………………………. (skip 4)

3) When the discharge input to the floodplain branch system is 80 $m^3 s^{-1}$,
   - The flow velocity in the branch is > 0, the habitat type is *parapotamon-A*.
   - The flow velocity in the branch is = 0, the habitat type is *parapotamon-B*.
4) When the discharge input to the floodplain branch system is 180 $m^3 s^{-1}$ (high water level),
   - The minimum depth at the upstream or downstream ends is > 0, the habitat type is *plesiopotamon*.
   - The minimum depth at the upstream and downstream ends is = 0 (disconnected), the habitat type is *paleopotamon*.

The 1D hydrological model was developed in 2009 by the EDUKÖVIZIG[2]. The 1D hydrological model does not cover all the side arms, 18% of them are outside of the model, mainly the *parapotamon-B* and the *plesiopotamon* type habitats. The results of the habitat classification are presented on GIS habitat maps and areal extent of the habitat types was computed using the ArcView 3.3 software.

4 Results

Flow velocities and discharge were calculated by the 1D hydrological model for all discharge scenarios. Graphs for the *3 weirs variant* (Figure 1) may demonstrate the results obtained in a similar way for the other variants.

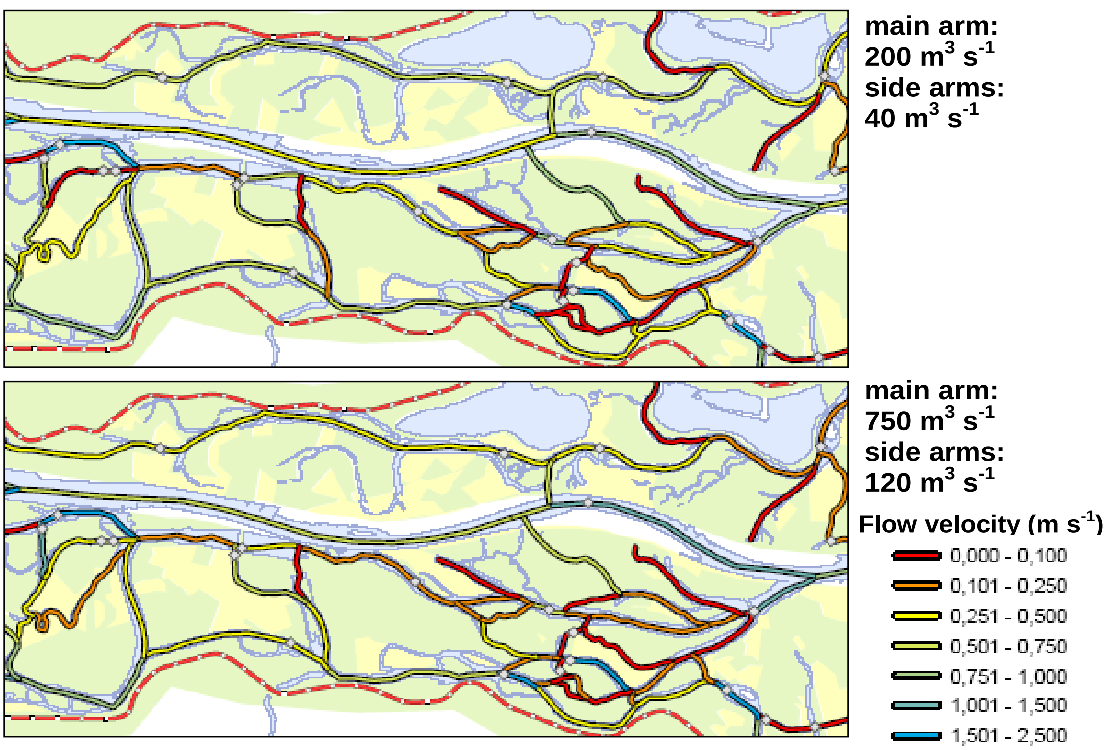

Figure 1. *Spatial distribution of 1D flow velocities for the "3 weirs" variant at different discharge in the upper part of the Szigetköz floodplain*

[2] EDUKÖVIZIG = North Transdanubian Directorate for Environmental Protection and Water Management

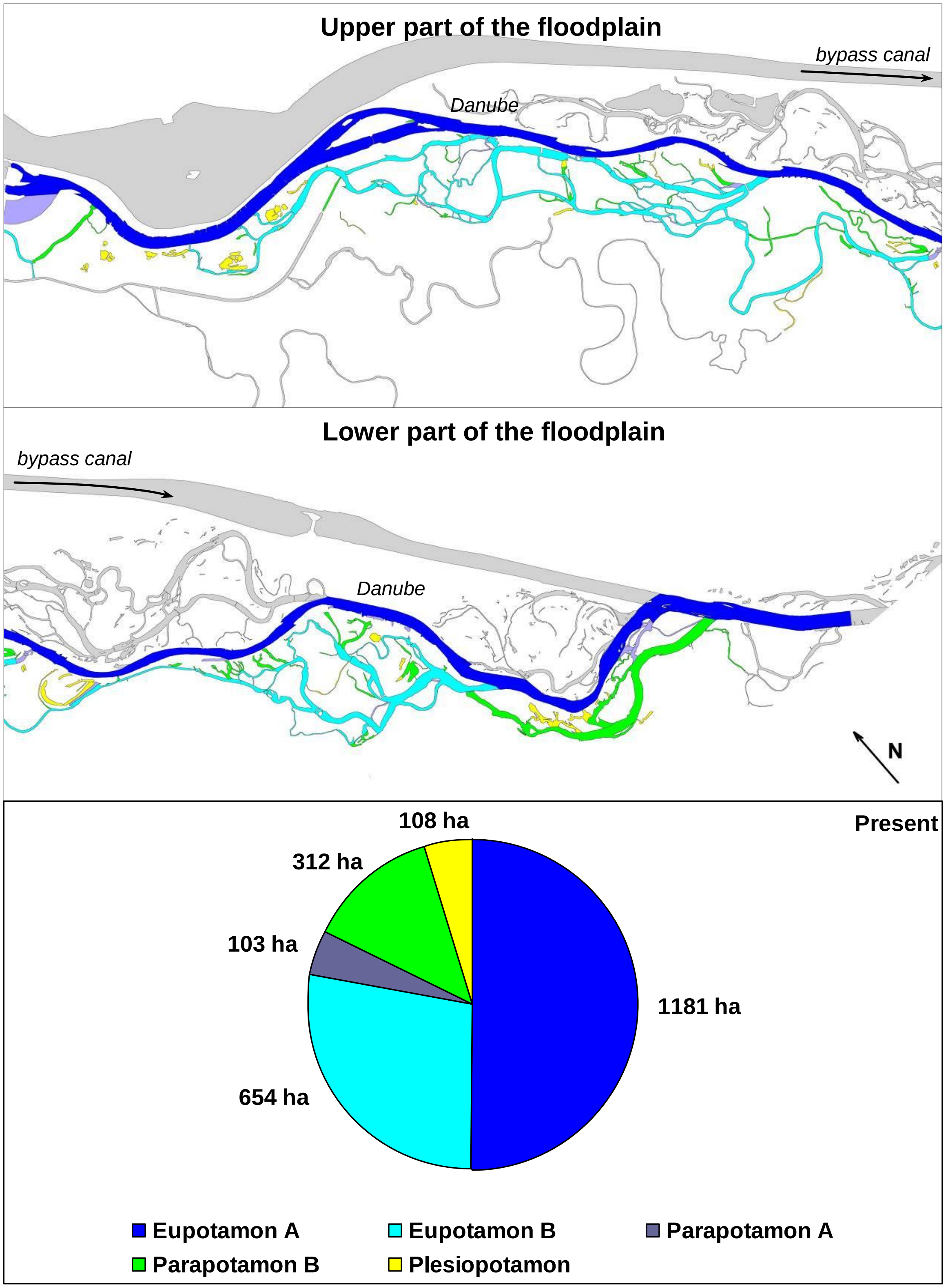

Figure 2. *Map and areal extent of the distribution of aquatic habitats along the active floodplain of the Szigetköz in 2008*

The calculated total area of the main arm and the branch system is 2360 ha on the right side of the active floodplain between Rajka and Sap. The eupotamon-A habitat type has the largest areal extent (50%), followed by the eupotamon-B (28%), parapotamon-B (13%), plesiopotamon (5%) and parapotamon-A (4%) (Figure 2).

The calculated proportion of the aquatic habitats indicates the probable alterations of the floodplain branch system according to the different rehabilitation measures. A decrease of the parapotamon-B habitats is verifiable in case of the 3 weirs variant, but the narrowing and the optimum filling scenarios do not significantly alter the recent ratio of the main habitat types (Figure 3).

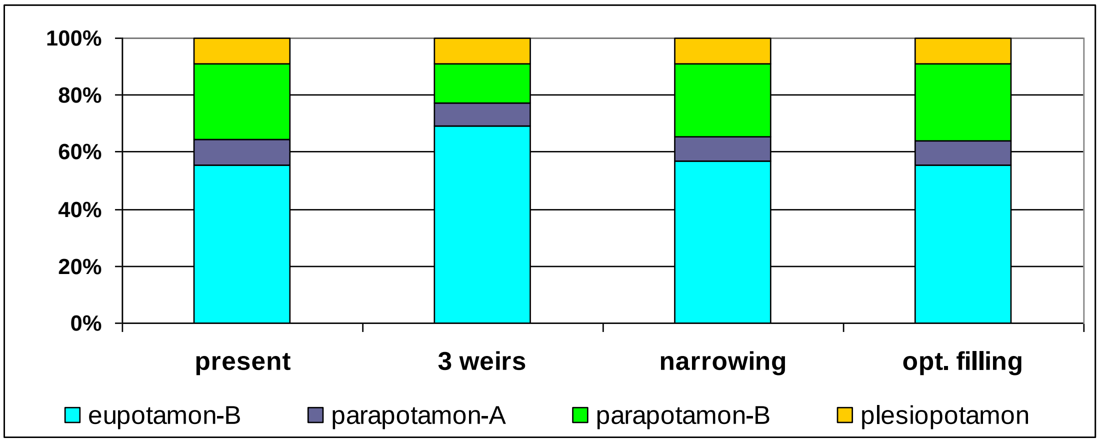

Figure 3. *Comparison of the aquatic habitat structure in the floodplain branch system of the Szigetköz section of the Danube between the present situation and the different scenarios of rehabilitation*

5 Conclusion

The 1D hydrological model is a useful tool for river restoration programmes to predict the future composition of the main habitat types in the floodplain side arm systems. The distribution of flow velocities and discharge over space and time are the most important factor for identification of the *eupotamon-B, parapotamon-A, parapotamon-B, plesiopotamon* type habitats. The connectivity of the side arms can be estimated by the longitudinal distribution of the water depth.

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Status, distribution and infection rate of the invasive crayfish species, *Orconectes limosus*, in the river Danube and its tributaries in Hungary

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Keywords: crayfish, Orconectes limosus, biological invasion, distribution, crayfish plaque

1 Introduction

The introduction of non-indigenous species is one of the most important anthropogenic impacts on freshwater ecosystems with many direct and indirect effects on native taxa. Introduced species can cause the degradation of natural habitats, alter species assemblages and trophic structure, displace or decimate native species (Aldridge et al. 2004; Gratton & Denno 2005). Simultaneous interactions such as competition and predation significantly influence the process of degradation (Mills et al. 2004). Among other invasive groups, such as plants, mussels and fish, also crayfish have important ecological impacts on aquatic ecosystems. Despite this, they have been often introduced outside their native ranges, either by deliberate stocking or even by bait bucket releases (Hobbs et al. 1989). Non-indigenous crayfish species (NICS) in Europe now outnumber indigenous crayfish species (ICS) by 2:1, and it has been predicted that they may dominate completely in the next few decades unless efficient methods of control are established to mitigate or stop their spread (Holdich et al. 2009). A decline in stocks of ICS has been recorded in many countries due to habitat loss, deteriorating water quality, overfishing, climate change, and most importantly from NICS and crayfish plague. The threat to ICS is so great in some countries that "ark" sanctuary sites are being established (Holdich et al. 2009). One of the three most widely-spread NICS in Europe is the North American spiny-cheek crayfish, *Orconectes limosus* (Rafinesque, 1817).

Orconectes limosus was introduced to Europe in 1890. By today, it is recorded from 20 countries in that continent (Holdich et al. 2009). It is particularly common in Western, Central and Eastern Europe. A proven vector of crayfish plague, caused by the fungus-like organism *Aphanomyces astaci* Schikora, this species is thought to have been responsible for the demise of many populations of ICS in Europe (Holdich et al. 2006). According to Puky & Schád (2006) it tends to inhabit the lower stretches of rivers and their tributaries. In consequence, populations of ICS in the upper stretches might be safe and not affected. *O. limosus* is less sensitive to land use changes and human activities than ICS (Schulz et al. 2002), and it can withstand habitats unfavourable to the ICS such as soft substrates, turbid and muddy waters, polluted canals and organically enriched ponds and lakes (Puky 2009). *O. limosus* can spread rapidly in different parts of Europe with strikingly different environmental conditions such as the Baltic region (Burba 2008, Holdich et al. 2009) as well as Central and Eastern Europe along the River Danube and its tributaries (see e.g. Hudina et al. 2009 for Croatia, Jansky & Kautman 2007 and Puky 2009 for Slovakia, and Pârvulescu 2009 and Pârvulescu et al. 2009 for Romania).

This article summarises the current knowledge on the status, distribution and also on the infection rate of *Orconectes limosus* by the crayfish plague pathogen in Hungary.

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2 Material and methods

The distribution of *O. limosus* was investigated in several sections of the River Danube, Tisza and Ipoly and the Sió canal. Active diurnal searches by turning stones and checking holes and trapping were used to prove the presence of the species. Besides crayfish-oriented surveys, valuable observations or collections were also made during the study trips of the Hungarian Danube Research Station staff along the River Danube and its backwaters. Several crayfish specialists were interviewed and other experts (e.g. ichthyologists) were contacted to incorporate their observations into the data base together with the available literature. In those investigations crayfish were caught by hand, netting, diving and dredging and also by electrofishing during ichthyological surveys (for more details see Puky et al. 2005).

Individuals collected for testing the presence of crayfish plague pathogen were kept separately while transported to the laboratory and stored deep-frozen at -80 °C. We used molecular method according to Oidtmann et al. (2006) to detect latent infection with *A. astaci* in some crayfish. DNA was extracted from soft abdominal cuticle of each tested individual and semi-nested PCR protocol was followed to amplify a species-specific fragment of ITS (internal transcribed spacer) in the rDNA region.

3 Results and discussion

It has been estimated that between one-third and one-half of the world's crayfish species are threatened with population decline or extinction (Taylor 2002). In Europe, NICS play an important role in decline of local species, especially as they carry and spread the crayfish plague pathogen, which is listed in the top 100 of the "World's Worst" invaders by the International Union for Conservation of Nature (IUCN) (Lowe et al. 2000).

Table 1. *Abundance and infection rate of O. limosus along different rivers in Hungary*

	Distribution	Abundance	Infection rate	Literature
River Danube	present from the Danube Bend to the southern border, also in tributaries, canals	high at some localities	The presence of *A. astaci* was proved, ratio of infected individuals varied	Puky et al. (2005), Puky & Schád (2006), Thuránszky & Forró (1987)
River Ipoly	gradually spreading north	low	No infection was proved	Jansky & Kautman (2007), Puky (2009)
River Tisza	present in the middle stretch	low	No investigation was carried out	Sallai & Puky (2008)
River Dráva	present in the Karasica stream	most abundant decapod	No investigation was carried out	Horvai et al. (2010)

The occurrence of *O. limosus* has been proved in the River Danube, River Ipoly, River Tisza, the Sió canal and canals in the Great Hungarian Plain (Table 1.). The species is known to be present in the River Danube since 1985 (Thuránszky & Forró 1987). *O. limosus* has established dense and successfully reproducing populations in Danubian side arms and even on dikes. In the River Tisza *O. limosus* is known to be present from the late 2000s along the middle stretch near the Kisköre reservoir (Sallai & Puky 2008). The Sió canal plays a special role in the Carpathian Basin connecting Lake Balaton to the River Danube. *O. limosus* moved there upstream from the river but no records are known from Lake Balaton so far. *O. limosus* exists in a large number of individual canals in the Great Hungarian Plain, some connected to the River Danube, others in the aquatic system of the River Tisza. The localities are spread over a large area with at least 250 km between the populations furthest from each other.

Aphanomyces astaci is present in populations of *O. limosus* along the Hungarian stretch of the River Danube. The highest infection rate was detected south of the Danube Bend, close to the site of the first record of the species for the country. No information is available on the potential infection by *A. astaci*, or population densities in the River Tisza or in the canals.

Large rivers such as the Danube or the Elbe function as natural migration corridors for freshwater invasive species such as *O. limosus*, which colonised the catchments of both rivers (Petrusek et al. 2006). The presence of this invasive species is suspected to be related to recent crayfish plague outbreaks affecting NIC populations in the Czech Republic (Kozubíková et al. 2008). Kozubíková et al. (2009) found that a high percentage, but not all individuals were infected in recent mortalities of indigenous species. This phenomenon may also be true for Hungary. It is likely that the rapid spread of this species in the River Danube and elsewhere in Hungary may be enhanced by deliberate introductions making the colonisation process faster and less predictable. Though ICS have been found co-existing with *O. limosus* in large rivers in Austria where the habitat diversity, discharge and current velocity was high and crayfish density was low (Pöckl & Pekny 2002), their protection is urgently needed. This would require practical measures including stricter regulation and control of introductions together with an information campaign.

Acknowledgments

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Mean residence time (MRT) of baseflow water in the Upper Danube Basin derived from decadal climatic signals in long-term isotope records of river water

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Keywords: Danube, isotope hydrology, climatic change, mean residence time (MRT), oxygen 18 (^{18}O)

1 Introduction

Tracing of hydrological processes by isotope investigations of river water is an actual research trend in isotope hydrology (Gibson et al. 2002). Main topic is the formation and age structure of baseflow (groundwater contribution to river discharge). Knowledge of the residence time of water in a catchment is necessary for a sustainable management of water resources. This paper describes a first attempt to determine the mean residence time (MRT) of water in a catchment by using decadal climatic signals in the $\delta^{18}O$ time series of a large river; the long-term $\delta^{18}O$ record of the Danube at Vienna serves as data base (Figure 1, see also Papesch & Rank 2010).

Long-term stable isotope records of precipitation water exhibit significant decadal changes in the isotopic composition of H and O (Figure 2, Rozanski & Gonfiantini 1990, Kaiser et al. 2001, Rank & Papesch 2005). Isotope ratios in river water are mainly determined by the isotopic composition of the precipitation water in the drainage area (continental effect, altitude effect, seasonal variations, storms; see e.g. Mook 2000, Rank & Papesch 2005). Several hydrological parameters and processes are modifying this isotopic signature and its temporal variations: delayed runoff of winter precipitation (snow cover), residence time of groundwater discharged to the river, confluence with tributaries, evaporation from lakes in the river system, climatic changes (changes in environmental temperature, spatial and temporal changes of precipitation distribution in the drainage area etc.) as well as anthropogenic influences on the hydrological regime (e.g. reservoirs, water abstraction for irrigation).

Since evaporation has minor influence on the isotopic composition in river water it can be neglected in most parts of the Danube Basin (Rank et al. 2009). Hence, isotopic signals of precipitation water are transmitted through the whole catchment and reflected in the isotopic record of river water. A comparison of long-term stable isotope records of precipitation and river water, therefore, should provide information on the residence time of precipitation water in the catchment.

2 Determination of MRTs using decadal climatic signals in long-term $\delta^{18}O$ time series of river water

The long-term $\delta^{18}O$ trend of several Austrian rivers – Danube tributaries and the alpine section of the Rhine – is similar to that of the Danube (Figure 3). Thus one can conclude that this trend in the order of decades represents a general climatic long-term isotopic signal – input from precipitation – in all hydrological systems. This suggests to use this signal for the determination of water ages (MRTs) in a similar way like tritium input by nuclear weapons in the past.

As a first attempt we compared $\delta^{18}O$ trends of precipitation and Danube water from Vienna on the basis of 10-year averages (Figure 4). Thus short-term and seasonal variations play only a minor role, short-term

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(event) $\delta^{18}O$ signals (maxima and minima) are eliminated by averaging (see also Figure 3). $\delta^{18}O$ time series of four precipitation stations of the Austrian Network for Isotopes in Precipitation (ANIP) were used for an average input signal: two lowland stations (Vienna 230 m asl, Bregenz 430 m), one medium-altitude station (Feuerkogel 1618 m) and one high-altitude station (Patscherkofel 2245 m, see Figure 2). Absolute values and amplitudes of the average input signal are in agreement with those of the Danube signal (Figure 4).

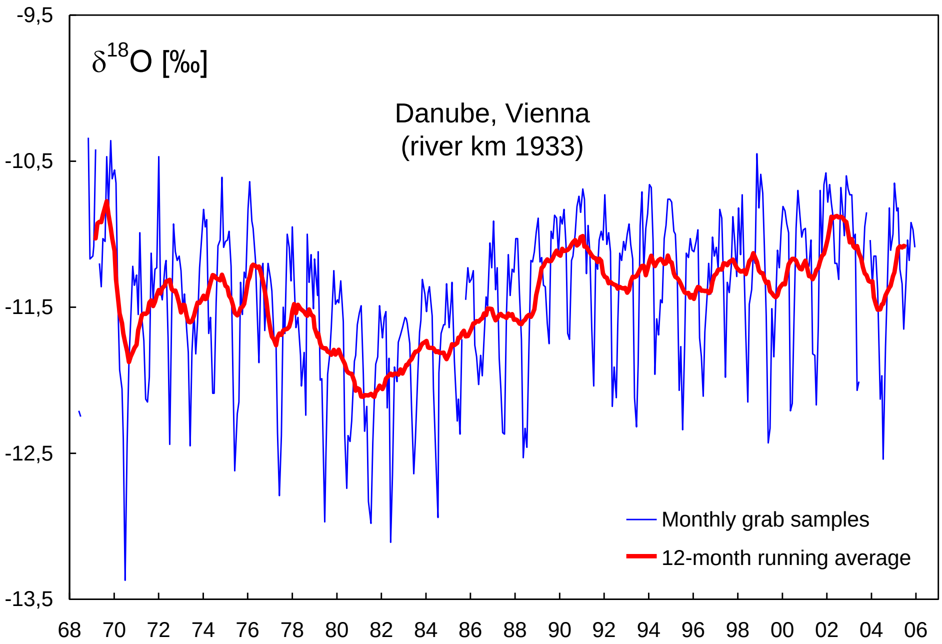

Figure 1. *$\delta^{18}O$ time series of the Danube at Vienna (monthly grab samples, 12-month running average) (Rank & Papesch 1996, updated). The $\delta^{18}O$ pattern reflects the general $\delta^{18}O$ trend of precipitation in Central Europe (Figure 2).*

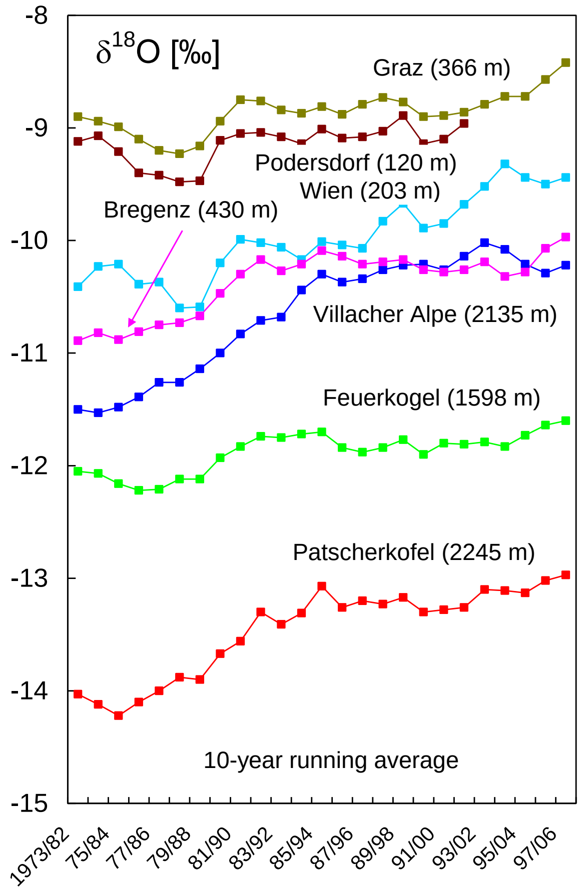

Figure 2. *Long-term $\delta^{18}O$ trend at several stations of the Austrian Network for Isotopes in Precipitation (ANIP) (Rank & Papesch 2005, updated). Mountain stations show lower $\delta^{18}O$ values than valley stations (altitude effect), stations with significant Mediterranean influence (e.g. Villacher Alpe and Graz) higher values than stations with predominant Atlantic influence (e.g. Patscherkofel and Bregenz, continental effect). The general increase of $\delta^{18}O$ values during the last decades is mainly a consequence of the increasing environmental temperature. But also changes in the seasonal distribution of precipitation may play some role (winter precipitation has low, summer precipitation has high $\delta^{18}O$ values). This climatic signal – especially the significant $\delta^{18}O$ increase during the 1980s - is more pronounced in mountain regions.*

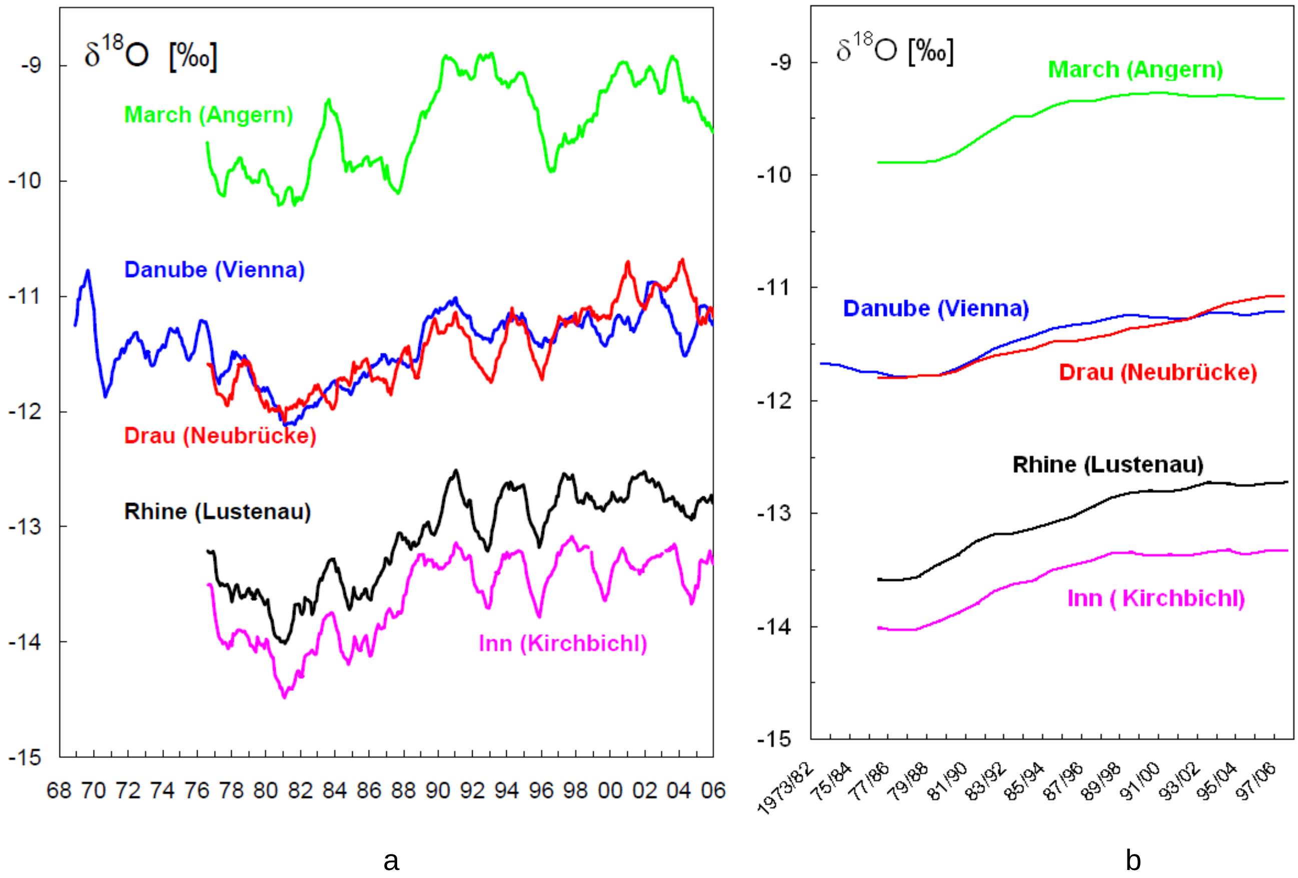

Figure 3. *Long-term δ^{18}O trend in Austrian rivers: (a) 12-month and (b) 10-year running averages*

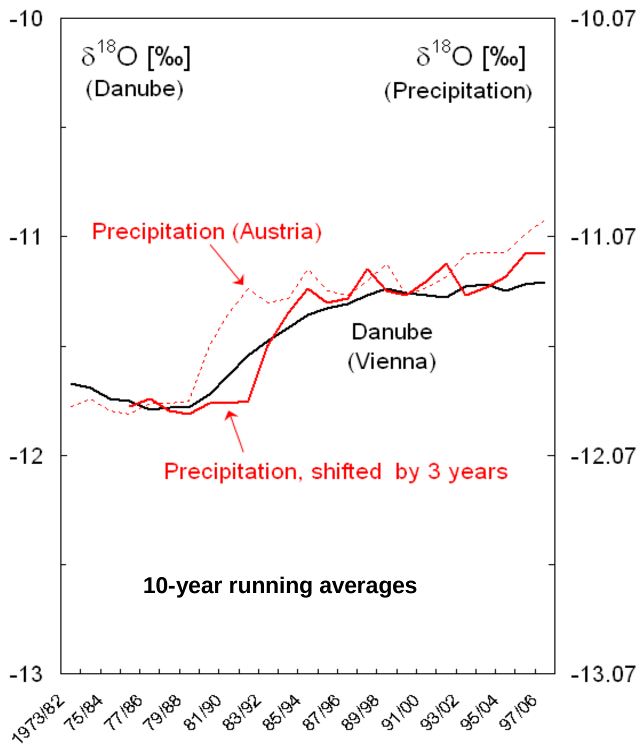

Figure 4. *Comparison of δ^{18}O long-term trends in precipitation in Central Europe and in Danube water at Vienna.*

The best agreement between the two $\delta^{18}O$ trend curves could be achieved with a shift of the precipitation curve (input) by about 3 years (Figure 4). In a simple model concept this corresponds to a MRT of the water in the drainage area of about 3 years. The smoother signal in the Danube reflects the age distribution of river water. As mentioned before, short-term influences were eliminated by 10-year averaging, thus the calculated MRT of about 3 years represents mainly baseflow from the Upper Danube Basin.

It must be emphasized that the MRT of about 3 years found out from $\delta^{18}O$ time series corresponds well with the value calculated from tritium time series of river water (Rank et al. 1998). This good agreement confirms that reasonable MRT values can be achieved by using long-term $\delta^{18}O$ signals.

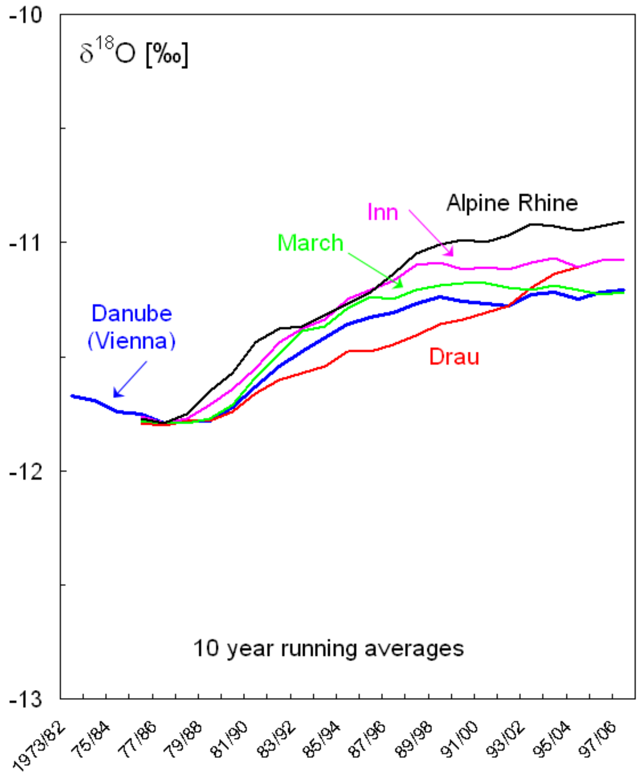

Figure 5. *Comparison of $\delta^{18}O$ long-term trends in Austrian rivers ($\delta^{18}O$ scale is valid for the Danube. The scale for the other rivers is shifted in order to get the same $\delta^{18}O$ baseline in 1986).*

Although different Austrian rivers exhibit a similar $\delta^{18}O$ trend, a closer look at the time series shows a few characteristic differences (Figure 5). The decadal climatic signal is more pronounced in rivers with high-alpine drainage areas (rivers Drau, Inn, Alpine Rhine) than in the Danube and in lowland rivers (March). This corresponds to precipitation where $\delta^{18}O$ variations are more pronounced at mountain stations than in the forelands (Figure 2).

The Drau River shows a much slower $\delta^{18}O$ increase (= higher MRT) than the other rivers (Figure 5). The existence of some reservoirs in the river system could be the reason for this, but also a greater influence of glaciers than in other catchments cannot be excluded.

3 Conclusions and outlook

Long-term records of stable isotopes in precipitation exhibit significant decadal climatic signals (more pronounced in mountainous regions). These signals are reflected in the isotope records of hydrological systems, if other influences like evaporation effects have minor influence on the isotopic composition. This is the case for most parts of the river system in the Danube Basin.

The temporal shift of significant sections in isotope records of hydrological systems can be used to determine the MRT (age) of water in the system. First evaluations show a shift of about 3 years for the climatic signal in Danube water at Vienna, most probably the MRT of baseflow water (groundwater discharge to the river) in the Upper Danube Basin. Typical alpine rivers – e.g. Inn, alpine section of the Rhine – exhibit a more pronounced climatic signal, the time-shift of the signal is similar to that of the Danube (except River Drau). The age distribution – residence time of river water in the catchment – is responsible for the shape of the signals in river water.

Decadal stable isotope signals may be used to determine MRTs of river and groundwaters by model calculations in a similar way like tritium input by nuclear weapons in the past. Such applications require long-term isotope records for the investigated water bodies. In this respect, ongoing activities of the Section of Hydrology of the IAEA to establish a global network for isotopes in rivers (GNIR) are an interesting initiative to make more long-term isotope records of river water available. The hydrological use of climatic signals is a strong argument to run networks of isotopes in precipitation and hydrological systems also in the future.

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Comparative assessment of the ecological state of sediments in the Ukrainian part of the Danube Delta and Dnipro and Boh Estuary

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Keywords: Danube delta, Dnipro and Boh estuary, sediments, toxicity, bio-indication.

1 Introduction

As a result of their unique physical, hydrological and biological conditions, deltas and estuaries are among the most diverse, productive, and ecologically important ecosystems. Conversely, estuaries often serve as a sink for many types of anthropogenic contaminants, including organic pollutants and heavy metals. In this investigation, the sedimentary environments of a large Ukrainian delta and estuary were compared by using chemical analysis, sediment toxicity testing, and bio-indicators based on benthic community indices[4].

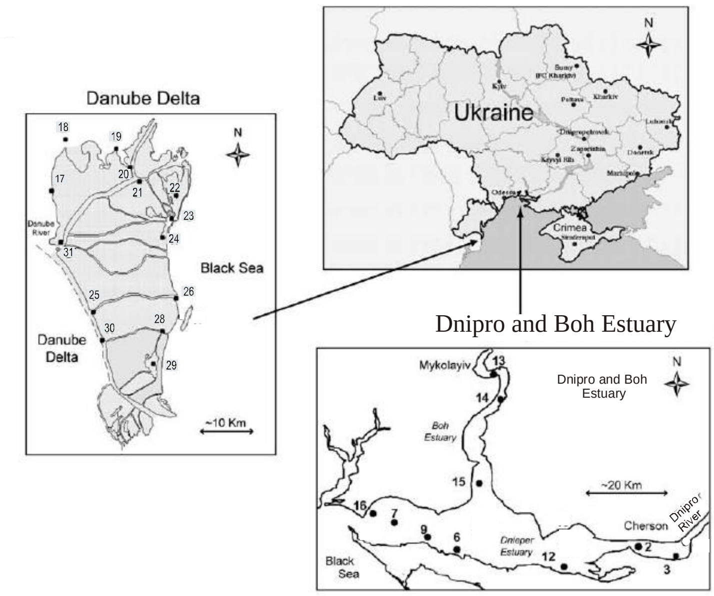

Figure 1. *Sampling sites*

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4 The study was carried-out with support from the United States Department of State and Environment Protection Agency under the project "Development and Application of Diagnostic Tools for Identifying Causes of Environmental Impairments in the Estuarine Systems of Ukraine"

2 Methods

Sediments were collected in September–October 2006, 2007 and 2008 in the Dnipro and Boh Estuary and in the Ukrainian part of the Danube Delta (24 stations with three replicates at each station, Figure 1).

Methods of sediment sampling, chemical analysis, sediment toxicity testing, and procedures for benthic community analysis have been reported previously (Ho *et al*., 2000; Romanenko 2006; Romanenko *et al*., 2008; Burgess *et al*., 2009). To evaluate the risk of adverse effects on biota the measured contaminant concentrations in sediments were compared with consensus-based sediment quality guidelines (MacDonald *et al*., 2000). The mean overall probable effects concentration-quotient (PEC-Q) attempts to predict the adverse effects of contaminated sediments by combining the expected effects of all measured contaminants for which PECs are available (Long *et al.* 2006).

3 Results

3.1 Contaminant concentrations

The three-year investigation demonstrated that the sediments in the Ukrainian Danube Delta and the Dnipro and Boh Estuary are less polluted compared to the most contaminated marine and estuarine sediments of the world (Ho *et al*., 2002, Burgess *et al*. 2009). For example, even the most polluted Ukrainian stations were considerably less contaminated than sites in North America and Asia. Our sediments were moderately contaminated, with most Danube Delta stations showing higher concentrations than in the Dnipro and Boh Estuary (Table 1). However, Station 2 (at the mouth of the Veriovchiha River) which receives industrial and municipal waste waters from the City of Cherson is characterized by very high concentrations of Zn, Cu, Cr, Cd and Ag, with levels up to ten times greater than at other stations.

Table 1. *Concentration ranges for contaminants in sediments collected in 2006, 2007 and 2008.*

Station	Concentration (mg/Kg)										
	Zn	Cu	Ni	Pb	Cr	Cd	Ag	Mn	∑ PAHs	∑PCB	∑pesticides
The Dnipro and Boh Estuary											
2	650.0-1481.0	137.5-228.0	24.0-50.0	4.8-100.0	369.0-384.0	4.70-10.00	2.00-7.60	368-531	80-33303	186.4-25.0	39.4-209.0
3	35.0-61.7	38.8-65.0	4.2-7.5	23.0-71.0	8.4-95.0	0.10-2.70	0.03-0.06	111-194	803-1488	1.3-36.0	6.8-27.7
6	2.5-129.0	0.7-28.0	2.2-16.8	1.5-70.0	0.8-15.1	0.01-0.10	0.01-0.14	5-138	146-5775	0.7-25.9	4.1-30.8
7	55.2-74.0	14.2-25.5	12.8-32.0	10.0-61.0	31.5-165.0	0.10-0.50	0.07-0.11	276-415	1378-5205	2.3-27.2	12.0-23.4
9	4.5-13.1	0.9-4.2	<0.8-3.8	1.2-2.5	1.3-7.5	0.02-0.03	0.02-0.03	19-20	83-8298	1.2-31.3	4.5-27.1
12	7.5-21.6	2.4-80.0	1.4-7.3	2.0-22.3	3.8-20.0	0.02-0.23	0.03-0.13	58-130	303-1227	0.6-8.7	6.3-21.8
13	7.3-9.8	1.7-6.5	1.0-9.8	1.8-11.8	3.6-25.0	0.01-0.11	<0.01-0.05	34-52	73-227	0.5-31.0	7.2-17.1
14	18.0-190.0	6.0-82.5	3.5-40.7	0.8-52.3	7.5-185.0	0.03-0.70	0.02-0.45	108-100	215-1460	1.1-65.1	14.0-59.4
15	10.5-15.5	3.0-9.0	1.5-9.5	0.7-27.3	5.6-25.0	0.02-0.20	0.01-0.23	74-75	655-1258	0.6-7.3	6.5-15.0
16	1.5-23.5	1.5-6.2	0.8-11.0	1.3-25.8	3.0-16.2	0.01-0.04	<0.01-0.25	21-302	96-397	0.3-41.2	2.0-19.0

The Ukrainian part of the Danube Delta											
17	90.8-98.5	32.2-55.0	21.9-42.0	10.3-56.6	34.3-130.0	0.33-0.55	0.06-0.10	316-356	251-2238	4.4-17.5	20.7-45.2
18	28.8-97.0	3.7-35.6	11.3-46.0	6.3-56.0	17.2-87.5	0.15-0.34	0.03-0.25	166-454	279-1400	6.2-15.5	4.7-19.6
19	35.0-50.6	11.3-29.0	13.8-46.0	4.8-45.8	20.7-40.0	0.05-0.16	0.03-0.05	180-390	73-700	3.1-75.3	11.5-36.2
20	47.5-142.0	10.0-46.0	18.5-59.0	5.3-70.0	52.2-60.0	0.10-1.42	0.07-0.17	484-700	278-4423	0.7-43.2	7.4-178.0
21	94.0-112.0	32.0-45.0	23.5-44.0	8.8-55.1	34.0-140.0	0.22-0.50	0.05-0.16	342-416	377-2337	12.2-81.3	0.6-65.9
22	99.0-104.0	37.0-40.2	21.3-45.0	9.5-66.7	34.4-137.5	0.25-0.50	0.05-0.15	342-458	504-3317	15.3-32.8	0.6-33.1
23	29.4-108.0	3.3-35.0	12.7-52.0	2.5-47.2	15.5-60.0	0.05-0.22	0.03-0.17	110-556	73-816	4.2-68.8	10.4-48.3
24	23.8-139.0	9.8-59.0	4.0-51.0	71.4-1.3	39.4-57.5	0.08-0.61	0.15-0.22	353-516	1850-4991	5.7-73.4	49.5-82.2
25	22.3-118.0	5.0-40.0	16.0-59.0	1.8-68.0	42.5-56.4	0.05-0.44	0.05-0.16	375-722	234-1718	0.4-12.1	1.2-80.1
26	28.8-85.0	7.3-30.0	11.3-39.0	3.0-43.6	20.4-115.0	0.11-0.58	0.03-0.18	119-386	320-1107	1.0-10.2	5.2-69.8
28	88.2-108.5	27.0-34.3	21.0-42.5	10.0-59.2	37.8-105.8	0.19-0.30	0.11-8.00	339-472	266-4495	1.3-20.8	17.2-51.0
29	57.5-74.0	16.0-25.1	22.4-33.8	6.5-34.8	31.7-100.0	0.13-0.33	0.06-0.18	296-379	415-1512	1.1-64.0	12.1-209.4
30	67.7-90.0	0.8-26.0	19.5-42.0	7.5-65.0	34.6-36.2	0.17-0.20	0.05-0.11	304-391	215-825	2.9-6.5	18.2-46.6
31	87.5-118.0	31.8-51.0	26.5-55.0	12.0-69.2	46.2-130.0	0.25-0.42	0.08-0.21	368-741	279-1805	3.3-24.8	0.4-99.7

3.2 Sediment Toxicity Testing

Toxicity tests in sediments showed consistently low survival of midges and Daphnia at only two stations (i.e., Station 2 and 29, Table 2). On average for both estuaries, the survival rate of midges (*Camptochironomus pallidivittatus*) and water fleas (*Daphnia magna*) exceeded 75%, which suggests relatively low sediment toxicity.

4 Benthic Community Analyses

Species richness and Shannon diversity indices for benthic assemblages at all stations varied significantly (Table 2). Minimum values for zoobenthos were registered at Station 2 and maximum values at Station 3; for phytobenthos, minimum indices were registered at Stations 23 and 24, while maximum values were recorded at Station 6. The Dnipro and Boh Estuary was mainly characterized by β-α-mesosaprobity (except Station 2 which was polysaprobic); the Danube Delta prevailingly by α-mesosaprobity and polysaprobity (Stations 18, 19, 22, 24, 26, 29). The maximum Woodiwiss index for the Dnipro and Boh Estuary equalled 4–7 and for the Danube Delta 2–6. The Mayer index was 3–16 and 2–10 for the Dnipro and Boh Estuary and Danube Delta, respectively.

Table 2*. Results of sediment toxicity testing and benthic community analysis (three-year ranges are shown). zb – macrozoobenthos, phb – phytobenthos, R – species richness richness, H' – Shannon diversity index, P&B – Pantle and Buck index, TBI – Woodiwiss index.*

Station	Toxicity Testing Results		Benthic Community Indices							
	Midges survival, %	Daphnia survival, %l	R, zb	R, phb	H', zb	H', phb	P&B, zb	P&B, phb	TBI	Mayer index
The Dnipro and Boh Estuary										
2	43.3-80.0	46.7-86.7	2-11	36-52	0.00-2.97	1.69-4.03	2.98-3.60	1.72-2.35	1-5	1-11
3	46.7-96.7	75.0-100.0	22-32	24-44	3.79-4.70	1.65-2.32	2.22-2.56	0.38-2.04	5	4-11
6	83.3-90.0	80.0-95.0	7-10	26-55	2.66-3.03	2.99-4.45	1.68-3.23	1.76-2.02	1-4	1-9
7	73.3-93.3	46.7-73.3	6-8	26-29	0.97-2.81	2.07-2.70	2.18-1.42	1.81-1.82	3-4	3
9	80.0-90.8	75.0-93.3	4-12	33-45	1.35-3.35	2.78-3.91	2.15-2.34	1.74-1.88	2-4	2-5
12	23.3-90.0	70.0-86.7	15-23	23-45	2.73-3.99	2.35-3.48	2.34-2.79	1.89-2.57	4-5	2-10
13	52.5-90.0	80.0-100.0	17-18	24-42	3.17-3.52	2.41-4.12	2.32-2.99	1.87-1.96	4-5	3-10
14	55.0-97.5	80.0-100.0	18-31	23-45	2.43-3.95	1.76-2.83	2.60-3.06	1.32-2.12	2-5	2-4
15	80.0-97.5	90.0-100.0	8-21	19-36	1.38-2.82	0.74-2.79	2.76-2.91	1.56-2.16	4-7	3-12
16	63.3-93.3	70.0-100.0	14-26	25-43	2.68-3.28	2.09-4.19	1.87-2.96	1.60-2.08	4-6	6-16
The Ukrainian part of Danube Delta										
17	52.5-85.0	70.0-95.0	5-7	13-22	1.91-2.59	2.47-3.07	2.87-3.23	1.99-2.05	2	4-3
18	83.3-96.7	80.0-93.8	4-7	8-25	0.47-2.08	1.83-3.45	2.80-3.57	1.31-2.27	2-3	1-2
19	80.0-90.0	80.0-93.8	4-17	8-32	0.90-1.82	1.74-3.17	3.09-3.71	1.85-2.38	1-2	2-6
20	35.0-83.3	80.0-93.3	6-11	11-20	2.10-2.88	2.74-3.13	2.86-3.07	1.96-2.99	2-4	5-7
21	60.0-83.3	80.0-93.3	5-9	10-33	1.76-2.87	1.68-4.30	2.51-2.95	1.91-2.48	2-4	4-5
22	50.0-86.7	90.0-100.0	6-9	24-54	1.74-2.11	2.37-4.77	3.63-3.72	1.71-2.38	2	3-4
23	50.0-83.3	80.0-93.3	2-21	5-34	0.70-3.85	1.49-4.06	2.87-3.22	2.16-2.31	4	3-9
24	70.0-80.0	61.1-93.3	3-13	22-29	1.32-2.99	1.62-3.44	3.00-3.67	1.84-1.94	2-6	3-9
25	80.0-90.0	86.7-100.0	5-8	8-20	1.96-2.55	1.01-3.01	2.40-3.43	1.68-2.09	2	3-5
26	66.7-76.7	73.3-93.3	5-6	9-18	1.30-2.52	2.41-3.03	2.44-3.53	1.79-2.25	2-4	5-6

28	73.3-86.7	60.0-80.0	5-12	4-24	2.13-3.31	1.75-2.81	2.51-3.35	1.91-2.41	3-5	3-10
29	56.7-92.5	40.0-85.0	4-7	33-46	1.89-2.58	3.23-3.94	3.11-3.69	1.75-1.96	2	2-3
30	76.7-92.0	66.7-93.3	5-13	5-16	1.87-2.06	1.29-2.26	2.53-3.08	1.88-2.45	2-6	5-10
31	70.0-93.3	73.3-100.0	8-10	9-15	2.08-2.83	2.62-3.14	2.50-2.69	1.61-2.23	2-3	4-7

5 Discussion

Calculation of expected toxicity (PEC-Q) for the total estuary area was performed without data from Station 2 (Figure 2), since the local source of pollution did not greatly influence the whole estuary. PEC-Q values >1 in the Dnipro and Boh estuaries were exceeded only for concentrations of Cr. In the Danube Delta, PEC-Q values were exceeded for Ni, Cr, Ag, and Mn. So the amount of all PEC_Q >1 for the Dnipro and Boh Estuary (3.18) was 5 times less than for the Danube Delta (17.28), and mean PEC_Q was only 0.1 compared to 0.23 in the Danube Delta (Figure 2). Analysis of mean PEC_Q values at each station separately confirms the expected higher toxicity of the sediments of the Danube Delta, although in general the confidence intervals overlap (Figure 3).

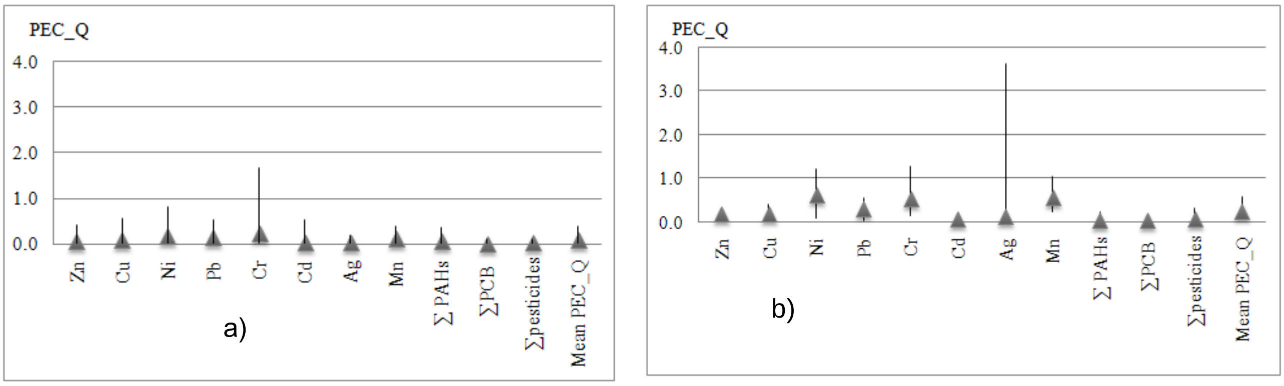

Figure 2. *Expected toxicity for several different chemicals across a) the Dnipro and Boh Estuary (without Station 2) and b) the Ukrainian part of the Danube Delta*

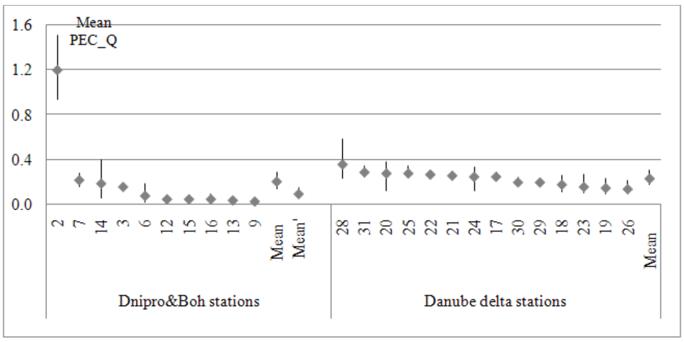

Figure 3. *Expected toxicity based on the PEC-Q at several stations (without Station 2).*

Toxicity testing did not reveal substantial differences between estuaries (Figure 4). Survival for *Daphnia magna* exposed to sediments from both estuaries averaged 83%. Midge (*Camptochironomus pallidivittatus)* mean survival was 77% for the Dnipro and Boh Estuary and 76% for the Danube Delta. However, in both estuaries, stations with reduced survival were detected; for example, Stations 2, 7 and 12 in the Dnipro and Boh Estuary and stations 20, 22, 23 and 24 in the Danube Delta.

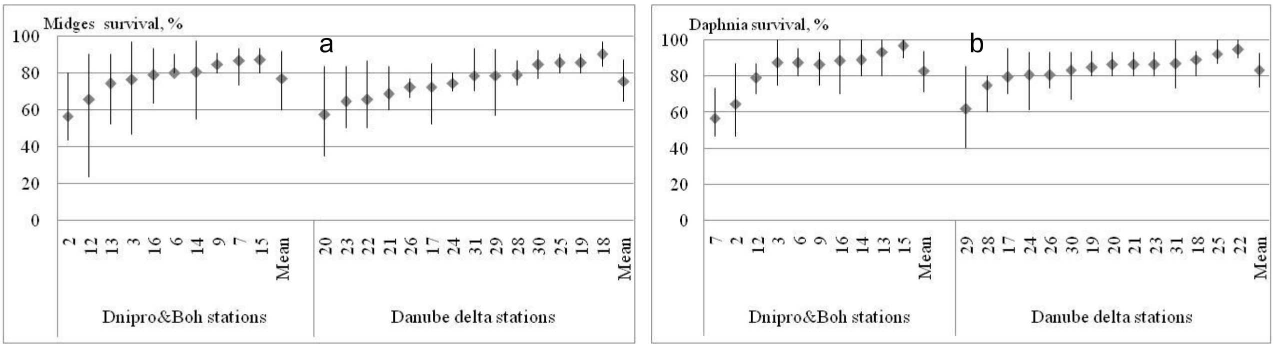

Figure 4. *Mean midge (a) and water flea (b) survival (%) in whole sediment toxicity tests.*

Benthic community analyses based on the state integral index of the assemblages (Lyashenko & Zorina-Sakharova, 2008), which combine all characteristics presented in Table 2, showed that the benthos of the Danube Delta had generally lower values than in the Dnipro and Boh Estuary (Fig. 5). The ranking procedure allows categorization of stations from ‘the worst’ to ‘the best’. However, this index disagreed with the results of the PEC-Qs and sediment toxicity testing. This may suggest sediment contamination did not affect the benthic assemblages, except for Station 2, where all three approaches for assessing benthic condition showed concordance: (1) the highest content of chemicals, (2) maximum mortality in sediment toxicity testing, and (3) minimum values of the state integral index.

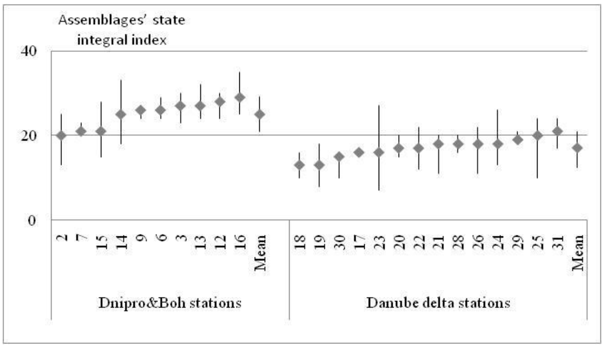

Figure 5. *Benthic community analysis based on the state of the benthic assemblages.*

The search for the relationships between the biotic characteristics, contaminant concentrations and expected sediment toxicity from the set of more than 2000 variables revealed only a few correlations which indicated the negative impact of some pollutants on benthic assemblages. In the Dnipro and Boh Estuary, increasing ∑PCBs, ∑pesticides and ∑*PEC_Q* caused a decrease in species diversity for phytobenthos and the TBI for zoobenthos. In the Danube Delta, the increase in ∑PCBs caused a decrease in TBI, in some years of investigations (fig. 6). Also, it was concluded that the increase in contaminants caused a decrease in the saprobiological indices that was possibly due to the loss of the indicator species.

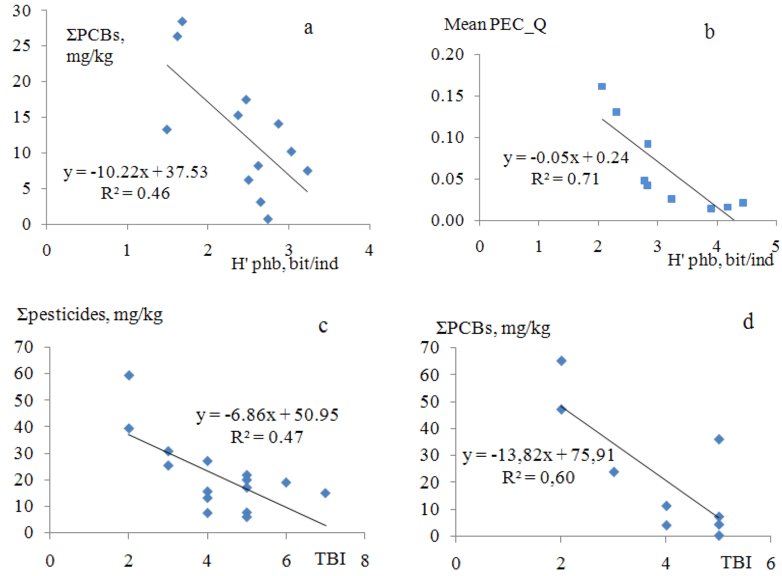

Figure 6. *The relationships between some biotic indices and the content of pollutants in the Dnipro and Boh Estuary and the Danube Delta (a – the Danube Delta, 2006; b – the Dnipro and Boh Estuary, 2007; c – the Dnipro and Boh Estuary, 2006 and 2008; d – the Dnipro and Boh Estuary, 2006)*

6 Conclusion

The Danube Delta showed slightly higher sediment contamination than the Dnipro and Boh Estuary; however, the non-correlation of the three variables PEC_Q, toxicity and benthos showed no risk to the biota.

Only at Station (2), the most contaminated site, did all three approaches show similar results: Mean PEC-Q = 1.2, the highest mortality, and the worst benthic community condition. The lack of agreement between the measures of benthic condition may reflect inaccuracies in the PEC approach or mis-application in these ecosystems (Burgess, R. *et al*., 2009), as well as the absence of a bio-indication assessment scale. On the other hand, under conditions of low toxicity, development of the benthic community is influenced by factors other than contamination, so it is not unexpected that results of the biological indicators and toxicity testing would disagree, although a few correlations suggest the influence of chemical contaminants on the biotic indices. In our opinion, the triad approach will work better under conditions of increasing toxicity. The current study demonstrates that several questions still exist and require further research.

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The Danube River Basin Management Plan (DRBMP) – challenges of an integrative policy

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Keywords: water management, WFD, sustainable use, biodiversity conservation, ecosystem services

1 Introduction

The adoption of the Water Framework Directive (WFD) represented a step forward for the European water law, as it integrated the recommendations of previous water directives, while introducing also new concepts, such as the river basin approach (Van Rijswick et al., 2010). This requires an increased transboundary cooperation in water management, at international and regional level, since river basins are hydro-geographical units not limited by political borders. Consequently, over the last decade water management has gradually evolved from fragmented local policy towards an integrative and interactive approach at larger scale (Wiering et al., 2010).

Encompassing 19 countries with different economic, social, cultural, and environmental heritage, the Danube River Basin (DRB) is the most international catchment worldwide (Sommerwerk et al. 2010). Also, the political background differs considerably: while 10 countries are EU Member States (MS) and one is in accession, 8 are non-MS and not obliged but willing to comply to EU legislation.

In these circumstances, cross-border cooperation to achieve an integrative water policy is a difficult task. However, based on the long history of international cooperation (Lindemann, 2006), and under the guidance of the International Commission for the Protection of the Danube River (ICPDR), the governments of the riparian countries cooperated well to produce the Danube River Basin Management Plan (DRBMP) and to establish a Joint Program of Measures (JPM; ICPDR, 2009). Science contributed significantly by providing improved field and lab methodology, basic data sets, predictive models and conceptual strategy.

2 DRBMP 2009

The DRBMP is a significant update of the Roof Report (ICPDR, 2005) and encompasses most of the available information on the DRB with regard to the present status of waters and main pressures to the aquatic environment. However, since EU legislation is continuously up-grading, aiming to assure sustainability (COM 400, 2009) and considering increasing pressures of human society (TEEB, 2008), the management plans should be considered as an interactive process: the future RBM cycles must continuously up-date the Significant Water Management Issues (SWMI) analysis and the JPMs to assure the implementation of EU requirements.

This paper emphasises major items that need further consideration and suggest some measures that might improve the implementation process.

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3 DRBMP – “Next generation”

Modern river basin management includes at least three major issues of WFD policy:

- internal relationships between water quality, quantity and hydromorphology, groundwater and surface water, natural water cycle, etc., combined into an integral water policy.
- external links with spatial planning, agriculture, nature conservation, urban and rural development, transport, tourism, etc.
- cross-border integration by considering the river basin as an administrative unit.

In addition, the Flood Risk Directive stimulates cooperation in flood risk management (e.g., warning systems). Therefore, transboundary cooperation reflects clearly an integrative management (Wiering et al., 2010) aiming to achieve sustainable development as an overarching long-term goal, where economic growth, social development and environmental protection are mutually supporting each-other (COM 400, 2009).

In order to comply with these new trends, we would like to emphasize several major items that need further consideration for the next RBM cycles:

1. **A conceptual shift of management strategies** – due to the strong links between water and land, the terrestrial ecosystems should be included in water management policy. Land use as well as disturbed interaction between aquatic and terrestrial biota affect water quantity and quality, river connectivity, and erosion processes. While trends for social and economic development are considered in RBMPs to harmonize the measures and integrate the best solutions, they need to be better balanced with ecology to mitigate environmental impacts.
2. **Integration of ecosystem services –** although the world is governed by money and price, many ecosystem services (i.e. benefits provided by the environment) have an intrinsic value that can hardly be conversed into money (e.g. biodiversity, genetic pool, oxygen supply, etc.). Together with the extrinsic value (such as food provisioning, water purification, climate and atmospheric regulation, flood/drought mitigation), the ecosystem services are vital for the human society. They need increasing recognition and integration in policies as recommended by TEEB (2008) to improve the well-being of present and future generations. In this context, the function of aquatic and terrestrial biocenoses needs further research and public recognition as this is crucial in assuring the good ecological status and water quality.
3. **Climate change** – there is increasing evidence of environmental changes due to global warming, both in terrestrial and aquatic ecosystems. The impact is also documented for the DRB, such as glacier melting in alpine headwaters, reduced river discharge and increased air and water temperatures (Sandu et al., 2009). Hence, combating and mitigating these effects by a proper water management policy became a key priority at EU level. Early actions are needed to build resilience in water and connected sectors (e.g. agriculture, transport, energy, tourism, industry, etc) as the impact driven by climate change is expected to be exacerbated in the future; moreover, recovery of natural water systems from unsustainable use (e.g. over-use of groundwater aquifers, over-exploitation of surface water resources) may take a long recovery time (COM 147, 2009).
4. **The ecological importance of wetlands** – their role is mentioned especially in connection with ecosystem services such as climate change mitigation, but they are important also with regard to water purification, groundwater supply, biodiversity, flood mitigation, human health, etc. Such areas should be protected from excessive use, in particular by regulation of land use, infrastructure and spatial planning. “*Where wetlands reduce floods, recharge groundwater and increase dry season flow, their hydrology is working synergically with water-resources managers and flood-defense engineers. Where wetlands have high evaporation demands or generate flood-runoff, they may create or exacerbate water management problems. Whatever functions they perform, wetland management should be an integral part of water bodies management...*” (COM 147, 2009).
5. **Protected areas** – the future RBM plans should intensify the focus on strong pressures, resulting conflicts and possible solutions. Raising awareness at basin level about their importance is needed to strengthen legal implementation. Multi-Criteria Decision Aid (MCDA) methods and Decision Support Systems (DSS) should be introduced and widely applied, as exemplified in the

Vienna Lobau Project (Hein et al., 2009). The use must be balanced and limited with regard to areas which are fully, partially or not protected. Further, the frequent overlap/hierarchy of existing (or new) status of protection on local, regional, national and international level must be considered in legal implementation (Sommerwerk et al. 2010).

6. **Invasive alien species** – the global spreading of alien/exotic species has dramatically increased in the past decades mainly due to human transport and mobility. There is intense scientific research about benefits and negative impacts of invasive terrestrial and aquatic species. Commonly native resident species are suppressed and possibly going extinct as usually the invasive species feature behavioral and functional advantages. Many examples are known where also economy was strongly affected (Reinhardt et al., 2003). Although the role of invasive species is still debated, they should be considered in future strategies (EC 11412, 2009).

7. **Overexploitation of natural resources** – overexploitation has abiotic and biotic components. For example, excessive gravel exploitation for commercial use and navigation purposes can enhance river bed incision and hence lower the groundwater table, highly impacting the hydromorphology. Overexploitation in fishery may lead to the extinction of species, as demonstrated with the highly endangered Danube sturgeon populations. Overuse of groundwater resources for drinking water, household consumption, gardening and irrigation cannot continue forever. In particular, water overuse during droughts, when the aquatic ecosystems are under high stress, should be limited. In the long term, alternative solutions should be considered, e.g. restricted use of hydropower plants; promotion of wind, geothermal or solar energy; favoring railway transportation over navigation; limiting water abstraction for agriculture by implementing efficient irrigation techniques, etc. In the context of sustainability, such excess uses must be better balanced and limited by harmonized law and regulation.

8. **Groundwater** – the Groundwater Directive refers not only to the transboundary aquifers, but also to the national ones; therefore, it is important that national groundwater bodies are considered and protected as well, as groundwater represents the largest freshwater body in the EU and a major source of public drinking water supply in many regions (Dir. 2006/118/EC). Although groundwater biota is not considered by WFD, its existence needs attention as the aquatic communities contribute to the improvement of water quality (e.g. microorganisms, phreatic fauna). Also, the effect of erosion/deposition on groundwater should be considered (see item 7). From a hydrological standpoint, pathways and flow direction, as well as in-/ex-filtration zones of major groundwater bodies should be investigated, documented and protected.

9. **Future Infrastructure Projects (FIPs) and hydromorphological alterations –** FIPs often impact aquatic ecosystems, their hydromorphological structure, in particular. The EU standard for assessing river hydromorphology (EN 14614:2004) must be applied to assess the status and alteration of rivers. In particular, this is crucial in the Middle and Lower Danube (Green Corridor) and the Danube Delta. Hence, FIPs should be considered in an integrative way at basin level, due to their interconnectivity and cumulative impact: e.g. the planned FIPs affect consecutive stretches of Tisza and Danube Rivers, with significant consequences visible in the next decades; the need for proper SEA/EIAs, and balanced measures between technical and environmental solutions should be emphasized. This applies specifically to priority issues such as navigation, hydropower dams and flood protection structures on river banks. To comply with WFD "no future alteration" requirements, the natural river course should not be affected (i.e., no channelization) and the impact on natural ecosystems must be mitigated by respecting the priority of prevention over mitigation and compensation.

10. **Sediments** – although sediments are not explicitly mentioned by WFD, they are an integral part of aquatic ecosystems and a crucial component of "good ecological status": They provide habitat for biota (benthos, fish, macrophytes) and can adsorb/store nutrients and hazardous/toxic substances like heavy metals and persistent organic pollutants (POPs). Suspended and bedload sediments reflect erosion and accumulation processes, hydromorphological structures (river bed, banks, islands, riparian zone) and groundwater connectivity. Disturbance by dams, gravel exploitation, dredging and channelization has a major negative impact on the riverine ecosystem.

11. **Water abstraction and hydropeaking** – while it is important to define the minimum ecological flow for water abstraction, hydropeaking (the artificial water level fluctuation, defined as the ratio of Q_{max} and Q_{min}) demands the definition of the variation range for relevant ecological parameters such as discharge, water temperature, sediment/suspension load, etc. There is growing experience and scientific research into the problem of hydropeaking: case studies have shown

that a ratio $Q_{max}:Q_{min}$ >5:1 is not acceptable from an ecological point of view, e.g., for fish populations (measures of remediation can be retention basins to break the peak flow); the "ideal" and ecologically acceptable ratio is <3:1; ratios between 3-10:1 may be acceptable under specific conditions but need to be thoroughly investigated. In addition, the rate of water level change and the change of water temperature induced by hydropeaking should not exceed 15 cm per hour and 5°C, respectively. Special emphasis needs to be given to sediment transport, since hydropeaking fosters colmation of the river bed sediments. Hydropeaking must also respect seasonally variable minimum ecological flow in an ongoing debate between scientists, users and politicians.

12. **The efficiency of fish passes –** fish passes are vital to maintain/re-establish the longitudinal connectivity. Theoretically, a good fish pass allows passing of all resident fish species and all life stages to ensure local and anadromous migration. These requirements must be approached as closely as possible. Further, in large rivers (width about 100 m and more) two fish passes on either bank should be established because most fish migrate along the banks. The function of fish passages is dependent on fish behavior and hydraulics and should be monitored.

13. **Water quality**

13.1. Reducing diffuse sources of pollution in agricultural areas – end-of-pipe solutions should be abandoned by applying best available technology (BAT) and practice in cultivation and fertilizer application to reduce agrochemicals and nutrient input to surface- and groundwater bodies. In this respect, creating buffer strips along small streams and stagnant waters are a successful strategy to mitigate pollution. Such measures can lead to significant water quality improvement downstream in the catchment (large rivers, lakes, oceans). Soil solidification, erosion and contamination are often neglected phenomena that reduce fertility, bias hydrological processes and impact human health.

13.2. Improved efficiency of Waste Water Treatement Plants (WWTPs) – in order to further improve water quality, the target efficiency of WWTPs should be higher than the present minimum requirement set to 80% for TP and 70-80% for TN by the Directive 98/15/EC. State-of-the-art standard technology allows a removal by 85-90% of C, N and P; applying BAT in specific situations can increase removal to 95% for C, >90% for N and 98% for P; also strategies to remove contaminated sludge are needed. The degree of connection to sewer collecting systems and their maintenance should be gradually improved, particularly in the Lower Danube Basin. However, alternate cheeper solutions as using wetlands or trickling filters in remote areas may be considered.

13.3. Hazardous substances – although a high number of chemical substances is currently in use, the risk assessment of toxic pollution in aquatic ecosystems is still based on few target compounds, the traditional monitoring program focusing on substance, rather than effect monitoring. The new Directive 2008/105/EC on environmental quality standards (EQS), aims to ensure a high level of protection against the risks of priority substances and other pollutants to the aquatic environment. A reliable diagnosis, prediction and mitigation of toxic impacts on aquatic ecosystems require effect-based identification of key hazardous substances, analysis, modelling and assessment of bioavailability and food web accumulation as well as a better evaluation of monitoring data on contamination, toxicity and ecological quality on a basin-wide scale (Teodorovic, 2009).

Monitoring is virtually impossible, but their proper retention in WWTPs (e.g. by adding supplementary steps such as charcoal filtration and ozonation) may reduce the risks for the aquatic ecosystems and finally, for human health (many of these products having sub-lethal effects at endocrine or neurological levels). However, policy should foster product control and recycling processes in order to protect the environment from hazardous chemicals.

4 Measures to improve cooperation

The EU policy is shifting towards a new integrative approach, promoting changes also at regional or national level; it is clearly stressed that "*business-as-usual is not an option and if no major new policy are put in place, past trends of biodiversity and ecosystem services loss will continue*" (TEEB, 2008).

However, transposing the international and national legislation into a real cooperation to improve the implementation, is a major challenge (Sommerwerk et al. 2010). According to Wiering et al. (2010) three major approaches are a prerequisite to achieve a successful cooperation:

- negotiation as a process to compromise between policy, interests and resources.
- analysis of cooperation (including norms, rules, procedures that guide the interactions between policy actors) by establishing cross-border institutions that contribute to water management.
- shifting the focus of policy making from organizational forms (actors, resources, institutional rules) to the content (ideas, concepts, problem definition, common goals).

The last approach focuses on discursive and cognitive processes; in this respect, a major role is played by transnational alliances of scientists, who share common knowledge about the environmental problems, but also common beliefs and objectives that are considered and integrated by the policy makers (Haas, 1990). The links are more easily established when the problem is seen as a joint problem and perceived in similar terms by all actors and when a community of scientists indicates a solution to the problem or encourages cross-border cooperation.

In the Danube River Basin, the JPM will enter now in the implementation phase. Although there is no general rule to guarantee success, several key items may contribute significantly (Wiering et al., 2010):

- availability and willingness to redistribute financial resources
- availability of knowledge
- legally binding commitments that are clear, transparent and feasible
- comparable rules and discourses in the countries involved
- the feeling of solidarity and urgency
- focus on issues that are not politically sensitive
- involving all stakeholders from the beginning may increase the chances of local cooperation

Besides these items, other important aspects are: focus on emerging and existing significant problems; transparency in information and communication will build up trust that is necessary for successful cooperation; leadership with a strong ethical and societal component.

The countries are responsible for achieving the goals and objectives. A closer cooperation and a restricted use of exemptions may lead to better and faster achievements (Van Rijswick et al., 2010). Further efforts should be directed towards the fullfilment of the above mentioned solutions, in order to enhance the implementation process and achieve the „good ecological status".

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Assessment of water quality in the upper course of Siret River (N-E Romania)

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Keywords: Siret River, water quality, phytoplankton, macroinvertebrates, fish populations

1 Introduction

The adoption of the Water Framework Directive (60/EC/2000) represented a significant step forward in the management of water resources; according to its provisions, by 2015 the water bodies should reach the "good ecological status", meaning that besides the assessment of water chemical quality and biological communities, the hydromorphological integrity of the aquatic habitat is taken into consideration.

In Romania, the responsible authority for water quality management is the National Administration Romanian Waters, by its 11 Regional Water Branches, comprising the major watersheds of Danube tributaries (www.rowater.ro). Siret Water Branch (SWB) comprises four divisions: Suceava, Neamt, Bacau, Vrancea.

Among the Romanian tributaries, Siret River has the highest discharge (average 250 m^3/s, www.rowater.ro/dasiret) at the confluence with the Danube River (rkm 155, upstream of the city of Galati).

The paper presents the assessment of water quality based on physico-chemical and biological quality elements over the period 2005-2009, in the upper course of Siret River.

2 Material and methods

With a length of 599 km (90% belonging to Romania and 10% to Ukraine), Siret River is the third longest tributary of the Danube and has the largest catchment in the country (46289 km^2, with 42890 km^2 in Romania) with a mean elevation of 485 m. For the ecological assessment, three sections of Upper Siret River were investigated: Upstream Siret - near the border with Ukraine, Hutani - downstream of two reservoirs and Lespezi - located after the confluence with two tributaries (Fig.1)

The monitoring included physico-chemical parameters (temperature, pH, suspended solids, major anions and cations, oxygen balance, nutrients), inorganic and organic pollutants (heavy metals, phenols, detergents) and phytoplankton, benthic algae, macrozoobenthos (abundance and saprobic index). The chemical analyses were carried out monthly, the biological investigations seasonally (three times/year for algae and macrozoobenthos) or once in three years (for fish) (SWBR, 2009). The data of fish fauna were processed by Siret Water Branch Bacau.

The following physico - chemical parameters were considered for this study: pH, total solids (TS), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), chloride, sulphate, calcium, magnesium, sodium, bicarbonates, conductivity. For nutrients, phosphates, ammonium, nitrite, nitrate and total nitrogen were determined, while for inorganic pollutants, the content of iron, manganese, copper and zinc was assessed.

The water quality is classified in 5 classes, according to EU- WFD and Romanian standards (class I- high, II- good, III- moderate, IV- poor, V- bad). The sensitivity of the aquatic communities to environmental stress was assessed by the saprobic index SI (Pantle & Buck, 1955; Sladecek, 1973): according to the benthic species,

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water is classified in five classes: class I-oligosaprobic, class II-beta-mesosaprobic, class III- beta- alpha-mesosaprobic, class IV- alpha-mesosaprobic and class V-polysaprobic.

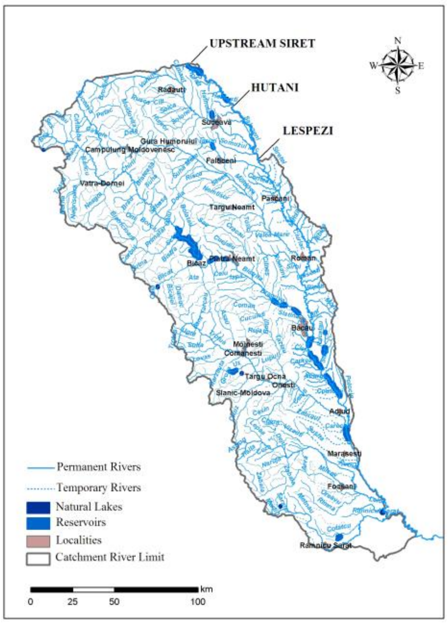

Figure 1. *Location of sampling sites along the Siret River Catchment: Upstream Siret, Hutani and Lespezi.*

3 Results and discussion

3.1 Physico-chemical quality elements

According to most of the physical and chemical parameters, the water quality of the investigated stretch between 2005-2009 could be generally classified in class II (Table 1). Sodium, chloride and sulphate concentrations were low in Upstream Siret and Hutani sections, but the content of calcium and magnesium could classify this stretch as class II according to Order 161/2006; in Lespezi, the content of chlorides, sulphates and calcium, magnesium indicates also class II. However, the chemical oxygen demand (COD) indicates class I in the upper part, increasing to class II in Lespezi.

The nutrients content is generally low in the upper sections (class I), but the high amount of nitrites could classify these stretches as class II (Tables 1, 2). The content of heavy metals is generally below the standard limits for class I, but manganese reached high concentrations in Upstream Siret in 2009, classifying this stretch as class III, while Hutani was considered class II in 2005 according to Order 161/2006.

Table 1. *Average values (± S.D., n = 12) for selected chemical quality elements in the Upper Course of Siret River in 2005-2009 (in grey italics, values exceeding the standard limits for class I, Romanian Order 161/2006).*

Siret River	**Year**	**COD-Cr (mg O_2/l)**	**NH_4-N (mg/l)**	**NO_2-N (mg/l)**	**NO_3-N (mg/l)**	**Total P (mg/l)**
Upstream Siret	2005	6.12±2.007	0.101±0.0584	*0.016±0.0189*	0.775±0.4084	0.030±0.01798
	2006	7.90 ±6.540	0.090±0.0786	0.009±0.01	0.902±0.2967	0.060±0.05842
	2007	6.28± 3.46	0.054±0.0695	*0.017±0.0155*	0.857±0.8975	0.040±0.01768
	2008	7.49±2.502	0.058±0.0496	*0.013±0.0059*	0.671±0.252	0.0229±0.01308
	2009	7.61± 1.784	0.057±0.0495	*0.012±0.0058*	0.794±0.2887	0.032±0.01814

Hutani	2005	8.11± 2.224	0.186±0.1554	*0.017±0.0068*	0.456±0.2662	0.041±0.03508
	2006	9.03± 3.956	0.173±0.0984	*0.043±0.1055*	0.774±0.4182	0.053±0.06453
	2007	8.63±3.41	0.107±0.0717	*0.019±0.0146*	0.570±0.3628	0.053±0.03675
	2008	8.74±1.877	0.102±0.0823	*0.027±0.0329*	0.722±0.2412	0.042±0.02190
	2009	8.22±2.032	0.064±0.0435	*0.014±0.0072*	0.752±0.3568	0.033±0.01604
Lespezi	2005	*12.85±5.539*	0.236±0.2418	*0.081±0.0581*	0.477±0.3583	0.012±0.00877
	2006	*14.50±12.123*	0.366±0.2968	*0.097±0.0486*	0.562±0.6472	0.016±0.01724
	2007	*13.46±6.586*	0.181±0.2425	*0.060±0.0347*	0.837±0.1367	0.093±0.03863
	2008	*11.91±3.641*	0.221±0.14	*0.041±0.0276*	0.190±0.1278	0.022±0.03861
	2009	*12.05±3.987*	0.298±0.1603	*0.034±0.0278*	0.088±0.0569	0.006±0.00769

The main point sources of organic pollution in the Upper Course of Siret River are urban wastewaters from Acet- Suceava- Siret Agency, Psychiatric Hospital Varful Campului - Botosani, ApaGrup Botosani and other municipal units; the emissions of these units exceeded the COD, ammonium, phosphorus, nitrites even in 2009 (SWBR, 2009).

The bad management of households contributes to diffuse pollution. At the end of 2006 only 51% of urban agglomeration (>2000 pers.) from Siret River Catchment were connected to the centralized sewer system (SWBR, 2009). In addition, agriculture contributes to diffuse pollution. Nitrogen emissions are 58% from agriculture and 15% from urban agglomerations for the year 2005; phosphorus emissions are 33 % from agriculture and 45 % from urban agglomerations in Siret River Catchment (SWBR, 2009).

Table 2. *Average values (± S.D., n = 12; for Mn n = 3) for selected chemical quality elements in the Upper Course of Siret River in 2005-2009 (in grey italics, values exceeding the standard limits for class I, Romanian Order 161/2006)*

Siret River	**Year**	**Cl (mg/l)**	**SO_4 (mg/l)**	**Ca (mg/l)**	**Mg (mg/l)**	**Fe (mg/l)**	**Mn (mg/l)**	**Cu (µg/l)**	**Zn (µg/l)**
Upstream Siret	2005	12.8±2.70	37.4±7.66	*72.7±20.01*	*17.0±13.26*	0.10±0.134	0.004	2.85	40.8
	2006	10.8±3.39	42.0±6.81	*66.6±17.81*	11.0±4.65	0.10±0.161	-	-	-
	2007	13.5±3.60	30.2±5.67	*58.0±15.92*	11.5±4.46	0.07±0.065	-	-	-
	2008	11.4±2.35	30.5±6.25	*54.0±18.83*	10.7±5.93	0.15±0.101	-	-	-
	2009	13.3±2.39	42.0±34.56	*58.2±13.57*	*10.1*	0.06±0.055	*0.135*	4.02	30
Hutani	2005	11.9±3.49	40.3±10.03	*53.6±12.57*	*20.5±13.30*	0.06±0.083	*0.070±0.1126*	19.10	73.4
	2006	11.8±3.93	45.2±7.45	*68.5±12.40*	*13.4±6.28*	0.09±0.089	-	-	-
	2007	14.6±6.31	34.9±7.43	*59.9±17.19*	*18.2±10.78*	0.06±0.064	-	-	-
	2008	12.8±2.47	36.3±6.28	48.4±14.12	*20.0±17.53*	0.09±0.058	0.004	-	-
	200	14.2±3.41	29.5±8.67	*53.2±6.69*	*12.7*	0.06±0.02	-	-	-

	9					6			
Lespezi	2005	*26.4±7.17*	73.3±36.86	*79.7±11.51*	*26.5±7.58*	0.13±0.084	0.025	6.20	0.00
	2006	*26.6±10.81*	*106.2±59.33*	*94.5±30.51*	*15.7±9.12*	0.13±0.097	-	-	-
	2007	20.8±7.63	36.9±8.09	42.9±9.36	*22.6±6.19*	0.02±0.009	-	-	-
	2008	21.1±7.60	49.3±19.05	*65.2±35.06*	11.4±5.94	0.09±0.163	-	-	-
	2009	*31.4±6.43*	40.2±22.67	*61.6±42.83*	-	0.02±0.005	0.041±0.0558	-	-

3.2 Biological quality elements

Monitoring of phytoplankton diversity helps to assess changes in nutrients input and contributes to pollution control. The phytoplankton diversity revealed low pollution in the Upper Course of Siret River: Bacillariophyceae were dominant in abundance (74%), followed by Chlorophyceae (12%), Euglenophyceae (3%) and Chrysophyceae (2%). The chlorophyll-a content ranged between 4.68 – 8.35 µg/l in all the investigated stretches (Table 3).

Over 20 species of benthic diatoms were identified in Hutani site. The saprobic index (1.93- 2.16) classified the stretch as beta-mesosaprobic between 2005 and 2009. In this section, the phytobenthos is dominated by Bacillariophyta (98 %) and Cyanophyta (2 %), with high densities from June to September.

Benthic macroinvertebrates are commonly used for the quality assessment of rivers (Birk & Hering, 2002). Along the investigated stretch, the highest diversity was recorded by Diptera (10 taxa), followed by Ephemeroptera (9 taxa), Oligochaeta (8 taxa) and Trichoptera (5 taxa); molluscs (Gastropoda 3 taxa, Bivalvia 2 taxa), Heteroptera (2 taxa) and Hirudinea (2 taxa) were also identified.

EPT-taxa (Ephemeroptera, Plecoptera and Trichoptera) dominated in the Upstream Siret, where they represented up to 52% in abundance, while Diptera recorded 34%. Downstream, the EPT-taxa decreased in abundance to 34%. The abundance of Oligochaeta increased in Lespezi section (23%), probably as a consequence of the increased organic pollution (COD-Cr content above the limits for class I). In the Upper Course of Siret River, a general decrease of EPT-taxa and an increase of Diptera abundance was noticed over the years (Table 4).

Regarding saprobic index classes (SI), most stretches along the Upper Course of Siret River can be considered as beta-mesosaprobic, except for the sections Upstream Siret in 2009 and Lespezi in 2006 and 2007 that were classified as beta-alpha-mesosaprobic.

Two out of four main tributaries, Suceava and Somuzu Mare, affect the water quality of the Upper Course of Siret River. Only few stretches, usually in the headwater region, can be classified as oligosaprobic; most of the investigated sites are beta-mesosaprobic, except for stretches affected by organic pollution, which belong to the beta-alpha-mesosaprobic category (the lower course of Suceava and Somuzu Mare Rivers – class III, affected by organic pollution from wastewater discharges and fisheries - data from the SWB reports 2006-2009).

Table 3. *Phytoplankton abundance (%), content of chlorophyll-a (µg/l) and saprobic index (in italics- class II, in bold- class III, Romanian Order 161/2006) in the investigated stretch between 2005 – 2009*

Siret River	**Year**	**Bacillario-phyceae**	**Chloro-phyceae**	**Eugleno-phyceae**	**Chryso-phyceae**	**Cyanobacteria**	**Chl-a**	**Saprobic index**
Upstream	2005	91.6	4.96	1.8	-	1.46	-	*2.07*
Siret	2006	96.73	3.2	-	-	-	-	*2.08*
	2007	67.14	18.89	-	4.3	-	6.3	*2.11*

	2008	71.5	15.67	2.92	2.43	1.19	-	*2.06*
	2009	84.58	2.48	3.16	1.5	3.23	-	*2.18*
Hutani	2005	81.6	1.36	1.26	2.1	4.97	-	*2.09*
	2006	92.3	0.6	-	1.36	1.8	-	*2.10*
	2007						4.68	
	2008							
	2009							
Lespezi	2005	81.6	9.06	8.16	-	1.14	-	*2.18*
	2006	92.3	2.3	1.33	-	2	-	**2.43**
	2007	77.9	11.53	1.6	-	2.4	8.35	*2.22*
	2008	73.86	7.07	3	7.9	6.26	-	*2.06*
	2009	70.8	15.50	3.16	4.5	6.03	-	*1.80*

Table 4. *Macroinvertebrates abundance (%) and saprobic index (in italics – class II, in bold- class III, Romanian Order 161/2006) in the investigated stretch between 2005 – 2009*

Siret River	Year	EPT taxa	Diptera	Oligochaeta	Molluscs	Heteroptera	Hirudinea	Saprobic index
Upstream Siret	2005	87.6	12.2	-	-	-	-	2.08
	2006	57.8	21.8	14.9	-	-	-	*1.92*
	2007	57.7	26.5	9.6	0.73	2.8	-	*1.84*
	2008	56.0	40.1	3.2	1.1	-	-	*1.86*
	2009	-	67.0	24.1	3.1	3.1	2.5	**2.69**
Hutani	2005	48.2	29	-	-	22.7	-	*2.24*
	2006	34.0	37.8	8.3	16.6	-	-	*2.15*
	2007	48.3	17.5	8.2	0.73	0.73	-	*2.04*
	2008	23.3	49.4	20.6	-	1.76	-	*2.04*
	2009	27.2	64.1	0.86	-	5.2	-	*1.97*
Lespezi	2005	68.7	-	-	6.2	-	12.5	*2.27*
	2006	59.4	17.7	-	11.4	-	5.2	*2.10*
	2007	17.5	43.1	8.6	4.36	-	20.4	**2.39**
	2008	12.9	40.9	37.3	3.33	1.9	3.33	*2.12*
	2009	10.5	50.0	21.6	-	15.5	0.9	*2.05*

The fish community is considered a good indicator of the overall anthropogenic impact (Schiemer, 2000, Lasne et al., 2007). There are many EU methods for assessing the ecological quality of the small and medium sized rivers based on ichthyofauna diversity. The scores from the European Fish Index (EFI) were evaluated; however, EFI is sensitive to water quality pressures, but not very good to emphasize hydromorphological pressures. The EFI produces a score between 0 and 1, which is directly translated into an EQ- class (1- high; 2- good; 3- moderate; 4- poor; 5- bad).

In 2006, 77 fish specimens of 8 species were collected from the three sites, which belong to the cyprinid river zone. In the first section, Upstream Siret, the EFI index was 0.624 (class 3), in Hutani section 0.895 (class 2) and in Lespezi section 0.748 (class 2). In the upper part, the dominant fish species were *Rhodeus sericeus amarus*, *Carassius auratus*, *Cyprinus carpio, Esox lucios, Alburnus alburnus* while for the downstream stretches, the dominant species were *Chondrostoma nasus* and *Leuciscus cephalus*. The EFI index class 3 for the Upper Siret indicates organic pollution originating mainly from wastewater discharged into the river.

4 Conclusions

Formerly in 2005 at its mouth, Siret was among the most polluted Danube tributaries with respect to organic pollution (UNECE, 2007); according to the report of National Administration Romanian Waters (NARW, 2007) the water quality in Siret River catchment was moderate to poor, class II - IV.

Our study shows that, after 2005, the water quality in the Upper Course of Siret River slightly improved and encompasses mostly class I or II in terms of physical-chemical conditions and specific pollutants, and class II in terms of biological quality elements. Some quality elements have exceeded the limits of class I, such as suspended solids, due to substrata characteristics (the geology of Upper Course of Siret River is siliceous, calcareous rocks mixed with organic soils).

Households affect water quality: nitrite concentrations were constantly high in the three sections studied in the Upper Course of Siret River. The content of heavy metals is generally below the standard limits for class I; only manganese reached high concentrations in Upstream Siret in 2009 (class IV) and Hutani in 2005 (class III). To reduce input from point sources of organic pollution further management measures are needed, such as a permanent monitoring of wastewater discharged into rivers and financing investments to modernize or build wastewater treatments plants in the Upper Course of Siret River.

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Water Framework Directive 2000/60/EC [WFD] - directive establishing a framework for Community action in the field of water policy.

Wastewater disinfection at river Ilz to improve bacteriological water quality: effects and constraints

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Keywords: fecal indicator bacteria; microbial source tracking; bathing water quality; UV irradiation; membrane filtration; ozonization

1 Introduction

Contamination with fecal microorganisms often hampers the use of surface waters for bathing purposes. Exposure to fecally polluted water might cause severe infections like gastroenteritis or else respiratory, eye-, ear-, and skin-related illnesses. Waterborne pathogens frequently involved in gastrointestinal diseases include enteric bacteria (e.g. *Salmonella, Yersinia, Clostridium,* and *Campylobacter* species), enteric viruses (Enteroviruses, Hepatitis A virus, Norwalk virus), and protozoan parasites (*Cryptosporidium* and *Giardia* species) (Stewart et al. 2007).

There are different sources that may deteriorate water quality: Municipal wastewater is one of the major sources and contains pathogenic microorganisms excreted by ill human beings and chronic carriers. Other point sources are storm water and sewer overflows. Moreover, fecal pollution can also originate from non-point sources like agricultural runoff or wildlife. Hence, effective measures to improve bathing water quality imply a detailed evaluation of the contamination origin.

If fecal input mainly results from wastewater treatment plants (WWTP) disinfection of secondary effluents is supposed to noticeably improve microbiological water quality. During wastewater treatment the number of bacteria decreases only marginally. This is even true for secondary treatment, such as precipitation, sand filtration, and polishing ponds (Baumann and Popp 1991). A satisfying reduction of fecal microorganisms – including pathogens – is only achieved by specific disinfection procedures like UV irradiation, membrane filtration, ozonization, or chlorination (Popp 1998).

Within a restoration project initiated by the Bavarian State Ministry of the Environment and Public Health to improve the microbiological quality of the River Ilz – a tributary of the Danube from the Bavarian Forest – a total of five WWTPs has recently been equipped with disinfection systems (UV irradiation; membrane filtration; ultrasound/ozone treatment). To monitor the disinfection efficiencies and the resulting effects on the water quality of the Ilz fecal indicator organisms were determined as prescribed in the Bathing Water Directive (Tab. 1). As these parameters indicate the general contamination of a water body only but do not provide any information about its origin an integrated approach was used for tracing back the sources of the remaining fecal pollution. This approach combined the already mentioned cultivation-based determination of fecal indicators and a quantitative Microbial Source Tracking (MST) method identifying genetic *Bacteroidetes* markers specific to human and ruminant hosts.

Table 1. *Microbiological parameters of the Bathing Water Directive 76/160/EEC*

Parameter	Guide value [per 100 ml]	Mandatory value [per 100 ml]
Fecal coliforms (*E. coli*)	1.0×10^2	2.0×10^3
Intestinal enterococci	1.0×10^2	-

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2 Material and Methods

Sampling: From April to October 2009 water samples were collected fortnightly from six sites along the River Ilz and from four tributaries between Hutthurm and Passau. Effluent samples were taken from the five WWTPs Hutthurm, Ruderting, Salzweg, Straßkirchen, and Neukirchen before and after wastewater disinfection. All samples were collected in sterile glass bottles and stored at 4°C until further processing (maximum 24 hours).

Fecal indicator organisms: Enumeration of *E. coli* and intestinal enterococci was carried out by standardized most probable number methods using microplates (ISO 9308-3 and 7899-1) with 1 (disinfected wastewater), 2 (river samples), or 4 dilutions (non-disinfected wastewater).

Microbial Source Tracking (MST): For quantification of the source-specific genetic markers aliquots of the samples were filtered through 0.2 µm polycarbonate membrane filters and stored at -80 °C until nucleic acid extraction. DNA extraction was performed according to Griffiths et al. (2000). Taq-Man qPCR analyses were carried out as described by Reischer et al. for ruminant- (2006) and human-specific (2007) *Bacteroidetes* markers on a CFX96 Real-Time System (Bio-Rad).

3 Results and Discussion

3.1 Evaluation of disinfection efficiencies

The different disinfection systems at five WWTPs along the River Ilz between Hutthurm and Passau mostly achieved a satisfying reduction of the fecal indicators *E. coli* and intestinal enterococci.

The principle of **membrane filtration** is based upon the separation of solids (particles, bacteria, viruses) suspended in an aqueous solution by means of a pressure difference. This technique yielded high reduction rates at WWTP Hutthurm. The effectivity of membrane filtration to remove microorganisms from wastewater has already been demonstrated in various pilot and technical plants in Germany and other countries (Wintgens et al. 2005; Shang et al. 2005; Bleisteiner et al. 2006). Membrane fouling, however, turned out to be a problem at WWTP Hutthurm causing severe flux decline and requiring intense cleaning efforts with chemicals harmful to the environment.

UV irradiation led to reduction rates of up to four log-units. At WWTP Ruderting more than 90 % of the disinfected effluent samples complied with the guide values of the Bathing Water Directive. Technical problems currently existing at WWTPs Salzweg and Strasskirchen led to considerable fluctuations of the fecal indicator concentrations in the effluent. These should, however, be resolved in the near future. Surveys at the River Isar already proved UV disinfection to be an environmentally sound and economically competitive method (Popp et al. 2004).

The third system for advanced sewage treatment combines **ultrasound irradiation and ozone treatment**. The applicability of this new technique was investigated in a commercial scale reactor installed at WWTP Neukirchen. Besides wastewater disinfection this technique is supposed to also be suitable for removal of micro-pollutants, i.e. pharmaceuticals or endocrine disruptors. For optimizing reactor performance different operation conditions were tested. Thus, reduction rates of fecal indicators showed considerable fluctuations due to the varying conditions. Ozone dosage of 8 g/h, for example, yielded indicator concentrations below the guide values of the Bathing Water Directive.

The results indicate that secondary effluents no longer account for a considerable fecal pollution in the investigated stretch.

3.2 Monitoring of the microbiological water quality

The effects of the advanced wastewater treatment on the microbiological water quality of the Ilz were monitored by determination of *E. coli* and intestinal enterococci. Under dry weather conditions fecal indicator concentrations never exceeded the mandatory values of the Bathing Water Directive at the six sampling sites along the Ilz during operation of the disinfection systems (Fig. 1). *E. coli* and enterococci levels varied between 4.3×10^1 – 1.5×10^3 MPN per 100 ml and 1.0×10^1 – 2.9×10^2 MPN per 100 ml, respectively. Compliance with the more stringent guide values, however, was only achieved in two cases at the sampling site "Triftsperre". Intense rain events led to a significant impairment of the microbiological water quality. Mandatory values were continuously exceeded (Fig. 1) with maximum concentrations of 2.8×10^4 and 1.7×10^4 MPN per 100 ml for *E. coli* and enterococci, respectively.

A slight improvement of the water quality was observed at the sampling sites "Unterilzmühle" and "Triftsperre". Heavy rain falls also caused a significant increase of fecal indicator concentrations in the four investigated tributaries (Fig. 1). Median values were about 1 log-unit higher during rain events.

The investigations revealed a considerable persistent contamination in the stretch between Hutthurm and Passau, although secondary effluents – as described – no longer contribute to fecal pollution. Noticeably *E. coli* and enterococci concentrations did not comply with the guide (dry weather) and mandatory values (rain events) even at the first sampling site "Pegel Kalteneck". This refers to high rates of fecal input in the catchment area of the Upper Ilz (upstream "Pegel Kalteneck"). Hence, a quantitative MST method was applied to specify the sources of the still existing fecal contamination.

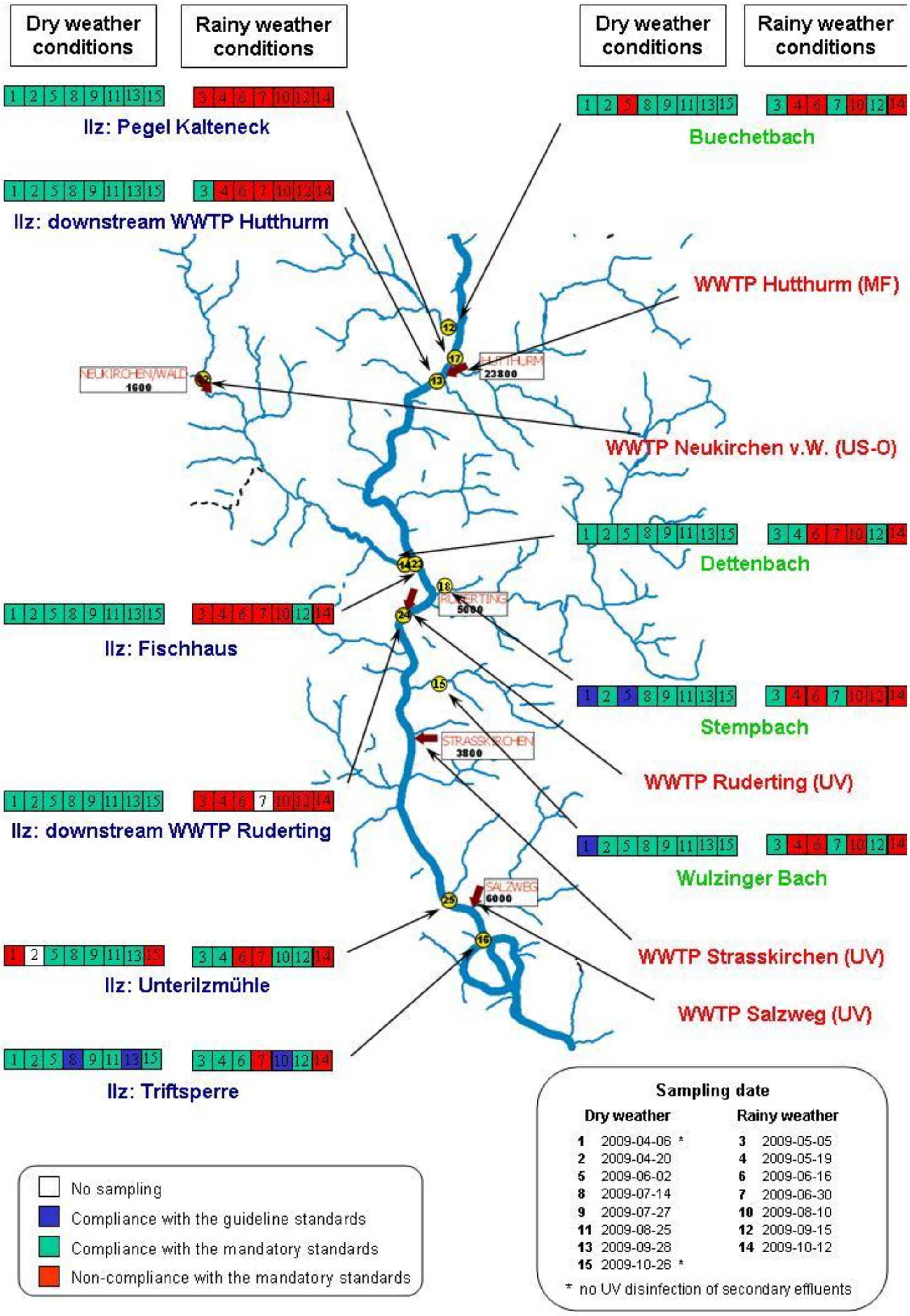

Figure 1. *Microbiological water quality at six sampling sites along the Ilz and of four tributaries between Hutthurm and Passau under dry weather (left column) and rainy weather conditions (right column). Water quality was assessed by estimation of fecal indicator organisms according to the Bathing Water Directive. MF: membrane filtration; US-O: ultrasound/ozone treatment; UV: ultraviolet irradiation.*

3.3 Microbial Source Tracking

Genetic *Bacteroidetes* markers specific to human (BacH) and ruminant (BacR) hosts were detectable at all sampling sites along the Ilz with almost equal frequency. No clear dominance could be observed. The occurrence of these markers in the environment and their temporal genetic stability has already been proved in previous surveys (Reischer et al. 2008). Under dry weather conditions median concentrations of around 1×10^4 BacH and 4×10^3 BacR marker equivalents (ME) per 100 ml were detected (Fig. 2). Both marker concentrations increased after heavy rain falls to median concentrations of 3.4×10^4 -5.4×10^5 ME per 100 ml for BacH and 1.5×10^3 – 1.4×10^5 ME per 100 ml for BacR (Fig. 2). In some cases this increase was more distinct for the human-specific marker and yielded BacH levels up to 2.5 log-units higher than BacR (e.g. at “Unterilzmühle” and “Triftsperre”). In the investigated tributaries the markers revealed considerable fluctuations concerning their dominance. Whereas in the Dettenbach the human-specific BacH marker was detected at levels far exceeding BacR throughout the study and irrespective of the weather conditions (BacH median: 2.9×10^4 ME per 100 ml; BacR median: 4.2×10^2 ME per 100 ml), no clear dominance of one of both markers was observed in the other tributaries Buechetbach, Stempbach, and Wulzinger Bach. For BacH and BacR both equal marker concentrations were found as well as varying dominance at different sampling times.

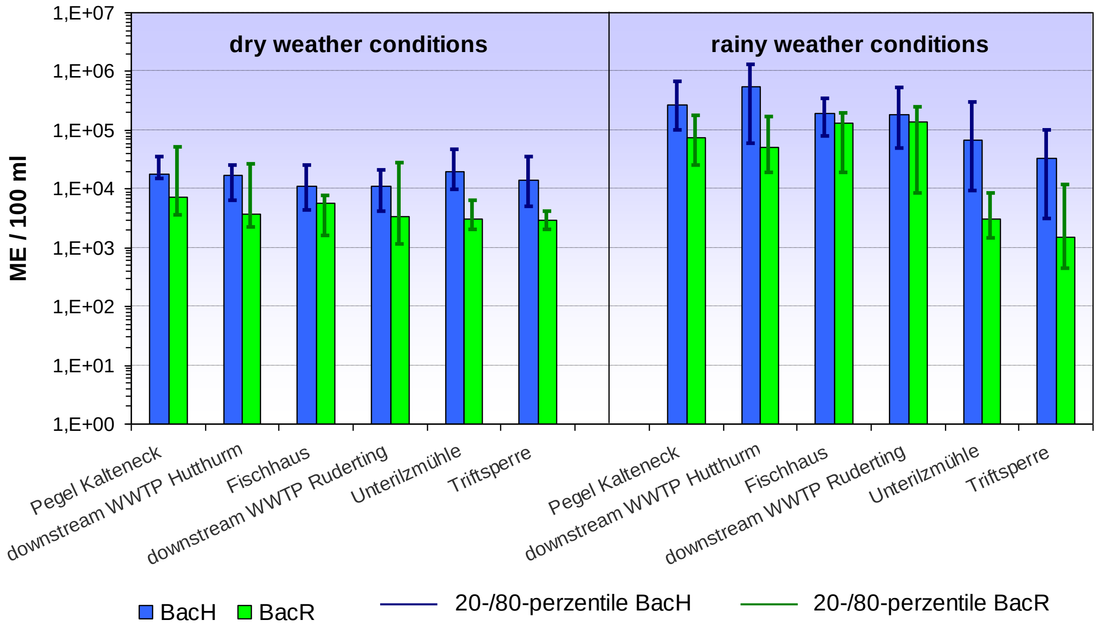

Figure 2. *Median values of genetic Bacteroidetes markers specific to human (BacH) and ruminant (BacR) hosts at six sampling sites along the Ilz. Error bars indicate the 20- and 80-percentile values. ME: marker equivalents.*

The results indicate both an agricultural and a human impact on the microbiological water quality. Whereas BacR markers presumably derive from surface runoff from agricultural fields, high BacH marker concentrations are probably due to the numerous small WWTPs in the catchment area of the Upper Ilz and to rural communities missing wastewater management infrastructure. Moreover, sewer and storm water overflows may be responsible for elevated levels of the human-specific marker, especially after heavy rain falls. Further investigations will be carried out in the bathing season 2010 to obtain enough data for statistical correlation analyses.

4 Conclusions

- Wastewater disinfection at five WWTPs along the River Ilz between Hutthurm and Passau mostly revealed satisfying reduction rates of fecal indicator bacteria. Thus secondary effluents no longer account for a considerable pollution.
- During the bathing season 2009 fecal indicator concentrations complied with the mandatory values of the Bathing Water Directive under dry weather conditions. Intense rain events, however, caused a

significant impairment of the microbiological quality of the Ilz and of four investigated tributaries. Mandatory values were then constantly exceeded.

- Microbial Source Tracking was applied to specify the sources of fecal contamination. MST analyses revealed both human and ruminant impact. The high human-specific marker concentrations, especially after heavy rain falls, suggest that sewer and storm water overflows as well as rural communities missing a wastewater management infrastructure are important causes for the high fecal loads.

Acknowledgements

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Natural and near natural floodplain habitats on the Lower Danube and their importance for Natura 2000 network and recent planning processes for the area

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Keywords: floodplains biodiversity, habitats of community interest, effects of navigation improvement

1 Introduction

Due to the training of the Danube River characteristic floodplain habitats and their specific, site typical biodiversity suffered a large loss in the course of the 20th century. On the Upper and Middle Danube this loss is evaluated to 95% of the former flooded area (WWF-DCP & WWF-Auen-Institut 1999; Schneider et al. 2009).

The large loss of floodplains subject to regular floods (73%) from the 1960s caused also a large decline of characteristic habitats and species along the Lower Danube in Romania and Bulgaria. Despite of these losses and water quality changes by intensive land use and sewage discharge, the Lower Danube still presents outstanding spatial heterogeneity in the remained recent floodplain areas. Almost natural river banks, 134 natural and near natural islands and new emerging islands provide numerous site-typical habitats with a specific biodiversity of plants and well adapted macroinvertebrates and birds. These habitats in a dynamic hydrological environment are important elements for the ecological status evaluation of the river stretches and the measures to be taken for the implementation of the Water Framework Directive (WFD) and the Natura 2000 network as well as for the sustainable development on the Lower Danube River.

Such river stretches were studied during various projects by field research (2004-2009) including analyses of botanical and faunistic biodiversity. Habitats with structural elements for microhabitats, species number and abundance were compared with habitats on the upstream stretches of the Danube River.

The habitats are important for the functioning of the ecosystems with complex interaction processes between the river and its floodplains. We studied the possibilities for habitat improvement and restoration in strong relation to needed flood protection measures. Finally the authors underline the need of conservation measures and sustainable development of the area in the context of the Natura 2000 network and the WFD. In particular, some stretches for sites of nature conservation value are threatened by planned navigation projects (ISPA I and ISPA II) as these encompass bottlenecks for navigation with important and valuable habitats. To combine user interests with nature values and to find a compromise between different user interests are discussed.

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2 Characteristics of the floodplain habitat types on the Lower Danube

In the floodplain transect from mean to highest water levels, the vegetation distribution corresponds to the hydrological dynamics and the dynamics of sediments with varying grain sizes. Flood intensity, duration, moment and frequency play an important role. Even though man-induced changes occurred and near-natural floodplain forests have been transformed into hybrid poplar cultures, a vegetation distribution along ecological gradients is clearly visible from the lowest levels in the river bed to the highest levels of the floodplain.

When considering the historical situation, i.e. the time when the broad Lower Danube floodplains had not yet been cut off from the river, drained and transformed for agricultural use, it becomes apparent that given the former floodplain extension and the small gradient, larger marsh areas with extended rush and reed stands must have existed in comparison with forest areas (General map of Central Europe made by the Austrian-Hungarian Empire and the Royal Monarchy 1889-1915 vs. Harta Dunării 1:50,000, Bucharest 1935). The high heterogeneity of the varying floodplain waters with their long and straight watercourses, flood channels, lakes of various sizes and depths that dry out partly during summer time is reflected by habitats that show a comparably large diversity as for their aquatic vegetation. Softwood floodplain forests were prevalent along the water courses and the main stream whereas hardwood floodplain forests were rare but still occur on the higher natural levees or on other more elevated floodplain spots (Schneider 2009).

Besides reeds, rushes and floodplain forests, grassland areas with alluvial meadows of couch grass (*Agropyron repens*) and creeping bent grass (*Agrostis stolonifera*) co-existed in the natural, dynamic floodplain. Extended grassland areas emerged along with the alluvial meadows as a result of floodplain forest clearings and the floodplains cut-off and drainage. At present this applies rather to grasslands used as pastures than to alluvial meadows that were subject to regular mowing.

Worth to be mentioned are the pioneer communities of ephemeral species developing on sand or mud banks that temporarily lay bare at low water levels. They may complete their life cycle within 2-3 months. Depending on the water levels, the so-called vegetation of muddy areas (Nanocyperion) in the river bed may occur yearly or in larger intervals. They comprise many rare species, which can live only in such places. Among the pioneer vegetation species are the characteristic macroarthropodes of the respective protosoils (Schneider et al. 2005; Schneider 2010).

3 The floodplain forests on the Lower Danube

Large areas of softwood stands with a predominance of white willow (*Salix alba*) are characteristic of the Lower Danube with its extended floodplains, low slopes and fine-grained sediments. They usually develop in the form of simply structured gallery forests along the river and on the islands. On the Lower Danube a large-scale natural regeneration of softwood forests is possible due to the existing natural river banks with protosoils. Intermediary stages between softwood and hardwood floodplain forests with white willow, black poplar (*Populus nigra*) and elm (*Ulmus laevis*) do mainly occur on the islands (Schneider 2009).

Here and there along the Lower Danube one may also find gallery-like forests that are characterized by black poplar and white poplar (*Populus alba*) in varying proportions. On sandier floodplain soils the white poplar also forms pure stands rather comparable to the Mediterranean *Salix alba* and *Populus alba* gallery forests as for their forest structure (FFH habitat type 92A0).

Due to the lowland river conditions with extensive reed-abundant wetlands, natural hardwood floodplain forests occur only on high natural river levees and are thus less expanded as compared to softwood forests. Moreover, with only few exceptions the hardwood floodplain forests disappeared as a consequence of man-induced changes in the course of decades or centuries. Only few patches of near-natural hardwood floodplain forests (Querco-Ulmetum) with Balkan oak (*Quercus pedunculiflora*), common oak (*Quercus robur*), elm (*Ulmus laevis* and *U. carpinifolia*) have been left. They may be found e.g. downstream of the mouth of Sâiu (Oltu Mic), along the Danube near the village of Navodari (Teaca), in the Cama Dinu area on the banks between rkm 510 and 521 (upstream of Giurgiu), near Greaca (downstream of Giurgiu, etc. and on the Bulgarian Vardim island. Locally, lianas like Greek liane (*Periploca graeca*), wilde wine (*Vitis sylvestris*) and the swallow wort (*Cynanchum acutum*) form thick curtains adding a tropical character to the Lower Danube forests. As these hardwood oak/ash/elm forests are extremely rare they require special attention from a nature conservation point of view (Schneider 2003, 2008, 2009; Schneider et al. 2009).

Due to its hydrological and morphological dynamics and the formation of new sediment banks on the Lower Danube - in particular the growth of already existing islands and the formation of new ones - one may observe all evolution processes of pioneer stages in willow stands, the natural regeneration of white and black poplar, the formation of gallery-like softwood forests and first settlings of hardwood forests. The white willow and black poplar forests on some small Romanian and Bulgarian islands that emerged on natural habitats without human interference are actual pristine forests, that, together with the pioneer vegetation of ephemeral species in the river bed at low water levels (below the mean water level) reach the highest degree of naturalness. Their development and survival depend on the water level dynamics, on sediment erosion and accretion. They stand at the beginning of a whole series of developments and are the prerequisite for a natural development of floodplain forests. As they have considerably decreased all over Europe, they deserve special attention from the point of view of nature conservation (Schneider 2003, 2010).

4 Habitats of community interest (included in the Natura 2000 network) (Fig. 1)

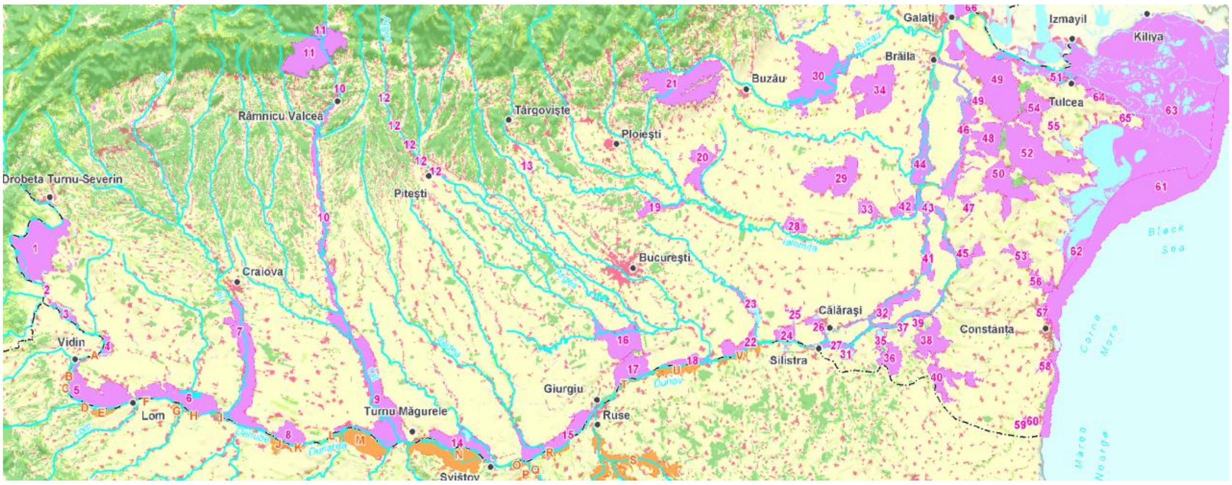

Figure 1. *Sites of community importance on the Lower Danube and the Danube Delta (Schneider et al. 2009). Pink areas = Romanian Natura 2000 sites; yellow areas = Bulgarian Natura 2000 sites; numbers correspond to the list given by Schneider et al. (2009).*

Among the habitat types occurring along the Lower Danube and studied from rkm 838 (Gârla Mare) to rkm 383 in 2004, from rkm 540-500 between 2007-2009, near Călăraşi in 2002), the following are listed in Appendix I of the Directive on the conservation of natural habitats and of wild fauna and flora (Doniță et al. 2005; Schneider & Drăgulescu 2005); the habitat numbers correspond to the numbers in the FFH Directive and the Interpretation Manual of the EU habitats (EC 2007); the * means priority habitat:

1340 Inland salt meadows

Small patches of this habitat type occur in the Danube floodplain, for example near the mouth of the Jiu River into the Danube and near Ghigera. This habitat type may also be found in some spots of the old Danube floodplain. The alterations of the Danube floodplain as a result of dyking and changed hydrological regime and a high evaporation due to the continental climate caused an extension of saline spots along the Lower Danube.

2340 * Pannonic inland dunes, incl. pannonic plain and neighbouring basins, e.g. dune area of Ciuperceni-Desa downstream of the town Calafat, dunes near Balta Luminoasă/Bechet, Dăbuleni.

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

This habitat type that includes old Danube branches and oxbow lakes occurs in different areas of the former and the recent floodplain of the Lower Danube (e.g. Balta Luminoasa, Balta Saica rkm 515-519, on the area of small Braila islands, and in the floodplains between Braila and the Danube Delta).

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

This habitat type occurs more rarely in the floodplains of the Lower Danube, it is however characteristic of smaller water courses and has been observed in the surroundings of Corabia. Along small groundwater streams that may be observed in the form of hillslope seepage along the floodplain borders one may also find a habitat type that shelters the watercress (*Nasturtium officinale*).

3270 Rivers with muddy banks showing Chenopodion rubri pp (pro parte) and Bidention pp vegetation

This habitat type is characteristic of protosoil surfaces that lay bare when water levels fall below the mean water level and are then settled by ephemeral species (*Lindernia procumbens, Heleochloa alopecuroides, Cyperus michelianus, Gnaphalium uliginosum* and others). It depends on the dynamics of water levels and the morphodynamics allowing protosoil surfaces to emerge. Such vegetation can only survive along natural and unspoilt river sections.

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

This habitat type comprises open stands of grasses and herbs which, as pioneer associations, are bound to xeric and calcareous sands. Along the Lower Danube it may be observed in the river's dune areas of Ciuperceni-Desa, near Balta Luminoasa / Bechet and Dăbuleni.

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

This habitat type comprises grassland associations of arid and semi-arid stands which are classified with Festuco-Brometea. It occurs along the floodplain borders on the slopes of the loess terraces.

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

This habitat type comprises moist tall herbaceous fringes, mainly composed of nitrophilous species that occur along the borders of the floodplains. Most frequent are fringes of Glechometalia and Convolvuletalia where the spurge *Euphorbia lucida* occurs as well. Specific for the Lower Danube are also fringes of *Aristolochia clematitis*, which is the foodplant for the caterpillar of the rare butterfly *Zerynthia polyxena*.

6440 River valley alluvial meadows of the Cnidion dubii

Temporarily inundated floodplain meadows of this type are very rare on the Lower Danube and do only occur in very small areas along hardwood floodplain forests (e.g. in the nature reserve Cama-Dinu upstream of Giurgiu, rkm 510-520). They shelter characteristic species such as *Clematis integrifolia*, *Galium rubioides*, *Carex praecox*, common skullcap *Scutellaria galericulata*, *Veronica longifolia* and others.

6510 Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)

Lowland meadows of this type occur rarely on the Lower Danube and usually show transition characteristics towards actual alluvial meadows of the Cnidion dubii type.

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

On the Lower Danube one may only find remains of hardwood floodplain forests that are composed of oak, elm and ash. Even though they were never really prevalent, oak-elm forests existed in some sections but have unfortunately been cleared. The last remains of this type of forest are extremely valuable as from a nature conservation point of view and deserve closer attention. The old oak trees of the floodplain offer habitats for a numer of rare coleoptera species. To name only a few exemplary spots one has to mention the remainders next to the Sâiu (Oltu Mic)-mouth, along the Danube near the village of Navodari (Teaca), next to the Vedea River mouth (rkm 540), in the Cama Dinu area, on the river bank between rkm 510 and 524, near Greaca downstream of Giurgiu, near the Arges River mouth, on the Bulgarian islands of Belene and most of all Vardim.

92A0 *Salix alba* and *Populus alba* galleries

Even though this habitat type is classified as floodplain forest with Mediterranean characteristics in the Mediterranean deciduous forests group, it may be considered as a characteristic habitat type of the Lower Danube. On the Lower Danube this habitat type shows a transition character between the typical Mediterranean gallery-like riparian forest and those of the Lower Danube. It is represented also at the lower stretches of Danube tributaries like the Jiu, Olt, Arges, Ialomita, Siret and Prut River.

92D0 Southern riparian galleries and tickets (Nerio-Tamaricetea and Securinegion tinctoriae)

Tamarisk shrubs (*Tamarix ramosissima*) occur along the Lower Danube and its tributaries, especially in places with a great dynamics where new sand areas do constantly emerge.

Natural or near-natural characteristic floodplain habitats do still exist in the Lower Danube area only, as it is subject to the river dynamics with periodical water level fluctuations, erosion and sediment deposition. These river stretches show high site typical biodiversity, habitat types and species, as exemplified above. Between rkm 838 and 383 the 50 sites analysed as base for proposals for the Natura 2000 network encompass 55 species of aquatic macrophytes and 961 species of semi-aquatic and terrestrial plants (Schneider et al. 2005; Schneider 2008, 2009). Two islands representative for the whole stretch, the protected sites Belene (BG) and Cama-Dinu (RO), are of high conservation value as for their biodiversity. In both areas 7 of the habitat types of community interest are present and a high plant diversity has been identified, in the Belene complex 372 species and in the Cama-Dinu area 331 species. The high degree of naturalness with site typical habitats and species is in contradiction with the status of the Lower Danube declared following the classification of the WFD as a heavily modified water body. Further, the planned measures for navigation improvement such as ground sills, groins and river bank reinforcements in the islands complexes of Belene and Cama-Dinu (ISPA II) will have serious negative consequences for the protected sites due to large-scale changes in hydrology deteriorating morphological structures, habitats and biota. Taking into account the high conservation value on the national and international level, it has to be reconsidered, which measures are strictly necessary and which can be reduced or cancelled. However, it is difficult to find an acceptable compromise for nature conservation, economic interests and sustainable development.

5 Conclusions

Despite of changes in discharge of the Danube (due to the Iron Gate power plants) and its tributaries (e.g. Olt, Arges, Siret) the analyses showed a high value from the viewpoint of biodiversity, many habitats and species being of community interest. This biodiversity is dependent on the still existing hydrological and morphological dynamics. If structures and dynamics are lost, all the various habitats will change or disappear. Considering these facts it is of great importance to pay special attention to the remaining natural or near-natural areas along the Lower Danube and to analyse very carefully how the state of habitats can be maintained and navigation improved, as these habitats depend on natural river banks and islands. The international importance of the Natura 2000 network must be stressed.

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Spatio-temporal patterns of zooplankton densities according to water chemical characteristics and hydrological events in a river floodplain system at the Danube (rkm 1498-1469)

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Keywords: Danube, floodplain, flood-pulse, zooplankton, chemical characteristics

1 Introduction

The spatial and temporal variability and complexity of the river floodplain systems induces a high biodiversity that makes investigations of lotic ecosystems extremely difficult. After the introduction the Flood Pulse Concept (Junk et al. 1989) and the Riverine Ecosystem Synthesis (Thorp et al. 2006) an increased interest was devoted to the dynamically changing connection between large rivers and floodplains (Hein et al. 1999, Baranyi et al. 2002, Berczik & Buzetzky 2006). The applied hydro-ecological research projects about large rivers and floodplains often focused on fish and benthic invertebrate assemblages, neglecting the great importance of the zooplankton in lotic food-webs and their suitability for biomonitoring.

Growth and density of lotic zooplankton depend on the area of retentive inshore habitats and the connection between the main channel and its adjacent floodplain water bodies (Reckendorfer et al. 1999, Baranyi et al. 2002, Zimmermann-Timm et al. 2007). The zooplankton assemblages of the floodplains are affected by abiotic (water age, physical and chemical parameters) and biotic characteristics (food-web, competition, predation) of each side channel (Dinka et al. 2006). Most of these parameters are defined by the overall discharge of the main arm, which varies over time (Lair 2005). Some studies have focused on zooplankton density and diversity patterns and the regulation of abiotic and biotic factors in large rivers, but the role of the hydrological regime in this process on natural floodplains is still unclear (Schöll 2009, Elosegi et al. 2010).

The aim of our study is to clarify the effects of flooding in different types of floodplain water bodies on hydrobiological processes during rising, standing and sinking water level. Our hypothesis based on previous field observations was that during high flood water chemistry changes along a gradient from the main arm to remote water bodies. Suspended matter and nutrient concentration would decrease, while the amount of chlorophyll-a would increase in the direction to eupotamal-parapotamal-plesiopotamal-conjunctive water bodies. We expected highest zooplankton densities in the plesiopotamal and lowest densities in the main arm.

2 Material and methods

The floodplain Gemenc (Duna-Dráva National Park) is situated between rkm 1498 and 1469, on the right bank of the Danube. It covers 180 km^2, which makes it the only notable floodplain of the Middle Danube today. It is also one of the largest floodplains in Europe, with unique natural value (Zinke 1996). As it is completely within the dam system, the characteristic hydrological processes of the river floodplain system are not disturbed. We can observe every characteristic “functional unit” (eu-, para-, plesio- and paleopotamal) of an ecological succession, providing a great opportunity to compare them simultaneously (Roux 1982; Guti 2001).

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The floodplain is 30 km long and 5-10 km wide. In this reach of the Danube the mean annual discharge is 2400 m^3s^{-1}, with a minimum of 618 m^3s^{-1} and a maximum of 7940 m^3s^{-1} (mean values). The water level fluctuation is monitored by the gauge at Baja (rkm 1479) and the maximum amplitude is 9 m. The slope is about 5 cm km^{-1} in the main arm, with a flow velocity of 0.8-1.2 m s^{-1} at mean water level. The river starts to overflow into the floodplain after it reaches a water level of 500 cm at Baja.

Three dates (23 May, 11 and 25 September 2007) with different hydrological regime (Fig. 2) and 19 sampling sites in the main arm (D1489), the parapotamal Rezéti-Holt-Duna (RDU) and Vén-Duna (VDU), and the plesiopotamal Grébeci-Holt-Duna (GDU) were chosen to clarify the effects of flood on zooplankton densities and water chemistry (Fig. 1 and Tab. 1).

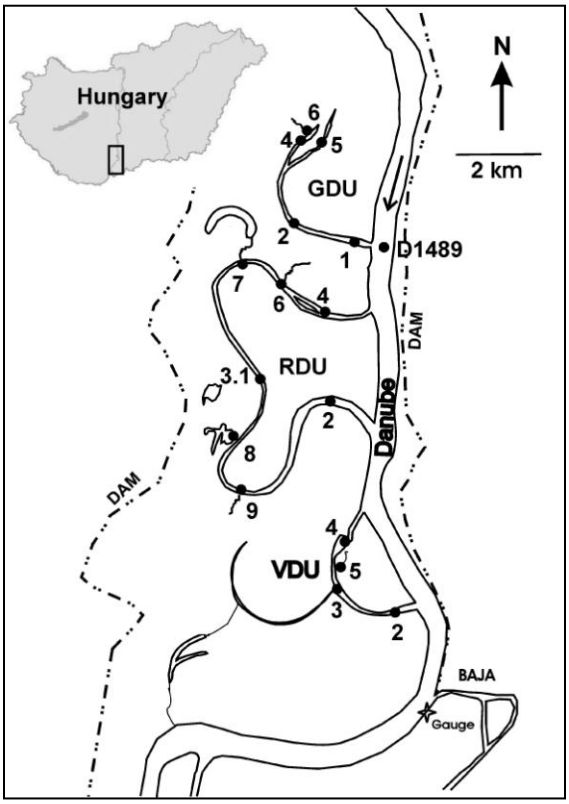

Figure 1. *The investigated area and the sampling sites*

The mean values and standard deviations of the water level during seven consecutive days prior to the sampling were taken into consideration to characterize the hydrological regime.

Table 1. *Characteristics and position of sampling sites*

	Site	GPS coordinates		Hydrological character
Eupotamal	*D1489*	N46º16.403’	E18º54.547’	the main arm, constant flow
Parapotamal	*RDU5*	N46º15.599’	E18º53.623’	15 km long side arm, mostly flowing
	RDU4	N46º16.015’	E18º53.645’	15 km long side arm, mostly flowing
	RDU3.1	N46º14.767’	E18º52.541’	15 km long side arm, mostly flowing
	RDU2	N46º14.224’	E18º53.192’	15 km long side arm, mostly flowing
	VDU4	N46º12.754’	E18º53.940’	5 km long side arm, constant flow
	VDU3	N46º12.118’	E18º53.843’	5 km long side arm, constant flow

	VDU2	N46º11.880'	E18º55.177'	5 km long side arm, constant flow
Plesiopotamal	*GDU1*	N46º16.495'	E18º54.104'	7 km long side arm, mostly stagnant water
	GDU2	N46º17.202'	E18º52.921'	7 km long side arm, mostly stagnant water
	GDU3	N46º17.451'	E18º55.610'	7 km long side arm, mostly stagnant water
	GDU4	N46º17.638'	E18º53.162'	7 km long side arm, mostly stagnant water
	GDU5	N46º17.641'	E18º53.261'	7 km long side arm, mostly stagnant water
Conjunctive water bodies	*VDU5*	N46º12.346'	E18º53.732'	small periodical inflow from the floodplain
	GDU6	N46º17.682'	E18º53.210'	small periodical inflow from the floodplain
	RDU6	N46º16.208'	E18º52.671'	small periodical inflow from the floodplain
	RDU7	N46º16.237'	E18º52.373'	small periodical inflow from the floodplain
	RDU8	N46º13.950'	E18º51.918'	stagnant, periodical floodplain water body
	RDU9	N46º13,412'	E18º51,967'	small periodical inflow from the floodplain

Water temperature (ºC), conductivity (µS cm^{-1}), pH, dissolved oxygen (mg l^{-1}) and oxygen saturation (%) were measured *in situ* with WTW Multi 340i or Hydrolog 2100 instruments (Grabner, Wien). Water samples were analyzed for NH_4-N, NO_3-N and PO_4-P with a Dionex DX-120 ion-chromatograph after filtration (Chromafil filter, 0.2 µm pore size). Clorophyll-a and suspended matter (SM) were determined by standard analytical methods (Golterman et al. 1978).

Zooplankton samples were concentrated by filtering 20 L (Rotifers) or 50 L (Crustacea) of water collected from the water surface through 40 µm (Rotifers) or 70 µm (Crustacea) mesh sized nets. After collection the samples were instantly preserved in a 4 % formaldehyde solution.

3 Results

On 23 May the water level in the main arm was 256 cm (Fig.2). The mean value of the previous 7 days was 275 ± 39.1 cm, while the hydrological regime was slowly decreasing, near stagnating. On 11 September the water level was 697 cm (higher than anytime during the previous week). The mean value of the previous 7 days was 398 ± 174.1 cm; thus the hydrological regime was strongly increasing. On 25 September the water level was 426 cm, while the mean value of the previous 7 days was 510 ± 94.3 cm; consequently the hydrological regime was steadily decreasing (Fig. 2).

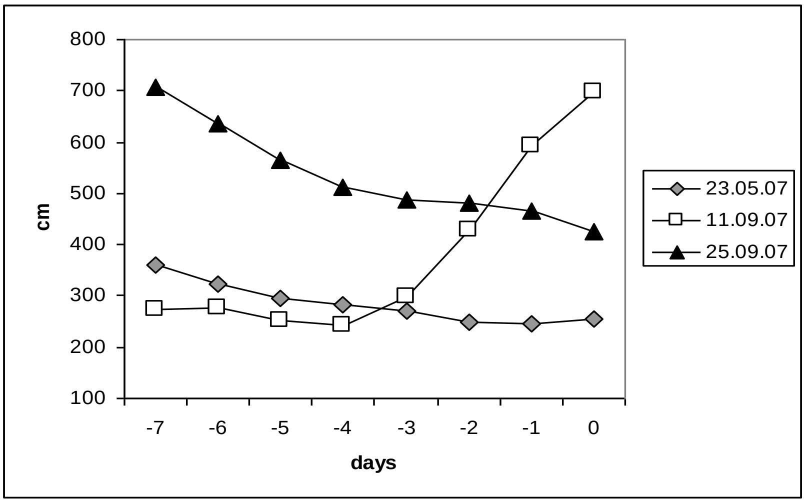

Figure 2. *Water level fluctuations in the main arm during seven days before the sampling date (zero)*

The patterns and differences in the physical-chemical characteristics and in the densities of the zooplankton assemblages depended on the hydrological regime.

On 23 May the temperature and ammonia and phosphate concentrations were lower in the main arm, while nitrate concentration was highest. Chlorophyll-a and SM concentrations were notably lower in the parapotamal side arms (Tab. 2). High differences occurred among the characteristics of sampling sites with identical hydrological character reflecting high habitat diversity. The densities of Rotifers and Cladocerans were highest in the parapotamal, while most Copepods occurred in the plesiopotamal. This can be explained by limiting low flow. In the eu- and parapotamal, where constant flow is typical, the zooplankton was dominated by Rotifers. In the plesiopotamal the longer water retention time favours biotic interactions among zooplankton groups leading to the dominance of Crustaceans (Schöll & Kiss 2008). At this time the conjunctive water bodies were dried out.

On 11 September, when water from the main arm flowed to the smaller water bodies of the floodplain, electric conductivity, oxygen concentration and pH were similar due to the short retention time (Tab. 2). However, the temperature increased, but the SM decreased with increasing distance from the main arm. The density of the three zooplankton groups was very low, with no notable differences between the sampling areas. The homogenizing effects of the flood reduce temporarily the habitat diversity and equalize the differences among zooplankton assemblages (Thomaz et al. 2007). In the whole floodplain the flowing water was more or less typically dominated by Rotifers, while Copepods and Cladocerans were virtually absent.

On 25 September the water flowed back from the floodplain to the direction of the side arms and the main arm. Water temperature and oxygen concentration were lowest, while conductivity was highest in the conjunctive water bodies, which can be caused by the longer retention time, which allows of getting on the local effects. The patterns of nutrient concentrations were mixed: maximum concentrations of ammonia and nitrate occurred in the main arm, maximum phosphate concentrations in the conjunctive water bodies. The chlorophyll-a concentrations were much higher in the plesiopotamal and conjunctive water bodies than in the eu- and parapotamal, while SM values were again highest in the main arm (Tab. 2). The densities of both Crustacean groups were highest in the conjunctive water bodies with longest retention time, but most Rotifers occurred in the plesiopotamal and dominated in all water bodies. The Copepoda/Cladocera ratio differed from the one observed during stagnant conditions on 23 May.

Table 2. *Physical-chemical characteristics and zooplankton densities in the different types of water bodies (SM-suspended matter, Cop-Copepoda, Clad-Cladocera, Rot-Rotifera)*

		T	Cond.	pH	O_2	Chl-a	SM	NH_4-N	NO_3-N	PO_4-P	Cop	Clad	Rot
		°C	µScm^{-1}		mg l^{-1}	µg l^{-1}	mg l^{-1}	µg l^{-1}	mg l^{-1}	µg l^{-1}	ind/50L	ind/50L	ind/50L
23.05.07. 256 cm	Eupot.	21.0	379	8.3	13.6	91.0	33.4	60.3	1.14	0	22	2	3625
	Parapot.	25.1	359	8.5	14.3	53.0	17.7	78.2	0.65	2.86	18	201	30915
	Plesiopot.	25.1	463	8.0	13.1	95.0	31.1	317.7	0.26	16.0	710	56	1500
	Conj. w.	-	-	-	-	-	-	-	-	-	-	-	-
11.09.07. 697 cm	Eupot.	14.7	340	7.6	8.6	2.0	116.4	66.0	0.80	28.6	1	7	500
	Parapot.	15.1	349	7.5	8.4	4.5	72.4	58.8	0.72	32.2	1	3	730
	Plesiopot.	15.5	364	7.5	8.0	2.0	20.1	68.0	0.83	35.2	0.5	1	875
	Conj. w.	15.6	355	7.6	7.8	3.0	6.0	43.0	0.70	47.0	1	1	375
25.09.07. 426 cm	Eupot.	15.7	386	7.7	9.3	5.0	34.4	60.0	0.90	27.9	2	7	525
	Parapot.	16.2	391	7.5	9.2	8.8	15.5	51.6	0.97	27.8	7	21	3540
	Plesiopot.	16.0	397	8.0	10.4	55.0	11.7	8.0	0.17	5.0	4	65	8585
	Conj. w.	15.0	409	7.6	8.0	33.0	14.5	16.0	0.23	39.0	15	84	2750

4 Conclusions and outlook

The effects of the hydrological regime represent the fourth dimension (time) in lotic ecosystems, especially in a river-floodplain system (Ward 1989).

The physical-chemical characteristics of the floodplain water bodies are influenced by local effects (e.g. flow, connectivity with the main arm, nutrient release from sediments, autochthonous primary production), by the seasonal/meteorological effects (temperature, duration and intensity of sunlight, precipitation) and by the direct effects of the hydrological regime. During stagnant water levels the intensity of local effects is dictated by the hydrological connectivity (as a hydrological distance from the main arm). The patterns of zooplankton assemblages depended more or less on the local characteristics. During higher floods, the direct effects of the hydrological regime became significant. The homogenizing effect of flood temporarily eliminates the physical and chemical gradients and sweeps out the local zooplankton assemblages. After the flood local effects begin to dominate again. According to our hypothesis the water chemical characteristics changes more or less along a gradient from the main arm to the plesiopotamal, but the characteristics of conjunctive water bodies are more diverse. The suspended matter and nutrient concentrations are the highest in the main arm and the lowest in the plesiopotamal/remote water bodies. After the flood event the densities of zooplankton groups are lowest in the main arm and highest in the plesiopotamal/conjunctive water bodies, but in the stagnating period the more dense assemblages occurred in the parapotamal.

Research about the effects of high floods on floodplain water bodies and their biota calls for further, more detailed investigations (e.g. the detailed nutrient cycle of the river-floodplain system; the influence of hydrological connectivity on the spatial and temporal biodiversity patterns; the role of the floodplains as a source of biota for the main arm) as it addresses an important aspect of the river-floodplain system in terms of conservation, water use and water quality.

Acknowledgements

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Floodplain restoration by dike relocation along the Elbe river and the need to monitor the effects

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Keywords: Elbe, floodplains, dike relocation, floodplain restoration, monitoring

1 Moore room for rivers - an introduction

In Europe, floodplain landscapes in the 21st century are characterised by fragmented habitats and depauperate communities. Since the Middle Age, floodplain forests were cleared and replaced by pasture and arable land or have been used for urbanisation. Many anthropogenic alterations to river systems such as the flow regulation for navigation and the building of dikes for land reclamation or flood protection have disrupted the lateral connectivity of river systems, leading to the disappearance of 70 to 90% of active floodplains of large rivers (Brunotte et al. 2009). The loss and degradation of floodplain habitats, as well as organic and chemical pollution and invasive species are major factors responsible for the decline of floodplain biodiversity (Tockner & Stanford 2002). Trade-offs exist between the conservation of floodplain ecosystem biodiversity and the human use of floodplain goods and services (MEA 2005; Dudgeon et al. 2006). Floodplains offer a remarkably diverse array of natural functions and services for humans; more than any other ecosystem type (e.g. Costanza et al. 1997; Maltby et al. 2009). Active floodplains have the ability to act as filters for sediments and dissolved pollutants (sinks), flood retention areas and natural habitats for highly specialised flora and fauna. Floodplain management and restoration measures should take into account the multidimensional structure of riverine ecosystems. Developing more natural riverine systems and improving the connectivity are key issues for floodplain restoration projects. Creating more space for rivers in floodplains by dyke displacement allow combining flood protection and ecological rehabilitation (Buijse et al. 2005; Scholten et al. 2005; Blackwell & Maltby 2006). At the German Elbe, reactivations of former floodplains are planned at 15 locations and will encompass 2,600 ha (ICPE 2003). However so far, implementation only occurred at three sites in UNESCO-Biosphere Reserve Riverine Landscape Elbe and covering a total surface of 580 ha (Scholz et al. 2009b). The involvement of the different stakeholder groups, nature conservation organisations and local people are essential for the acceptance and achievement of such integrated management approaches (Puhlmann & Jährling 2003; Moss & Monstadt 2008). Ecological motivation for floodplain restoration is the re-establishment of the hydrological processes to improve the dynamics and functions of floodplain ecosystems and restore their biodiversity. However, higher connectivity with the river may also increase nutrients and pollutants inputs (Lamers et al. 2006). Thus, a long-term monitoring of the effects of dike relocation or creation of new retention surfaces is a prerequisite for successful restoration of further floodplain areas.

In this paper we present an innovative multidisciplinary research design to study the effects of the first large-scale floodplain restoration project realised at the German River Elbe – the Rosslau dike relocation.

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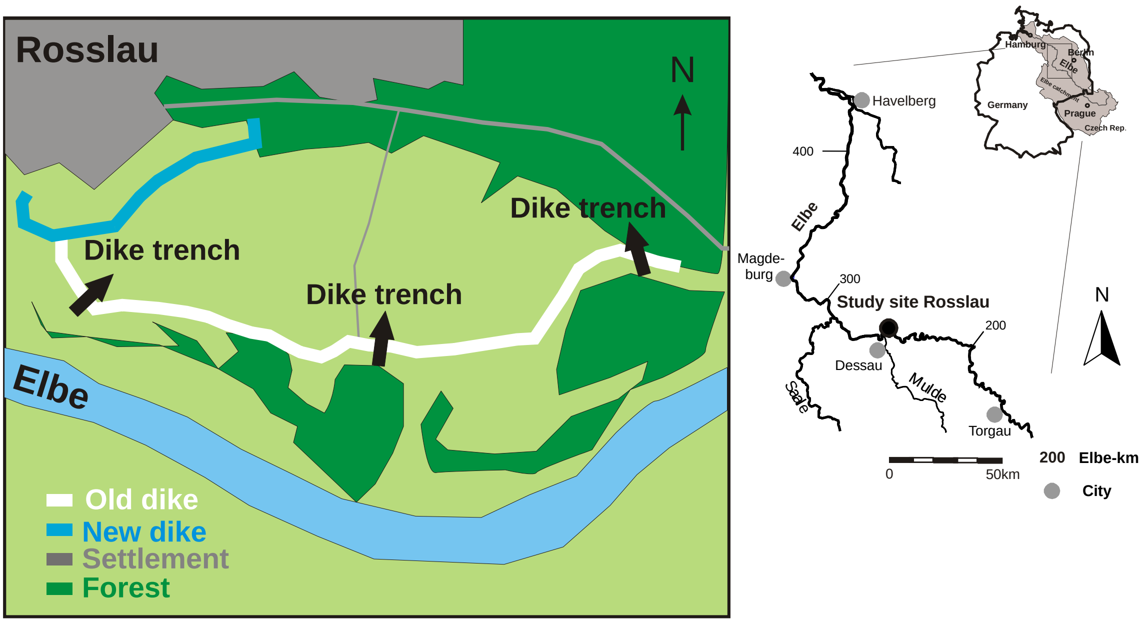

Figure 1. *Dike relocation „Rosslauer Oberluch" Middle Elbe*

2 Dike relocation in the Rosslauer Oberluch

The first large implemented floodplain restoration project along the German Elbe was realised in 2006 in the city of Dessau-Rosslau after a planning phase of 15 years. In Rosslau, the high restoration costs of the old dike line motivated the stakeholders to build a less expensive smaller dike close to the city, and to reopen the former floodplain at three locations (fig. 1). Today the 140 ha of reconnected floodplain are used for flood retention, agriculture (grassland), forestry, drinking water supply, and as recreation area. Nevertheless, the Rosslau area showed already in the beginning of the project a high restoration potential and hosted diversified floodplain habitats (alluvial grasslands, reeds, riparian forests, and permanent or temporary water bodies). Former arable land has been transformed to extensive riparian grasslands and plantations of floodplain forest already in the beginning of the planning phase during the 1990s (Scholz et al. 2009b).

3 Monitoring approach

Since spring 2006, a multidisciplinary research platform for floodplain ecology is established by the UFZ as a part of the TERENO-Program (=TERrestrial ENviromental Observatoriato) to study short-term and long-term effects of floodplain restoration on floodplain ecosystem services and functions in the Rosslau area. A BARCI approach (Before-After/Reference-Control-Impact design (Lake 2001) with a stratified, randomised study design developed and tested in the RIVA project and HABEX project (Henle et al. 2006; Scholz et al. 2009a, b) sets the scientific basis to all participating disciplines and is to be considered as the core of the research platform. According to the BARCI approach, three different sub-areas have been chosen: restoration area, untouched active floodplain (reference area), and former inactive floodplain (control area). The stratified, randomised study design with interdisciplinary study plots covers flood-channels and depressions; wet grassland; and mesophilous grassland. The rationale behind the stratification was to capture the full range of hydrological conditions and to distribute the plots approximately evenly across this range, despite great differences in the area. The Rosslau project requested that every scientist has to work on the same plot, thus enabling a proper study of the relationships between the different kinds of data. It allows representative monitoring data and repeated surveys of the same plots for biotic (molluscs, insects, vegetation) and abiotic (soil, nutrients, pollutants, hydrology) factors. All the locations for sampling abiotic and biotic data were restricted to fixed locations within the 30m x 15m study plot. The localities for the different botanical, zoological, and soil surveys within plots are shown in figure 2. Since in floodplains the elevation is of paramount ecological importance, we oriented each plot to minimize elevational heterogeneity within plots.

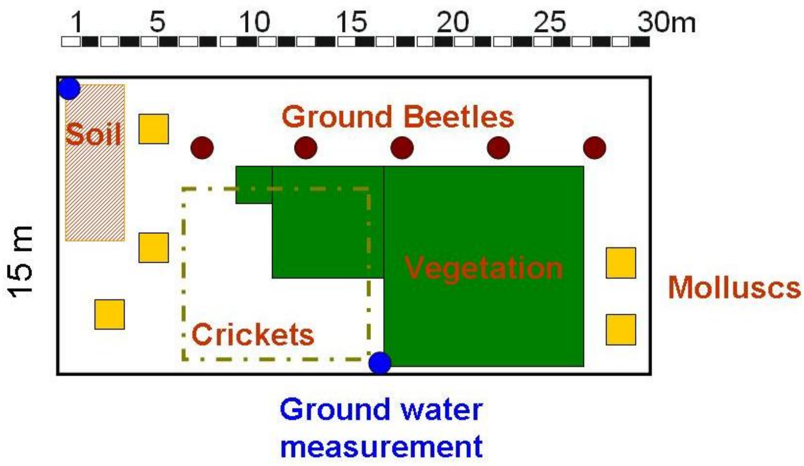

Figure 2. *Standard survey plot (Henle et al. 2006, modified)*

4 Bioindicator species groups

Suitable and effective bioindicators have to fulfil general criteria in two ways: firstly, economic and logistic suitability (time- and cost-efficiency, personnel and knowledge requirements) and secondly, biological efficiency (taxonomic, sensitivity, and variability criteria) (Dziock et al. 2006; Scholz et al. 2009a). In the Rosslau project, four species groups were chosen: vascular plants, molluscs (shelled snails and mussels), carabid beetles, and grasshoppers. Other studies on bioindication in floodplains have also adopted these groups (e.g. Murphy et al. 1994; Henle et al. 2006), indicating their abundance in floodplains and their high indicatory relevance for ecological changes in floodplains. Additionally, these species groups cover a wide gradient of mobility. Plants move only by distributing their diaspores, molluscs are slow and often passively distributed by water, carabides can run quite fast on the ground, some species can fly, and grasshoppers are quiet mobile insects including seasonal migrants. The wide gradient of mobility should be advantageous, because the degree of mobility determines the strategy for how a species copes with flooding (Lytle & Poff 2004). Immobile species need adaptations to withstand seasonal or erratic floods, or their occurrence is restricted to the uppermost parts of the floodplain. Mobile species can more or less avoid longer contact with the water by moving to drier places. The species groups have in common that they are sensitive to changes in flood regime and can tolerate the high nutrient input by the river typical for active floodplains. They contain species that have a strong relationship to hydrological variables on a small scale, which is one of the pre-assumptions to use them for bioindication (Henle et al. 2006). Independently from the plots we are doing a survey of amphibians (highly mobile, sensitive to landscape context) and mosquitoes (possible disease vectors) on temporary and permanent waterlog water pools. These habitats are the key habitats for their reproduction and therefore predominant for the meta-population of these species groups in the study site.

5 Abiotic Data

Additionally to the biotic data we are gaining abiotic data in the field. Soil variables are obtained in the field (e.g. soil type) as well as in the laboratory (e.g. grain size, nutrients or C/N ratio). Grassland management shows considerable differences in cultivation among and within the study sites (depending on their relief). For example, on the uppermost flat parts, grassland use is more intensive compared to the flood-channels, which are not accessible for agricultural machines. Under the assumption of stable conditions of land use, water variables were assumed to be the most important environmental factors determining species occurrence and abundance in floodplains. In most cases, they are also most difficult and time-consuming to measure, making them a most important potential focus for measuring the restoration efforts. Hydrological variables (groundwater and inundation) were measured at least fortnightly using gauges in each of the 36 study plots. Data analysis is applied to obtain inundation, groundwater depth, minima, maxima, amplitudes, means, and standard deviations for biologically relevant time periods.

6 Outlook and conclusions

Until now, for all disciplines a (Status Quo) pre-flood survey was successfully carried out. The soils of all study areas showed typical features of floodplain soils. Mollusc communities differed between the 3 sub-areas, being more diverse in the active floodplain; whereas ground beetles and grasshopper community composition mainly depended on small-scale morphological features. Vegetation is more diverse in the restoration and reference areas than in the active floodplain where nutrient loads from the Elbe may favour nitrophytes (Scholz et al. 2009b). First flooding of the restoration area by the Elbe occurred in spring 2009 and 2010 and the field monitoring is ongoing. However, to assess the effects of the dyke relocation on biodiversity, a long-term monitoring is needed.

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Hydromorphology of Mures River (Romania, Hungary)

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Keywords: Hydromorphology, Mures

1 Introduction

The EC Water Framework Directive (WFD) introduced hydromorphology as a necessary supporting quality element to assess the good status of surface water bodies. In the Danube River Basin Management Plan (DRBM) and the Joint Programme of Measures (JPM) of the ICPDR hydromorphological alterations are listed amongst the significant pressures (ICPDR 2009). The hydromorphological assessment is also one of the key elements in the Monitoring Networks to elaborate the final design of HMWBs (Heavily Modified Water Bodies). Hydromorphology is shaped by the hydrological regime and geomorphological processes and, hence, provides the basics for the habitat mosaic in riverine landscapes.

The hydromorphological conditions of almost 75% of all European rivers are impacted by man. Therefore, the EU countries are under pressure to prepare respective inventories and assessments. However, method development and surveys are still incomplete and, presently, in many CEE countries only so-called rapid risk assessments of hydromorphological characteristics exist.

Recent studies in the Lower Mura and Drava Rivers (Schwarz 2007, 2008) as well as along the Danube River (ICPDR 2008) exemplified the importance of continuous and harmonized assessments across the Danube River Basin (DRB) to support regional and transboundary river management. Our Mures investigation adds another IAD contribution to the long-term river development in the DRB (Schwarz 2010).

2 Approach and methods

The Mures River (largest tributary of the Tisza River, 760 km long, catchment area 28,000 km², mean discharge 180 m³/s, Sandu & Bloesch 2008) was investigated from its headwaters to the mouth by a CEN conform hydromorphological method (assessment of channel, banks and floodplains, CEN 2004). Field work by boat and on land was supported by excellent historical maps (beginning from 1780 with first Austrian Military Survey, Arcanum Edition Budapest) and high resolution satellite images (GoogleEarth 2005-2010). Moreover, recent literature (Schwarz 2007, 2008; ICPDR 2008; Sandu 2008) and WFD assessment (ICPDR 2009) were considered.

At the beginning, the historical data as well as the general geomorphological characterisation of the river result in a large-scale subdivision of the river in upper, middle and lower sections and respective main characteristics such as slope, channel geometry (planform – straight, braiding, meandering, and width variability), substrate as well as discharge. The river was further subdivided according to the status of channel, banks and floodplains, individually for right and left bank (the average length of segments is some 2 km with high variability from 250 m to some 18 km, according to significant changes). In total about 1,430 individual segments of channel, banks and floodplains were assessed and mapped (exemplified in Figure 1).

An access database was developed hosting the continuous survey data which can easily be connected to the GIS application showing the individual assessment values or even single parameters (e.g., in-channel features such as bars and islands).

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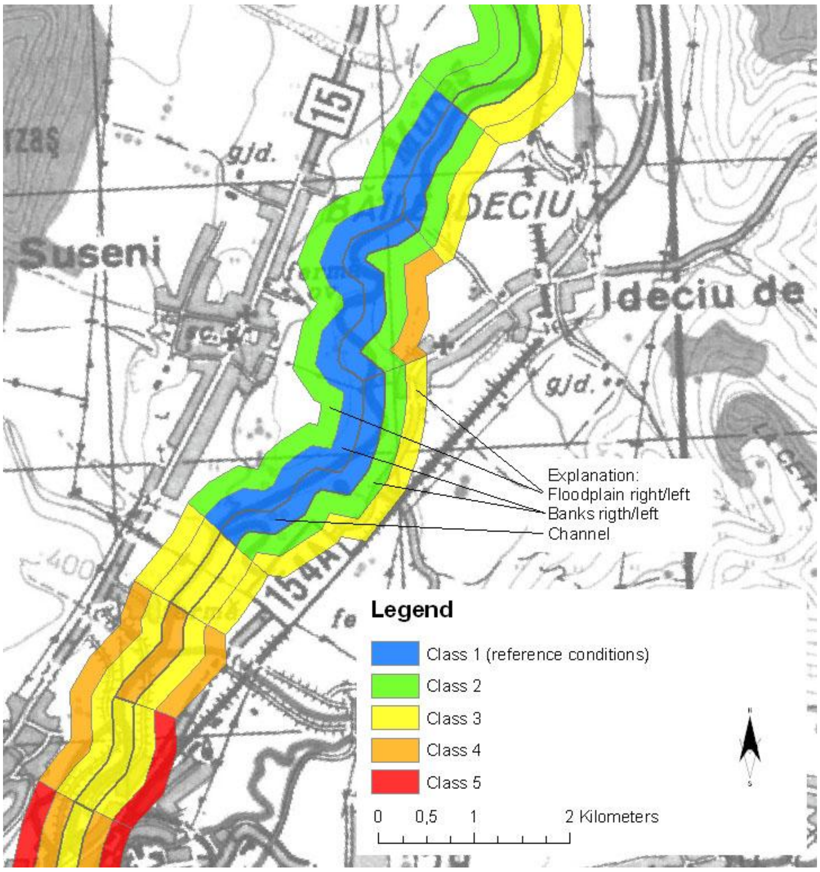

Figure 1. *Hydromorphology in a stretch of the Middle Mures River. Color ribbon visualisation for the assessment in five classes (described in detail in figs. 2-5). Maps for the whole river are given in Schwarz (2010).*

3 Results and discussion

Channel – The Mures is still a relatively natural (80% in class 1 and 2, Figure 2) and homogenous river (mostly meandering, only one mountain breakthrough in the upper catchment with short anabranching/braided reach). Only four dams influence water and sediment regime; however, the most important sediment recharging rivers such as the alpine Strei and tributaries as well as the very upper Aries are impacted by hydropower dams.

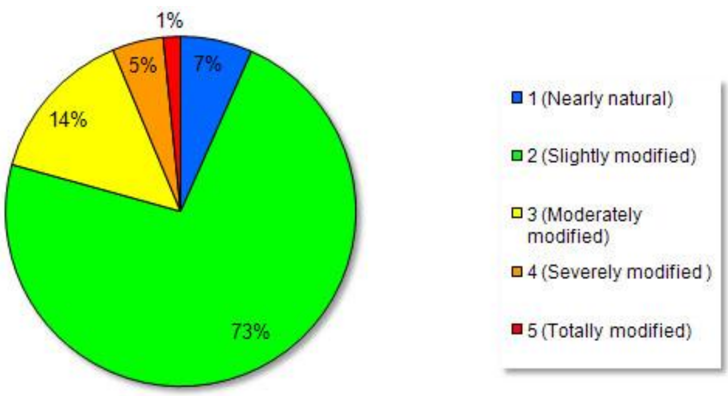

Figure 2. *Mures main course over 760 rkm: Channel assessment in five classes. The assessment classes 2-5 explain/illustrate the present status and indicate the deviation from class 1 (reference conditions). Strong impact on the channel amounts to 6% of the total length.*

The strongest hydromorphological alterations were found in stretches through towns (flood protection) and the straightened lower course (70 km in Hungary, navigation). Recent river regulation projects for flood protection are evident in the middle course (in total some 50 km). However, the strongest impact is by far commercial sediment extraction along the middle and lower sections (e.g. between Arad and Lipova (50 rkm) 11 mining sites in the main channel); this potentially favours channel incision, which is under-represented in the assessment due to still near-natural planform (sinuous and meandering channels with gravel bars). Historical analysis calculating former river length (sinuosity), width variability, bars and islands with pioneer habitats indicates a rather limited lateral shift of main channels in the middle still meandering course and a decline of fluvial dynamics since the beginning of 20th century.

Banks – The river banks are enforced in Hungary as well as downstream of the Mures Nature Park west of the city of Arad in Romania. But also along steep banks meanders are protected where infrastructure is nearby (railway, road, flood protection dike) leading to uniform banks on the entire middle course of the river (and obviously in town stretches). In total there are still remaining variable banks typical for meandering rivers with steep banks and point bar banks indicated by the occurrence of class one and two (43%, Figure 3). During the survey several new river engineering projects (river regulation, flood protection) along the middle course were observed intensifying the pressure on the system. Such measures should be restricted to absolutely necessary stretches (only constructing on right or left bank, not the whole channel and banks); compensation measures should provide substantial improvements (e.g., channel widening and lateral connectivity) in close vicinity of these impacts.

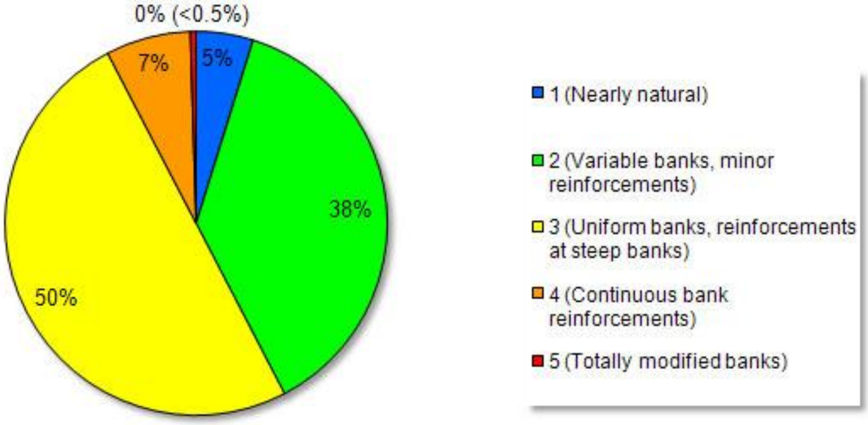

Figure 3. *Mures main course over 760 rkm: Bank assessment in five classes. Strong impact on the banks amounts to 7% of the total length.*

Floodplains – Larger forested floodplain areas have nearly disappeard; however, significant parts of the remaining floodplain are pastures (particularly in the middle course). The loss of floodplains amounts to some 67% (morphological floodplain area is 213,920 ha, remaining active floodplain is 70,660 ha, Figure 4) which is much less than for the Danube River with 72-95% (Schneider 2002). Main reason for the loss was the construction of floodprotection dikes along the lower 100 km of the river partially in Romania but mainly in Hungary. The hydromorphological situation of floodplains should be subject of further research. Although fine sediments accumulate, the channel deepens (mainly due to gravel over-exploitation) and floodplains gradually dry out. Sediment supply is diminished as the still meandering river has no major lateral erosion due to bank protection and, hence, incision is significantly increased. In total (18%) there are still many remnants, paleochannels and oxbows in the floodplains which should be subject of protection and restoration. However, compared with the historical situation the ecological potential and hydromorphological dynamics of the active floodplain is strongly reduced. The still remaining floodplains should be used as pasture (keeping where ever possible the current level of grazing) and the connectivity between river and floodplain should be improved.

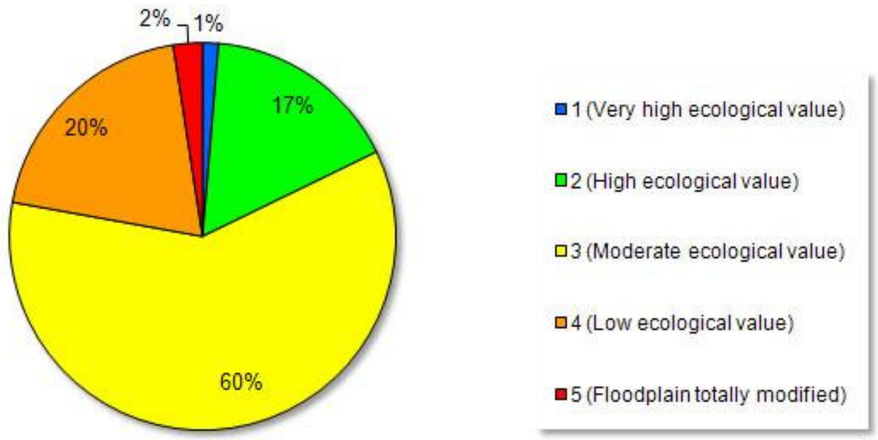

Figure 4. *Mures main course over 760 rkm: Floodplain assessment in five classes. Strong impact on the flood-plains amounts to 22% of the total length.*

Overall hydromorphological assessment – In total only 9% of the river are strongly altered (Figure 5, corresponding WFD class 4 and 5), 45% are moderately changed (class 3) and 46% are in good or near natural condition (class 1 and 2).

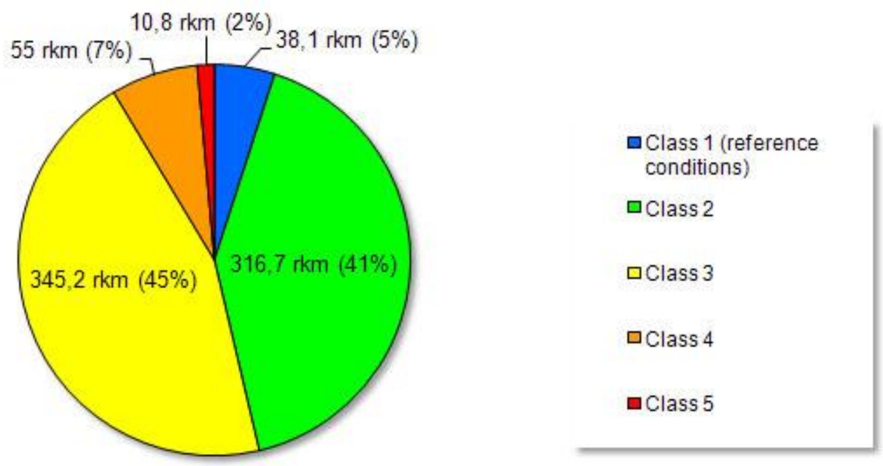

Figure 5. *Mures main course over 760 rkm: Overall total hydromorphological assessment in five classes (mean of channel, banks and floodplain evaluation) coloured in WFD classification scheme.*

The overall assessment indicates the rather good hydromorphological status for half of the river and the still minor part of artificial sections (only 10%) which is an impressive low value compared with many western European rivers. However, the slow degradation of the whole river system, evident through the assessments of banks and floodplains, is mostly driven by gravel over-exploitation and, hence, unbalanced sediment budget.

4 Outlook and conclusions

With our survey and maps (Schwarz 2010) we have successfully applied European methods for the hydromorphological assessment for a large river in Romania. This allows the inter-comparability of assessments by other countries. Since natural and anthropogenic changes are a permanent process we propose to update the assessment every six years, but in many cases it would be sufficient to analyse only selected stretches or even single parameters after restoration measures or respective impacts. The long-term development of the river can be well assessed based on historical records and the derived reverence conditions.

For the Mures River, the situation presents as follows:

- The river still hosts some near-natural stretches with highest protection priority. In this respect, soft eco-tourism could help to sustain the local people.
- Larger stretches still have typical meandering characteristics that need to be protected, in the long term, by adequate spatial planning. The Hungarian stretch, protected by Natura2000, has a great potential for river and floodplain restoration.
- In general, we find a sustainable river and floodplain use; however, local anthropogenic impacts cannot be overlooked (few existing dams and ramps as well as intensive river regulation work within settlements and along infrastructure).
- Infrastructure concepts like the construction of a highway through the lower Mures valley, new hydropower plants as well as development of settlements and infrastructure are the most important future threats for the riparian landscape.
- Excessive gravel mining is currently the most negative factor impacting the sediment household of the river; in addition, sediment supply from tributaries is reduced by reservoirs.
- The CEN assessment does not respect appropriately the intensive sediment extraction and the complex reaction of the channel/substrate and banks. Hence, gravel extraction causing channel incision must be considered much better in hydromorphological inventories.
- Sustainable sediment management in gravel bed rivers (including tributaries) is highly recommended. Erosion and accumulation of sediments are important functions of the riverine ecosystem and influence flood protection to a great extent.

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MODELKEY DSS as supporting tool for River Basin Management Plan definition: results from application to Elbe and Danube

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Keywords: Elbe, WFD, risk assessment, multi-criteria decision analysis, decision support systems

1 Introduction

The European Water Framework Directive (WFD) 2000/60/CE (EC, 2000) prescribes a series of tasks for properly assessing and managing river basins with the ultimate aim of achieving a good ecological and chemical status of surface waters by the end of 2015. The Ecological Status (ES) of each water body has to be evaluated and classified by using biological Quality Elements (QE) as key parameters and physico-chemical, chemical as well as hydromorphological QE as supportive parameters. Moreover, the Chemical Status (CS) has to be evaluated by comparison of measured concentrations of priority substances in water, sediment and biota compartments with Environmental Quality Standards (EQS) set at EU-wide level.

In this context, one of the main objectives of the MODELKEY project was the development of a risk-based Decision Support System (DSS) guiding decision makers in assessing and managing river basins according to the WFD requirements (i.e. MODELKEY DSS). In particular, Integrated Risk Indices (IRI) based on a Weight of Evidence approach (WoE; Burton et al., 2002) was developed in order to evaluate and classify the ES and CS at site-specific scale (i.e. sampling stations). Moreover, to prioritize hot spots at basin scale (by integrating both environmental and socio-economic information) a mathematical procedure based on Multi Criteria Decision Analysis (MCDA; Kiker et al., 2005) methods was developed.

The MODELKEY DSS was applied to both Elbe and Danube River Basins.

In this paper, main results obtained by DSS application to Elbe are presented and discussed (the results obtained for the Danube River will be given in the oral presentation). A set of biological, chemical, physico-chemical, and hydromorphological indicators have been evaluated in relation to available reference sites and then integrated according to a set of fuzzy rules implemented in the software system. Results at basin and site-specific scales for both river basins were visualized on GIS maps through the DSS's output visualization interface.

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2 The MODELKEY DSS

The MODELKEY DSS is an innovative software system that combines several risk-based assessment tools supporting the river basin management. It allows classifying the ecological and chemical status of individual water bodies or (monitoring) locations and it prioritizes hot spots by integrating environmental and socio-economic information. All these features are available in a simple-to-use, geographically resolved, GIS-based software system structured in three modules: environmental, socio-economic and prioritization. It offers adaptability to various rivers and local conditions, perfect coherence with the language and the reporting requirements of the WFD, technical simplicity and preferential flexibility, transparency and traceability of results, enhanced by strong graphical interface visualization.

The MODELKEY DSS is user friendly and freely downloadable from the MODELKEY project website (www.modelkey.org) after registration.

2.1 Environmental module

The environmental module of the MODELKEY DSS carries out an integrated risk assessment on the basin of concern. It aims at evaluating the overall status of fluvial ecosystems and provides decision makers with useful information for WFD-compliant management purposes: i.e. both ES and CS of rivers, the biological communities at risk (i.e. key ecological endpoints) and the most responsible causes of impairment (i.e. key stressors and key toxicants). This information turns out to be very useful to direct investigative monitoring activities and to target consecutive interventions.

The module uses environmental indicators as input. Environmental indicators are organised into a hierarchy and aggregated according to dedicated fuzzy inference rules. The output is provided through specific visualisation tools.

2.2 Hot spot prioritization module

The hot spots prioritization module is aimed to support water managers in targeting their economic efforts to those sites along river basins that strongly need management interventions. To this end it takes into account both environmental (i.e. risk assessment) and socio-economic (e.g. water uses valuation) perspectives. Specifically, a set of socio-economic indicators distributed across different economic agents (i.e. consumers and firms) and water uses (i.e. agricultural, industrial, energy production, residential and recreational) are proposed and calculated. By integrating socio-economic and environmental information, sampling sites as well as water bodies are ranked and hot spots are visualized and selected by means of GIS tools.

3 Application to Elbe River Basin

3.1 Used dataset and indicators

Information on habitat typologies and related reference sites were provided by the German Federal Institute of Hydrology (BfG) as confidential information.

Based on data availability in the BASIN DB (official database of the MODELKEY project), the Integrated Risk Assessment (IRA) methodology was applied to assess the environmental quality of Elbe in 2006. Raw data were available to calculate the following indicators in the majority of sampling sites:

- Biological indicators: Evenness (Pielou, 1969), Margalef (Margalef, 1984), Shannon (Shannon & Weaver, 1949) and Simpson (Simpson, 1949) for invertebrate fauna and phytobenthos (general degradation); NBI-N (Nutrient Biotic Index-Nitrogen), NBI-P (Nutrient Biotic Index-Phosphorus) (Smith et al., 2007), BBI (Belgian Biotic Index), BMWP (Biological Monitoring Working Party), SPEAR (Species At Risk) (Liess & von der Ohe, 2005, Von de Ohe et al., 2007) for invertebrate fauna (eutrophication, general degradation, organic pollution and toxic pressure);

- Chemical indicators: Chemical Status (CS), Toxic Units (TU), Potentially Affected Fractions (PAF; Posthuma et al., 2002), Chemical Comparison With Reference (CCWR);
- Hydromorphological indicators: Simplified AusRivAS (Parson, 2002).

Socio-economic data were available in each region only for 2008. The following indicators were calculated for five water uses, i.e. agricultural, residential, energy production, recreational and industrial:

- Water consumption in cubic meters;
- Market efficiency as GDP per cubic meter;
- Lerner Index (Varian, 2006) as representative of market competition conditions.

3.2 Examples of results at site-specific and basin scales

Figure 1 reports the ES final classification for a group of sampling sites located in the Sachsen region of the Elbe River Basin. Each pie chart shows the sampling point's membership degree to one (100%) or two (complementary percentages) WFD status classes (i.e. high, good, moderate, poor and bad) represented by using WFD standard colours coding: slices are larger or thinner according to the probability of belonging to each status class. The membership degree mainly ranges from poor/moderate to good/high apart from one site characterised by a partial membership degree to bad status.

As an example, the site Schirmbach Mundung is investigated (black arrow in Figure 1). The IRA methodology assigns about 70% membership degree to good status and about 30% to moderate status.

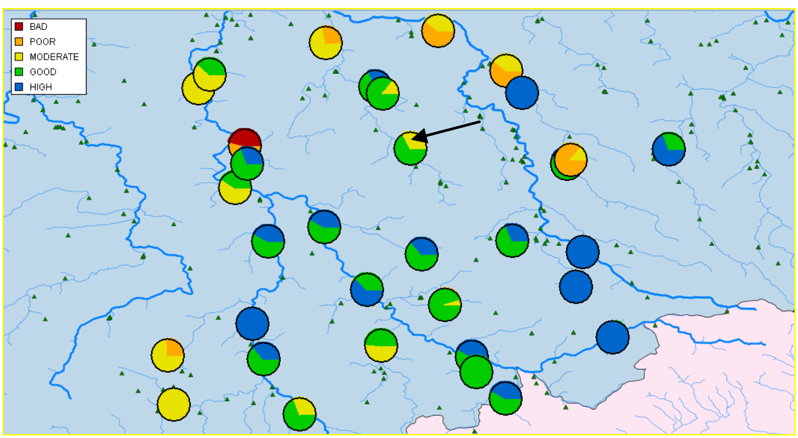

Figure 1. *Pie charts visualising membership degrees to WFD status classes for a group of sampling sites located in the central part of the Elbe River Basin. The black arrow indicates site Schirmbach Mundung.*

The availability of socio-economic information allowed the estimation of the socio-economic importance of various regions. As an example the socio-economic output of a specific administrative region of the Elbe River Basin is visualised (Figure 2). The region under investigation is Berlin that has a membership degree varying from low to medium class. Exploring the intermediate results that give a contribution to the estimation of the socio-economic importance of the region, the overall water usage for industrial and agricultural purposes seem to be the most relevant.

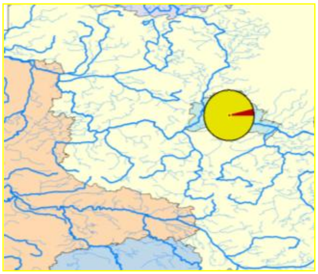

Figure 2. *Pie chart showing the socio-economic importance of Berlin (blue, yellow, red mean high, medium, low socio-economic importance, respectively).*

Finally, Figure 3 reports the site priority distribution over the Sachsen region of the Elbe River Basin (as environmental indicators could not be calculated in other regions).

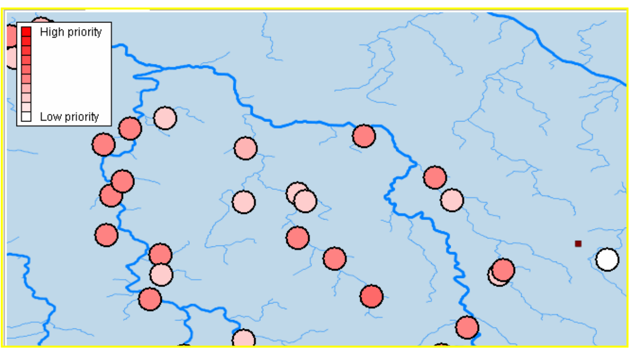

Figure 3. *Site priority distribution over the Sachsen region of the Elbe River Basin. Red, pink and white colours mean high, medium and low priority, respectively.*

4 Conclusions

The experimental application of the IRA methodology turns out to have several advantages. It allows using and aggregating information on different quality elements as recommended by the WFD. It expresses ES classification as membership degree to one or two WFD classes: this provides decision makers with easy-to-understand results including uncertainty estimation. The user can consider any types of data and indicators according to his assessment goals, can adjust membership functions defined for biological indicators based on local responses at reference sites, and can provide his expert judgment to biological indicators' hierarchical aggregation. CS is refined by taking into account other chemical indicators such as TU and PAF that enlarge the spectrum of chemical substances and estimate potential toxicity of mixtures. The IRA methodology is transparent and flexible, and the tiered assessment procedure allows to address new monitoring activities when there is missing information or discordance among indicators and results are highlighted.

In addition, the results of the hot spots prioritization procedure will guide the decision maker to focus further investigations and to target remedial efforts to those sites or water bodies where poor environmental conditions could compromise current or future important socio-economic uses of water resources. This kind of results, visualized by GIS maps, could help the decision maker in discriminating among sites or water bodies characterized by similar water quality but showing a different socio-economic usage of water resources: in this case the procedure assigns higher priority to those regions where water resources are largely and rationally used.

For the abovementioned reasons, the MODELKEY DSS is suggested as the new tool for supporting the future generations of River Basin Management Plans.

Acknowledgements

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The possible effects of climate change on the phytoplankton communities in the Danube river, Hungary

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Keywords: Danube, simulation modelling, climate change scenarios, algal blooms

1 Introduction

Effects of climate change on near-natural ecosystems can be analysed by weather dependent simulation modelling of seasonal community dynamics. Complex models comprising physical, chemical and biological parameters (e.g. nutrients, trophic links) of freshwater systems have been successfully used (Elliott et al. 2005; Mooij et al. 2007; Komatsu et al. 2007). However, in the methodology of modelling approach, which brings relevant findings to the field of climate change research, still there are several unresolved issues. (Sipkay et al. 2009). The basic problem is the lack of combined models and their complicated feasibility. Such models require a large amount of data about environmental parameters. However, there is not enough and adequate information about these parameters. Therefore tactical models are constructed which aims at highlighting the most influential environmental factors (such as temperature), but at the same time a lot of important information is disregarded. Nevertheless, the tactical models could be beneficial if the general functioning of ecosystems is in focus (Hufnagel & Gaál 2005; Vadadi-Fülöp et al. 2008; Sipkay et al. 2008a, 2008b; 2009).

We aimed to develop a discrete-deterministic model answering questions of seasonal dynamics of riverine phytoplankton by using daily temperature data as input parameters. In this way we can get a model of wide applicability concerning global warming related issues. To answer the question how phytoplankton abundance may be affected by global warming by 2100, the data series of climate change scenarios were used as additional input parameters. Predictions of our model, however, are valid only for the Danube River stretch at Göd and for the assumed constancy of disregarded factors. Furthermore the model should be treated with precaution because the scenarios are also products of models (check General Circulation Models and Regional Climate Models, IPCC 2007). In addition, the effect of linear temperature rise was tested.

2 Modelling approach

Long-term series of phytoplankton data are available in the Danube River at Göd (1669 rkm) owing to the continuous record by the Hungarian Danube Research Station of HAS of weekly quantitative samples between 1979 and 2002 (Kiss 1994). Phytoplankton was sampled from the surface water layer of the streamline and expressed as biomass (mg l^{-1}).

The high sampling frequency makes our data suitable for weather driven simulation models. We assume that temperature is of major importance for the seasonal dynamics of phytoplankton. Further, the phytoplankton reaction curve as a function of temperature is taken as the sum of temperature-growth optimum curves. The availability of light is respected, too, as it has also a major influence on the seasonal variation of phytoplankton abundance. Further abiotic and biotic effects are not respected as model parameters but may be implicitly considered by the modelled processes.

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First, a „strategic model”, which is considered as theoretical simulation model, the so-called TEGM (Theoretical Ecosystem Growth Model, Drégelyi & Hufnagel 2009a, 2009b) was used, which involves the temperature optimum-curves of 33 theoretical phytoplankton populations covering the possible spectrum of temperature. This model was adapted to field data from the Danube River (tactical model), considering that excess nutrients varied greatly during the study period (Horváth & Tevanné Bartalis 1999). The “tactical model” is a simulation model fitted to the observed temperature data set. Assuming that excess nutrients represent a specific environment for phytoplankton, two sub-models were developed, one for the period of 1979-1990 with large nutrient excess (sub-model „A”) and one for the period of 1991-2002 with small nutrient excess (sub-model „B”). The two periods reflect the observed reduced nutrient load of the Danube (Behrendt et al. 2005). Both sub-models can be described as the linear combination of 20 theoretical phytoplankton populations. The two versions of the model differ only in the shape of the temperature reaction curves defined by the mean and variance. The tactical model portraying 24 years is derived from the sum of sub-model „A” and sub-model „B”. Biomass (mg l^{-1}) of a certain theoretical phytoplankton population is the function of its biomass measured a day before and the temperature or light coefficient:

$$N_{i,t} = \min(R_T; R_L)^v \cdot N_{i,t-1} + 0.005$$

where

$N_{i,t}$ = biomass of theoretical phytoplankton population „i” at time „t”,

R_T = temperature dependent growth rate, described by the density function of normal distribution,

R_L = light dependent growth rate, including a sine curve representing the scale of light availability within a year,

v = species-specific factor of growth rate,

$N_{i,t+1}$ = biomass of the theoretical phytoplankton population „i” one day after time „t”,

0.005 = a constant for the mass of spores (which was built into the model so as to avoid extinction of the population).

To define whether temperature or light is the driving force, a minimum function was applied. The model was fitted to the daily temperatures of 1979-2002 provided by the Hungarian Meteorological Office by the help of the Solver Optimizer Program of MS Excel. Then, the model was run with the temperatures of climate change scenarios as input parameters. The data base of the PRUDENCE EU project was used (Christensen 2005); these were daily temperatures proposed by the A2 and B2 scenarios of IPCC (2007) which were specified for the period of 2070-2100. Three data series were used including the A2 and B2 scenarios of the HadCM3 model developed by the Hadley Centre (HC) and the A2 scenario of the Max Planck Institute (MPI). The simulated temperatures for the period of 1960-1990 (supplied by the above-mentioned institutes) were taken as control. Each scenario incorporates 31 replicates, i.e. 31 years representing the temperatures of the period around 2070-2100 each containing 365 days. From these 31 replicates we took 24 in order to compare them statistically with those of the 24-year long (1979-2002) observed data. In addition, the effect of linear temperature rise was tested step-wise by increasing the initial temperature by 0.5, 1, 1.5 and 2°C as input variable to the model.

The model outputs were verified by statistical methods using the Past software (Hammer et al. 2001). Yearly total phytoplankton biomass was defined as indicator and calculated as the sum of the monthly average biomass to avoid extreme values. One-way ANOVA was applied to compare means of the model outputs. A post-hoc Tukey test (Tukey’s pairwise comparisons) was applied to test for significant difference between model outputs. Homogeneity of variance was tested with Levene’s test, standard deviations were compared with Welch test (Hammer et al. 2001).

3 Results

The simulated phytoplankton biomass fitted quite well to the monthly average biomass observed (r = 0.74, r^2= 0.55) (Figure 1).

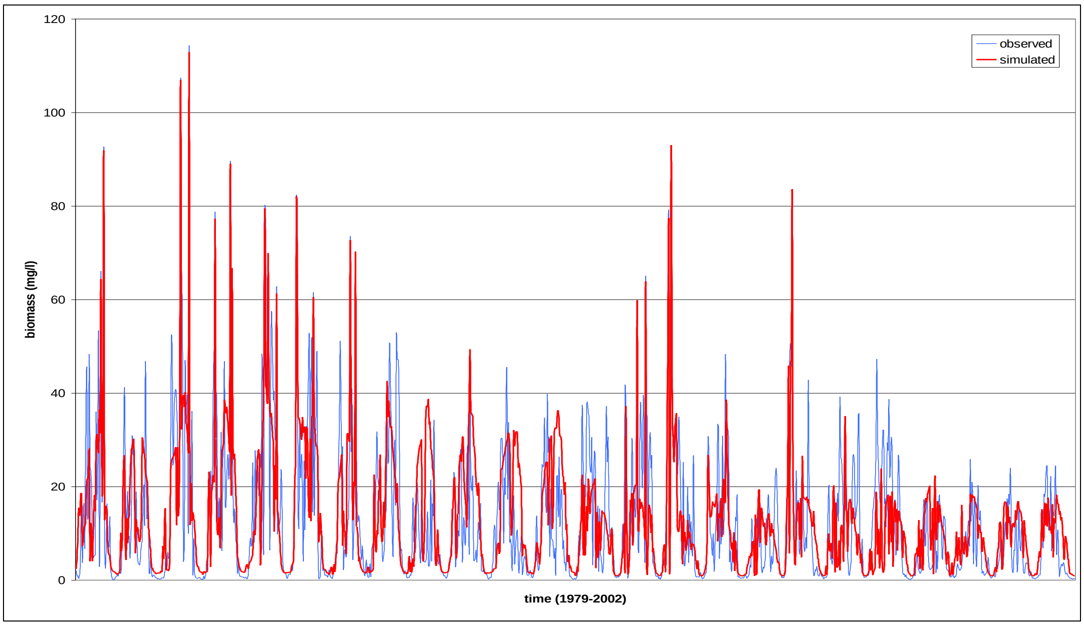

***Figure 1.** The Danube Phytoplankton Model fitted to the data series of 1979-1990, including sub-model "A" for the period of 1979-1990 and sub-model "B" for the period of 1991-2002.*

Phytoplankton biomass varied significantly between outputs for scenarios and observed data (one-way ANOVA, p<0.001, Figure 2A). Variances were not homogeneous (Levene's test, p<0.001) and resulted from the significant differences of standard deviations (Welch test, p<0.001). Tukey's pairwise comparisons implied significant differences among the outcomes of A2 scenario (of MPI) and of sub-model „A" (p<0.05).

Examining the effect of linear temperature rise revealed also significant differences between outputs (one-way ANOVA, p<0.001), and variances were not homogeneous (Levene's test, p<0.001); again, this was due to the significant differences of standard deviations (Welch test, p<0.001). Tukey's pairwise comparisons indicated that there were significant differences between the outputs for the period of 1979-2002 and outputs at 2°C temperature rise in case of sub-model „A" (Figure 2B). Furthermore, 0.5, 1 and 1.5°C rises in temperatures of sub-model „A" implied significant differences to the outputs of sub-model „B" (p<0.05). Despite of these findings the outputs within sub-model „B" showed large-scale similarity (p=1). This indicates that at high nutrient load (sub-model „A") phytoplankton communities show a more different response to global warming when compared to low nutrient load (sub-model „B").

It is evident from Figure 2A that biomass increased largely at scenario A2 (MPI); however, biomass output for the period of 1960-1990 increased notably as well (sub-model „A"). Nevertheless, standard deviation was too high in both sub-models. Linear temperature rise caused a drastic biomass increase in sub-model "A", while sub-model "B" yielded not significant changes (Figure 2B).

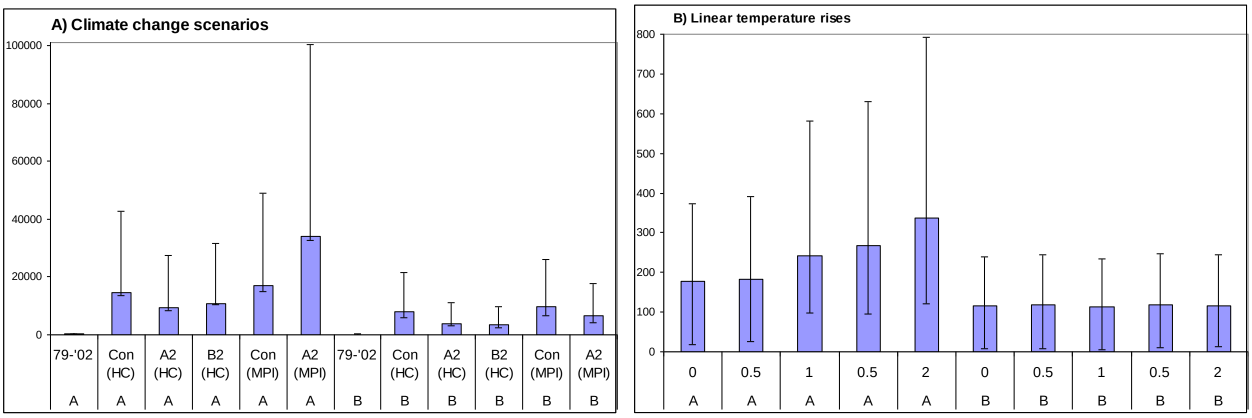

***Figure 2.** Monthly means of yearly total algal biomass (mg l^{-1}) for the model outputs for the period of 1979-2002 („79-02"; based on measured data of temperatures) compared with outputs of the model run with the data series of climate change scenarios (A, left) and of linear temperature rises (B, right). Sub-model „A" and „B" are presented separately. HC=Hadley Centre; MPI=Max Planck Institute; A2 and B2 scenarios; Con = control; 0; 0.5; 1; 1.5; 2: degree of linear temperature rise (^{o}C). Columns: mean; vertical lines: SD*

4 Outlook and conclusions

By adapting the TEGM model we managed to develop a model that fits to the measured data quite well. Beyond the indicator of yearly total biomass introduced in this study, further indicators need to be defined in the near future and used in order to get a better understanding of the possible effects of climate change to the phytoplankton of the Danube River.

Interpretation of model outputs for climate change scenarios is rather difficult. The model outputs for the control period of 1960-1990 and the period of 1979-2002 when observed temperature data were used as input parameters showed remarkable differences. Major variation within data series of certain climate change scenarios may account for the high standard deviations observed in the model outputs. This result draws attention to the constraints of applicability of scenarios.

In case of linear temperature rise a clear answer is received: high temperatures result in greater abundance of phytoplankton but only at high nutrient concentration (as it was experienced between 1979 and 1990). Moderate nutrient supply does not favour algae even if temperatures increase by 2°C. Thus, biomass is not expected to increase notably when nutrient loading of rivers has been reduced. Our model suggests that global warming brings drastic changes to nutrient rich environments but would not greatly effect the phytoplankton of nutrient poor water bodies.

Global warming can influence the trophic state and primary productivity of inland waters in a basic way (Lofgren 2002). Bacterial metabolism, rate of nutrient cycling and algal production all increase with rising temperatures (Klapper 1991). Generally, a combination of climate change and anthropogenic pollution enhances eutrophication (Klapper 1991, Adrian et al. 1995). Respective models predicted increased phytoplankton abundance in systems with higher trophic state (Elliot et al. 2005, Mooij et al. 2007, Komatsu et al. 2007). This is in line with our results of linear temperature rise, but valid only in waters with high nutrient concentration.

Looking at the variation of phytoplankton biomass only is not relevant enough if one aimed to explore the effects of climate change. Freshwater food webs show rather characteristic seasonal dynamics, thus, the effect of climate is the function of season (Straile 2005). Further indicators should be included into the model to elucidate seasonal changes of phytoplankton. Such indicators may be the seasonal population peak (e.g. blooms) or the threshold value of 50% of the annual total biomass. Thus, model development and improvement remains a never ending task.

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A Hungarian Rotifer database system advantage for Danube research

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Keywords: database, rotifera, Danube, Hungary

1 Introduction

In the river zooplankton rotifers play an important role; however, water currents, turbidity and lack of food provide an unfavorable environment for the potamoplankton. However, side branches, oxbows and near bank areas with low flow provide breeding habitats for plankton. These zones of large rivers show higher rotifer abundance (Donner 1970, 1972; Wallace et al. 2006). Our results from 2008-2009 showed that rotifers make up the highest proportion of zooplankton in the River Danube (70-95 % of the abundance and biomass). We found 92 rotifer taxa in the main branch and 83 taxa in the side branch near Göd (rkm 1669).

The references to rotifer species of the Hungarian Danube Basin are mostly in Hungarian, German or more recently in English. The first paper is from Tóth (1861) about the rotifers of the Hungarian Danube stretch. The collection and systematization of taxonomic data is important for the understanding of ecological functions of species; hence, results of new research must be integrated into previous knowledge. This confirmed our earlier viewpoint that the collection of information in well organized databases serves as an effective tool for easy data access and utilization. We developed a new database system for collecting rotifers data on a national scale, which provides correct information for different water systems (lakes, ponds, rivers, canals etc.). There are many taxon lists available from the internet, which can provide current, accurate and reliable information about species in general (FE 2004, Froese & Pauli - FishBase 2010, GBIF 2010). There are more internet databases with information about Rotatoria, e.g., FADA (2007) or an illustrated online catalogue of the Rotifera in the Academy of Natural Sciences of Philadelphia and the Rotifer Systematic Database; our data base is complementary and specifically focused on Hungary (Rotifer 2003).

2 Methods: Database Management System (DBMS)

Our database contains recordings of rotifer species in the Hungarian fauna based on scientific papers. Numerous tables facilitate easy access to up-to-date information on valid taxon names, synonymous taxon names, paper quotations (name of author(s) and journal, year of publication), date and place of sampling with GPS coordinate or by settlement, habitat type, photos of the animal and habitat maps based on recent data. The objective is to create a well manageable, user-friendly interface, which supports dialogue for querying various details on species and map visualization. The database operating system integrates functions like Google and Yahoo. The Rotifer database is flexible, scalable and the uploading is chronological, beginning with Tóth (1861) to recent days. Database management systems (DBMS) ensure the continuous operations of regular user processes, access to databases in networked, multi-user environments. At the beginning only large IT companies used DBMS software to process enormous amounts of data on high performance computers (e. g. Yahoo!, Cisco, NASA, Lucent Technologies, Motorola, Google, Silicon Graphics, HP, Xerox and Sony Pictures). However, DBMS also became significant in science because of the huge and ever changing

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taxonomy databases (NCBI 2010), the storage of genetic data, their relationships to classification categories, as well as the related multimedia contents (photos, sound and video information, etc).

Searching and filtering on the user interface is designed for simple use (for example only one species occurrence in the country) or for complex queries (specific place, river, or period).

Finally, each settlement data is displayed using the Google Maps API. This is a free solution to show the sampling sites. It is also quite fast, faster than operating the system on an another dedicated ArcGIS Server.

At present, the data uploading is in progress, users can only see the „Under Construction" message. According to the plans in the middle of June the database will work at full functionality. Uploading species photos will be the next step.

The Administrator can give passwords for scientists to upload their own pictures and most recent publications.

Aiming to minimize costs, we developed an open access starting system. The DBMS is MySQL in which metadata, dictionaries, basic data tables and geographic coordinates of sampling sites of the species are stored (Valade & Ballad 2008).

MySQL is an open source-code (GNU) multiuser, multiline, special application of SQL based database management for the server-side. (DuBois 2009) is a widespread database management system; we used LAMP system (Linux–Apache–MySQL–PHP) (Yank 2003). Yii is a speed and component based (object guided) PHP framework for developing web application containing each component required for further development. It supports user management in group style, controlling and screening of data, character sets of foreign languages and it is easy to expand (Winesett 2009).

3 Application and outlook

The basic data table is complete and contains a species list (with synonymous names), names of water bodies, geo-coordinates with settlements, and information on publications (Figure 1). The data entry interface is in Hungarian because most of the references are in Hungarian, but the query interface will be in two languages, English and Hungarian. This application will be useful to give a much easier access to know the Hungarian rotifer fauna for foreigner researchers. Published data that had only been published in Hungarian was made accessible for researchers in other countries. It also gives a complete faunistical notion about the little known Hungarian rotifer fauna. The database will be finished and functional by August 2010.

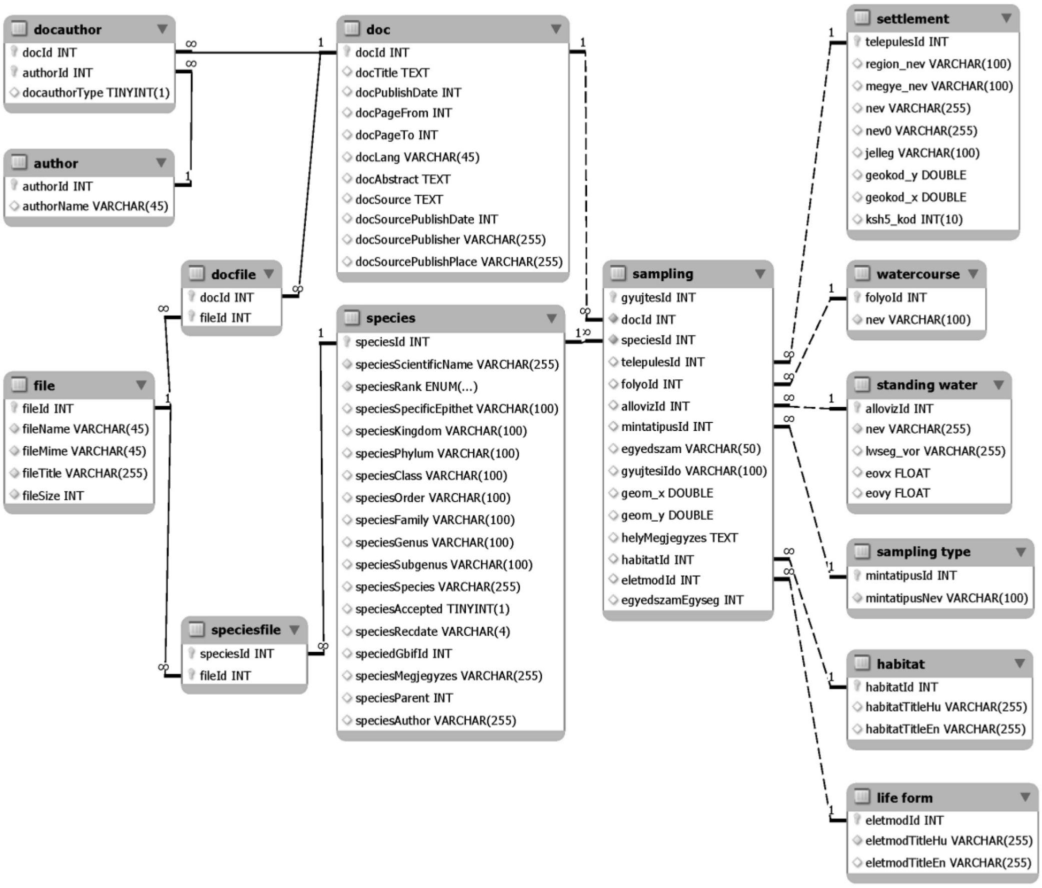

Figure 1. The structure of the data tables in the Hungarian Rotifera Database

4 Conclusions

Presently, the Hungarian Rotifera Database is unique in Europe in the sense that it couples all previously published data on Rotifera with map visualization. With this application, information on the Hungarian Rotatoria fauna will be more accessible and later it can be connected to other databases on the Internet (e.g. FishBase, GBIF). By harmonizing data structure, contents will be comparable with other databases.

After the completion of data upload it will be possible to expand the system to European scale. As species protection measures should ideally operate on larger geographical scales, this expansion will potentially support decision making in transboundary or pan European issues.

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Can reservoirs compensate oxbow disappearance? The amphibian fauna of the Rétközi reservoir and the Várközi oxbow lake

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Keywords: amphibians, faunistics, Monitor2000, sound monitoring, Rétközi reservoir, Várközi oxbow lake

1 Introduction

According to comparative analyses the sixth extinction wave on Earth is happening now (Chapin et al., 2000). Amphibians are one of most endangered animals; one third of the known species are threatened by extinction making it a global problem (IUCN et al., 2008). There are a lot of reasons behind this process ranging from global climate change and wide-spread diseases (Pounds et al., 2006) to habitat disappearance and vehicular traffic (Puky et al., 2005). In Europe the main cause is the loss and alteration of habitats. This is especially true for riparian floodplain habitats along large European rivers mainly because they have been regulated during the past two centuries; often even the remaining parts have been altered by various human use. As a consequence, their former function in the life of amphibians has been limited. To compensate previous habitat loss, it is an urgent task to protect still existing, and to create new, amphibian habitats. This makes monitoring of amphibian populations in riparian habitats a most important scientific and conserving activity. While along the Hungarian stretch of the River Danube a long-term data series exists (Puky, 2007), only scattered studies on the floodplain of its largest tributary, the River Tisza are available (Marián, 1960, 1963, 1977; Gyovai, 1989; Wubbenhorst et al., 2000). However, sound monitoring is being applied, a method satisfying modern requirements of scientific and environmental-friendly ecological surveys. This paper summarises the results of 2009 surveys on the amphibian fauna of a reservoir and a nearby semi-natural oxbow along the River Tisza in Hungary.

2 Study area

Field work was made in Szabolcs-Szatmár-Bereg county, Hungary, along the upper stretch of the River Tisza (Figure 1). The Rétközi reservoir (48°16’30” N, 22º01’50” E) was built in 1990 replacing a marsh which could not be used for agriculture or other purposes as inundation occurred regularly. The reservoir is 4 km long and 1-1.5 km wide with a surface of 400 hectares. It was built to regulate inundation and floods and is connected to three inundation canals and to the River Tisza. It is near Szabolcsveresmart and partly surrounded by woods of hybrid black poplars and locust trees and agricultural fields.

Várközi oxbow lake is a nearby semi-natural habitat on the other side of the village. It is 1.1 km long and 55 m wide on average with a water surface of 6 hectares. Its average depth is 1.5 m. It is well overgrown with macrophytes and has no direct connection to the River Tisza, but is regularly fed by floods of the river. In summer it often dries out (Pálfai, 2001). It has the quality of a nature reserve and protection was suggested by Wittner et al. (2005).

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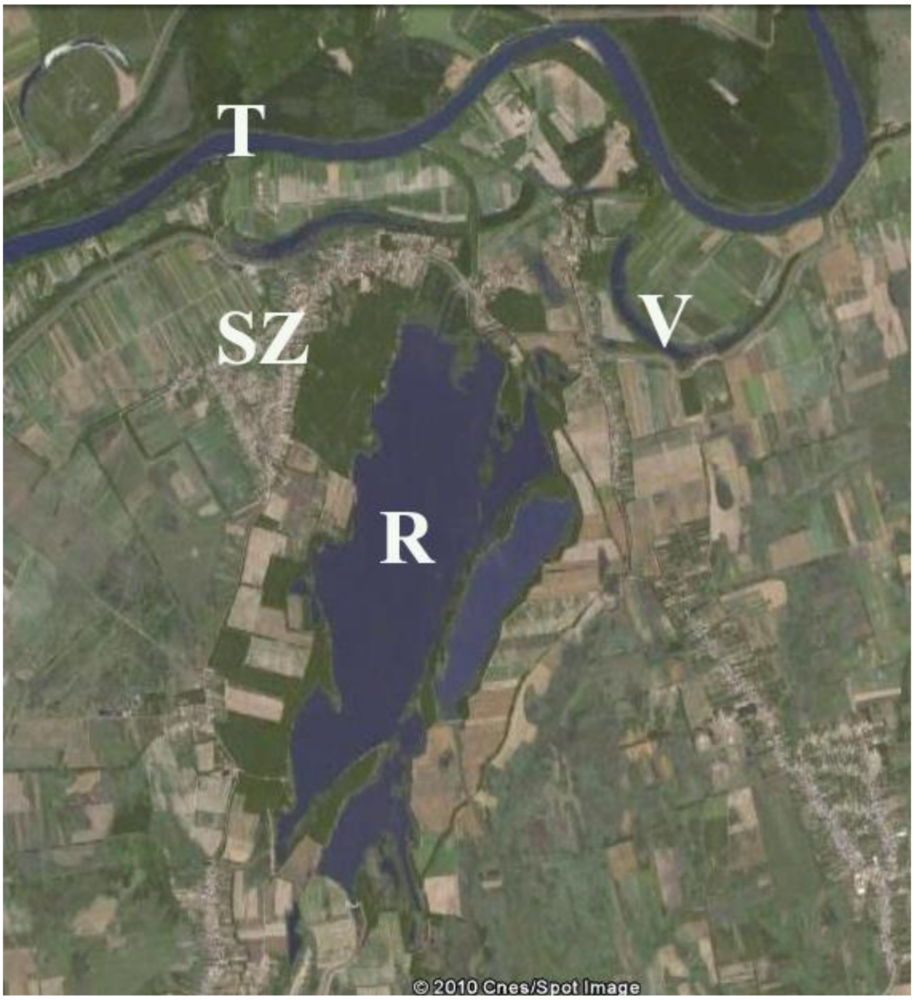

Figure 1. *Satelite image of the Rétközi reservoir (R) and the Várközi oxbow lake (V). (T = River Tisza, SZ = Szabolcsveresmart village)*

3 Methods

Sound monitoring is used from 1981 (Mossman et al., 1998) and is part of North American Amphibian Monitoring Program (NAAMP) and Marsh Monitoring Program (MMP) (Weeber & Vallianatos, 1999). These studies have been carried out at the Great Lakes with the aim of determining amphibian population size and following annual changes. In Europe, similar studies were carried out in the Netherlands (Smit et al., 2000) and in Switzerland (Pellet & Schmidt, 2005). The adaptation of this method for Hungary was made in the the Monitor2000 programme producing the manual and recorded sounds for species identification (Anthony & Puky, 2001).

Sound monitoring was performed in 2009 during the breeding period (March-July) of anurans according to Anthony & Puky (2001). Five surveys were necessary because species croak in different periods. Ten sampling stations were selected along the reservoir and five along the oxbow lake, 500 m apart. Surveys started 30 minutes after sunset if conditions (e.g. wind speed) were appropriate. At each sampling station the observers listened for five minutes and noted species presence, the intensity and direction of the calls. We used the Wisconsin index to characterise the calling intensity of the frogs and toads (Mossman et al., 1998). The call index is 1, if individuals can be counted and there is pause between the calls. It is 2, if calls of individuals are distinguishable but some calls overlap. It is 3 if there is a full chorus, i.e. calls are constant, continuous and overlapping. In addition, weather conditions were recorded and the distribution of habitats from which anuran calls could be heard were mapped during the day. Besides sound monitoring, visual encounter surveys and night searches were also applied in detecting the presence of amphibians. Cluster analysis with Ward method was used on the basis of species heard at the stations, and their call index.

4 Results

Bombina bombina, Bufo bufo, Epidalea viridis, Hyla arborea, Pelophylax ridibundus, Pelophylax lessonae, Pelophylax kl. esculentus were detected in distinct periods. During the first survey (28 March, 2009) no amphibians were calling but green toads (Epidalea viridis) were found migrating to their breeding habitats. Nine days later a full chorus of the European tree frog (Hyla arborea) and the European fire-bellied toad (Bombina bombina) could be heard from the Rétközi reservoir as well as from the Várközi oxbow lake, while common toads (Bufo bufo) only called from the reservoir. During the third survey (25 April, 2009) the first calling individuals of edible frogs (Pelophylax kl. esculentus) were detected together with species already indicated in previous surveys. During the fourth survey (24 May, 2009) mainly edible frogs called in the reservoir, while in the oxbow lake green toads, edible frogs and pool frogs (Pelophylax lessonae) were recorded. During the last survey (3 July, 2009) only P. kl. esculentus could be heard. The presence of moor frogs (Rana arvalis) and common spadefoots (Pelobates fuscus) could only be detected with visual encounter surveys and night searches but not with sound monitoring.

5 Discussion

Sound monitoring worked well in the detection of amphibians along the River Tisza in Hungary. It was especially effective in detecting *H. arborea* and *B. bombina* populations, and it also turned out to work well in separating the species of the *Pelophylax* complex. *R. arvalis* and *P. fuscus* were not detected by sound monitoring, because they call from underwater and their sounds are low, consequently they can only be heard from nearby. The call intensity of Rétközi reservoir and the Várközi oxbow lake amphibian communities were significantly different from each other (Figure 2). However, there were two exceptions: H1 station appeared in the reservoir group, and T5 was similar to oxbow stations. It seemed to be caused by habitat-related characteristics, at H1 the terrestrial vegetation (hybrid black poplars) is similar to those of the reservoir stations while at T5 the aquatic vegetation (mainly reed) resembles to the habitats of the oxbow lake.

The occurrence of species was different at the two sites. *H. arborea* and *E. viridis* were more abundant at the oxbow lake, while *B. bufo* was only heard at the reservoir. The rarest amphibian in the survey, the pool frog could only be found at the oxbow lake (this separation was also proved by an ongoing genetic investigation). It is the smallest species of the *Pelophylax* complex outcompeted by other members of the group; its survival seems to depend primarily on the habitat offered by the semi-natural oxbow lake. As this species is known to disappear from riparian habitats along rivers in Europe, such as the valley of Rhine in Switzerland because of habitat degradation (Lippuner & Heusser, 2001), its protection is of special concern.

During the coming years several new reservoirs are planned in the framework of the New Vásárhelyi Plan, a river-regulation oriented programme along the Hungarian stretch of the River Tisza. They can be valuable habitats for protected and endangered amphibians if some areas are formed with similar attributes to an oxbow lake. Also, due to their high conservation value, oxbow lakes must be placed under stricter protection than today.

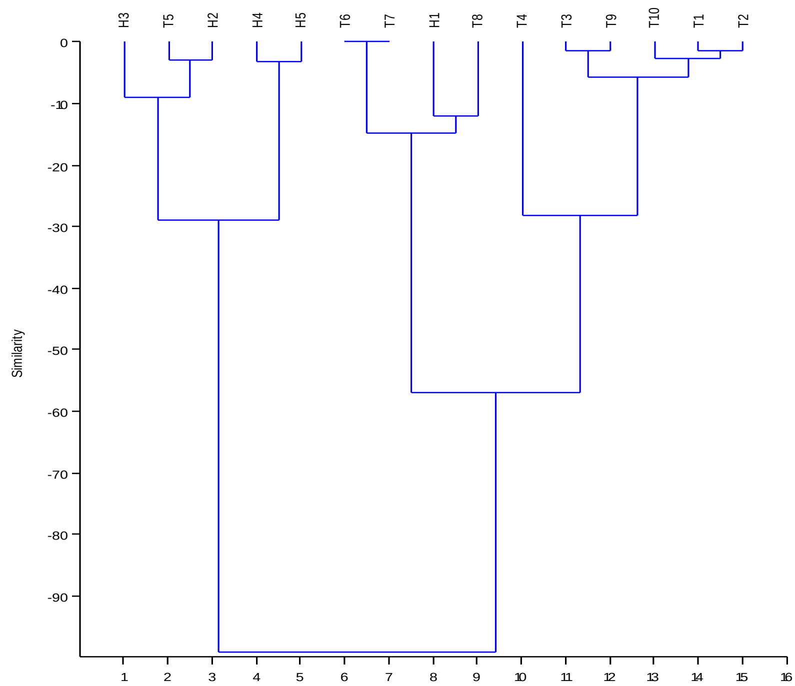

Figure 2. *Cluster analysis comparing sampling stations based on Wisconsin index (T= reservoir, H= oxbow lake, numbers indicate stations)*

Acknowledgments

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Defining biological benchmarks for the intercalibration of the Danube River

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Keywords: Danube, intercalibration, macrozoobenthos, macrophytes, metrics

1 Introduction

One of the key elements of the European Water Framework Directive 2000/60/EC (WFD) is to ensure "good status" for all surface waters by 2015. The first step towards this aim was to create a River Basin Management Plan by 2009 based on the outputs of a basin-wide characterisation process. Furthermore, pursuant to Article 13 (5) of the WFD, the Member States may supplement the River Basin Management Plan by the production of more detailed programmes and management plans for sub-basins. The International Commission for the Protection of the Danube River (ICPDR) recently published the first management plan (ICPDR 2009) according to the requirements of the WFD. To classify the ecological status of surface waters countries are using different biological assessment methods (Birk & Schmedtje 2005). Although these methods are based on common principles such as the use of Biological Quality Elements (BQE) and assessment against near-natural reference conditions, they differ in how the biological data are sampled, processed and evaluated. This poses the problem that status classification between countries in international basin management may be incomparable.

According to the WFD status classification of a water body depends on how much the biological community is deviating from undisturbed (reference) conditions. Obviously, in Europe's very large rivers undisturbed conditions no longer exist (Buijse et al. 2005; Van Looy et al. 2008). In this regard Birk & Hering (2009) developed an approach establishing "biological benchmarks" based on data from sites of at least good environmental status. The biological benchmark was defined as "the condition of the biological community that represents the reference as the result of transnational harmonization.

This paper is mainly based on data sampled during the second Joint Danube Survey (JDS2, Liska et al. 2008). Following an approach similar to Birk & Hering (2009), biological benchmarks are established for the Danube River. Secondly, we derive Danube Intercalibration Stretches based on existing typologies and biological data. Within each stretch we identify biological metrics that describe the macrophyte and macrozoobenthos communities and which can be used for the purpose of intercalibration.

2 Setting biological benchmarks and global definition of least disturbed conditions

The basis for our analysis were selected environmental parameters sampled at 78 sites in the main channel of the Danube River. The data included basic physico-chemical parameters, chemical quality elements and hydromorphological descriptors. We conducted a Principal Component Analysis (PCA) and extracted a complex gradient. We then identified sites in Least Disturbed Conditions (LDC; Stoddard et al. 2006), which serve as a basis for setting biological benchmarks.

Parameters reflecting the longitudinal river gradient (e.g. slope, average channel depth, average surface velocity and distance from mouth) appeared to be mostly correlated to PCA-axis 1. Parameters that are related to abiotic pressure (e.g. morphological evaluation scores, dissolved oxygen concentration, impoundment, naturalness of bank slope) determined PCA-axis 2. This second component was thus identified as the anthropogenic pressure gradient. It covers the whole length of the Danube River and reflects impairments, for instance, from major riparian cities or impoundments, as well as National Parks and other near-natural reaches (Figure 1).

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We then set a threshold value on the pressure gradient based on the TNMN water quality classification (e.g. ICPDR 2007), supplemented by including the overall hydromorphological quality of each site (Table 1). We identified 20 sampling sites in good and 26 in moderate abiotic status, with the majority of sites failing the class thresholds for hydromorphological quality. None of the sites would reach high abiotic status since none held high hydromorphological quality. The worst gradient score for sites in good abiotic status was taken as a threshold for the definition of LDC sites: all good status and seven moderate status sites were identified as such.

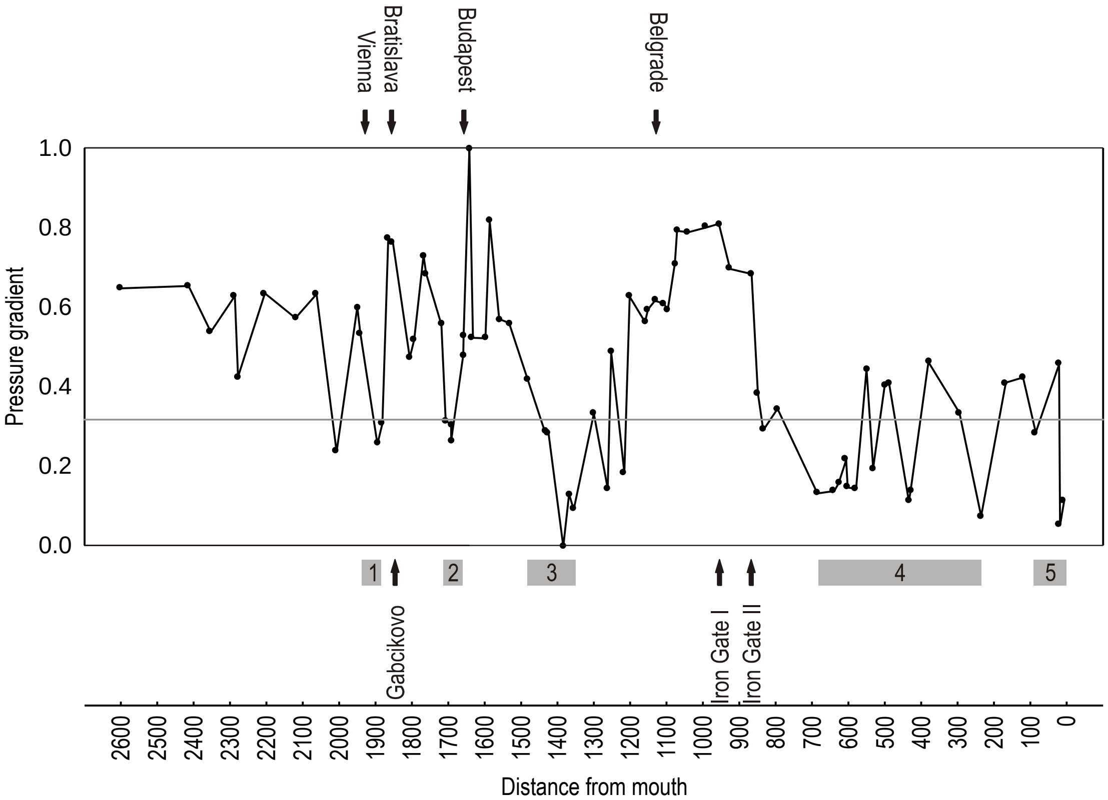

Figure 1. *Pressure profile for the Danube River, specifying the locations of major cities, impoundments and important wetlands. The complex pressure gradient (including hydromorphology, impoundments, bank slope and O_2 concentration) is measured in values between 0 (near-natural) to 1 (severely impaired). The gray line represents the LDC-threshold, the worst gradient score for sites in good abiotic status. 1=Danube-Auen National Park; 2=Danube bend; 3=Duna Drava National Park; 4=Lower Danube Wetland System; 5=Danube Delta. Points indicate the sampling stations of JDS2 (Liska et al. 2008).*

Table 1. *Abiotic classification scheme to identify sampling sites in good and moderate status ($N\text{-}NH_4$=Ammonium, $N\text{-}NO_2$ = Nitrite, $N\text{-}NO_3$ = Nitrate, TP = Total Phosphorus, $P\text{-}PO_4$ = Orthophosphate, DO = Dissolved Oxygen, HYMO = Overall hydromorphological quality class; all concentrations given in mg/l).*

Abiotic status class	$N\text{-}NH_4$	$N\text{-}NO_2$	$N\text{-}NO_3$	TP	$P\text{-}PO_4$	DO	HYMO
good	≤ 0.3	≤ 0.06	≤ 3	≤ 0.2	≤ 0.1	≥ 6	≤ good
moderate	≤ 0.6	≤ 0.12	≤ 6	≤ 0.4	≤ 0.2	≥ 5	≤ moderate

Good abiotic status represents TNMN classes I and II, whilst moderate ecological status comprises class III. Sites failing these thresholds fall in classes IV and V (ICPDR 2007).

3 Delineating Danube Intercalibration Stretches

To establish the basis for the definition of Danube Intercalibration Stretches (DIS) we reviewed the studies on the Danube Section Types presented in Moog et al. (2008) and Litheráthy et al. (2002). Due to their coherent designation and high relevance in the international river basin management the adaptation of these section types was a prerequisite for our work. Furthermore, we respected the JDS data (Liska et al. 2008), especially the cluster and ordination analyses of macrozoobenthos, macrophyte and diatom data, and the distribution of phytoplankton chlorophyll-a and biomass along the entire course of the Danube.

In addition, we carried out constraint cluster analysis for the biological data. By combining the information derived from these various sources we delineated the four intercalibration stretches shown in Figure 2. Three section types from Moog et al. (2008) are not included in the intercalibration typology (1: Upper Course of the Danube, 7: Iron Gate Danube, 10: Danube Delta). These reaches were either non-international parts of the Danube (Section 1), or featured specific Danube sections that are not sufficiently covered by the JDS2 data (Section 7 and Section 10; only four JDS sampling stations each). Furthermore, the DIS are in line with the delineation of the upper, middle and lower course of the Danube (Literáthy et al. 2002).

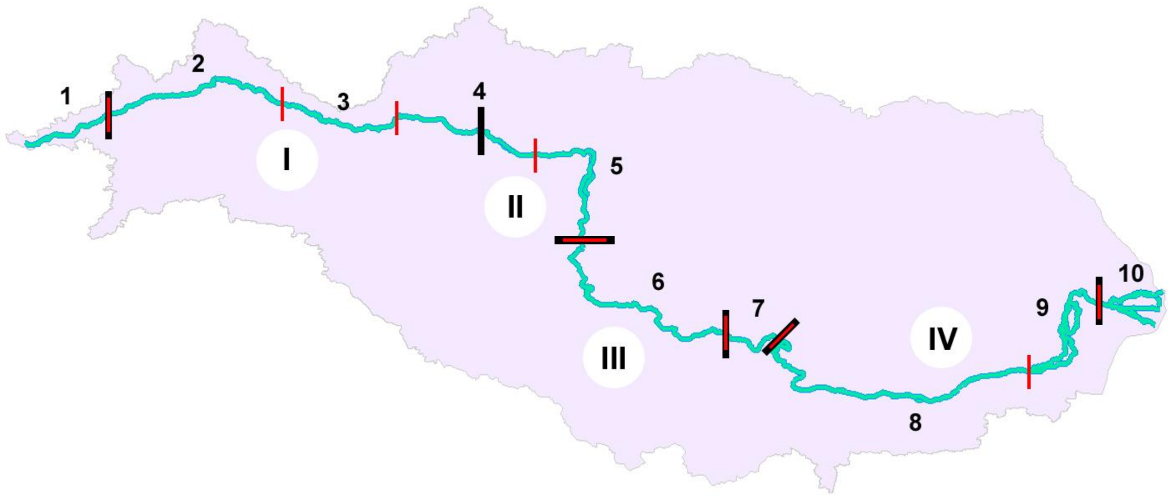

Figure 2. *The location of the Danube Section Types (Moog et al. 2008) (Arabic numerals, red borders) and the Danube Intercalibration Stretches (DIS) (Roman numerals, black borders) on the River Basin District map. I = Upper DIS; II = Northern Pannonian DIS; III = Souther Pannonian DIS; IV = Lower Pannonian DIS. Danube Sections Types 1, 7 and 10 are not covered by the DIS delineation.*

4 Testing the biological response to the pressure gradient

We used the macrophyte and macrozoobenthos data sampled during JDS2 to describe the assemblage patterns via Detrended Correspondence Analysis (DCA) and applied indirect gradient analysis to investigate relationships between the pressure gradient and the biological assemblages. The outcomes reveal that the pressure gradient is significantly influencing the macrozoobenthos and macrophyte communities. Except for the Lower Danube Intercalibration Stretch the multivariate community descriptors are significantly different between LDC and non-LCD sites for each stretch.

Table 2. *Selected macrozoobenthos metrics for the different Danube Intercalibration Stretches, the groups for which they are indicative (highest median value) and the number of sites (LDC and non-LDC) within the stretch. All median values between groups are significantly different (U-test, p<0.05).*

DIS	Biological Metric	Indicative for	Number of sites
All stretches combined	LIFE (Lotic-Invertebrate Flow Evaluation)	LDC	24 LDC 45 non-LDC
	German Saprobic Index	non-LDC	
I	% Grazers and Scrapers	LDC	3 LDC 9 non-LDC
	% Gravel-prefering	LDC	
	% Littoral-prefering	non-LDC	
	Austrian Saprobic Index	non-LDC	
II	% Rheophilous	LDC	3 LDC 15 non-LDC
	LIFE (Lotic-Invertebrate Flow Evaluation)	LDC	
	GOLD (Gastropoda-OLigochaeta and Diptera)	LDC	
III	Czech ASPT (Average Score Per Taxon; Armitage et al. 1983)	LDC	7 LDC 10 non-LDC
	% Oligochaeta	non-LDC	
	Oligochaeta (number of individuals)	non-LDC	
	German Saprobic Index	non-LDC	
IV	LIFE (Lotic-Invertebrate Flow Evaluation)	LDC	11 LDC 11 non-LDC
	GOLD (Gastropoda-OLigochaeta and Diptera)	LDC	
	% Mud-preferring	non-LDC	

Several biological metrics are reflecting these differences on the stretch-specific level for the macrozoobenthos community (Table 2). These include the Lotic-Invertebrate Flow Evaluation (LIFE; Extence et al. 1999) for all stretches, DIS II and IV, and the percentage of rheophilous taxa in DIS II, both indicating higher current velocities at less disturbed sites. Two saprobic indices (German and Austrian), scoring higher with increasing organic pollution, show higher values at non-LDC sites in several stretches. The Portuguese GOLD index (Buffagni et al. 2005) that decreases with higher proportions of Gastropoda, Oligochaeta and Diptera abundances, shows lower values at non-LDC sites for DIS II and IV. A similar indication is given by the Oligochaeta abundance and number of taxa in DIS III.

For the macrophytes only the Austrian Index for Macrophytes AIM (Pall & Mayerhofer 2009) was responsive to the pressure gradient in the Upper DIS. We deduced a number macrophyte indicators from a correlation analysis of taxa abundance with the pressure gradient, 13 of which are in DIS III (Table 3).

Table 3. *Macrophyte taxa significantly correlated to the pressure gradient (p<0.05), including the Danube Intercalibration Stretch (DIS) and the groups for which they are indicative (negative correlation to the pressure gradient = for LDC; positive = non-LDC).*

DIS	Taxon	Indicative for	DIS	Taxon	Indicative for
I	*Cinclidotus fontinaloides*	LDC	III	*Phragmites australis*	non-LDC
I	*Fontinalis antipyretica*	non-LDC	III	*Potamogeton gramineus*	non-LDC
I	*Rhynchostegium riparioides*	non-LDC	III	*Potamogeton nodosus*	non-LDC
II	*Phragmites australis*	non-LDC	III	*Potamogeton perfoliatus*	non-LDC
III	*Azolla filiculoides*	non-LDC	III	*Sagittaria sagittifolia*	non-LDC
III	*Ceratophyllum demersum*	non-LDC	III	*Salvinia natans*	non-LDC
III	*Lemna gibba*	non-LDC	III	*Vallisneria spiralis*	non-LDC
III	*Lemna minor*	non-LDC	IV	*Bidens sp.*	non-LDC
III	*Myriophyllum spicatum*	non-LDC	IV	*Scirpus lacustris*	non-LDC
III	*Najas marina (N. major)*	non-LDC	IV	*Tamarix ramosissima*	LDC

5 Conclusions and outlook

The homogenous nature of the JDS-data allowed for the development of a common approach to identify complex pressure gradients and fix thresholds to define least disturbed conditions. The general aim is to discover relationships between human pressure and biological status, and then to describe the biology under defined conditions. It sets the basis for intercalibration of the Danube River and the methodology can be extrapolated to other large rivers.

We fixed the LDC threshold on the pressure gradient that represents a complex combination of individual pressures at the sampling sites. The abiotic classification scheme only had a supportive character, validating the qualitative significance of the gradient. The LDC sites can generally be described by the following features: On average, the sites are located in reaches that show good hydromorphological quality of the channel, the banks and the floodplain. None of these reaches feature worse than moderate hydromorphological quality, and no monitoring site is situated in an impounded section. The water at LDC sites shows average oxygen concentrations of 8.6 mg/l, and the means of the nutrient values measured in the water fall within good status of the TNMN classification scheme (Table 1). The mean width of the riparian corridor amounts to approximately 2.1 km, and at least some large woody debris is present at most sites. On average, both banks feature natural slopes and the immediate vicinity of most sites is dominated by natural land cover (riparian vegetation, floodplain forest).

Our DIS focused on the establishment of practical intercalibration units that reflect homogeneous entities with regard to biological populations. The results of the statistical analyses supported our proposal of the four DIS. The distinct biological features of each DIS and those of other rivers seem to require defining biological benchmarks for intercalibration on a stretch- and river-specific basis.

The pressure-response analysis reveals an obvious relation of the macrozoobenthos and macrophyte communities to the abiotic pressure gradient. The strong correlations of the macrozoobenthos fauna with the pressure gradient can be reviewed by various aspects of, and metrics that describe the community. The stretch-specific analysis reveals that each stretch represents a particular entity and underlines the importance of setting stretch-specific biological benchmarks against the globally derived pressure gradient. In addition, LIFE index and Saprobic Index show significant differences for the entire river course. Following Birk & Hering (2009) biological benchmarks can be set using selected summary statistics for the metric distributions at LDC sites. For example, the distribution of the German Saprobic Index values shows good status for the majority of LDC sites.

For the macrophyte community only the Austrian Index for Macrophytes AIM was found to be significant for the upper DIS. However, we deduced a number of indicator species, which can serve as a basis for further development of metrics for the Southern Pannonian DIS. For the two upper Danube stretches the relevance of this approach could particularly be increased by expanding the data basis. Although an inclusion of additional reaches in least disturbed conditions is not feasible (since no more such reaches exist at the Upper Danube), for a more detailed description of least disturbed conditions the number of samples from LDC sites could be enlarged.

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Long-term changes of fish fauna in the Hungarian section of the Ipel River

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Keywords: historical fish fauna, species richness, invasive species, natural reference, river restoration

1 Introduction

Rivers have long been affected by several types of human influences that have a negative impact on their integrity. Nowadays, improvement of ecological status of a river system is an increasing demand of the society but the delineation of the environmental objectives for rehabilitation is often restricted by a lack of knowledge of pristine conditions. The possibilities of direct investigation of undisturbed rivers are very limited; therefore, historical information from the pre-regulation period can be used for describing the original state. Due to their complex habitat requirements fish are sensitive indicators for the ecological integrity of a river (Karr 1991) and long-term changes of fish fauna can be reconstructed from old catch records, data of early publications and habitat descriptions from archive maps (Carrel 2002, Wolter et al. 2005, Winter et al. 2008).

The Ipel is a medium size regulated river along the border of Hungary and Slovakia. Its source is at 1020 m above sea level in Slovakia and its tributary is at Szob at rkm 1708 of the Danube. The length of the river is 257.4 km, its catchment area is 5108 km^2 and its mean discharge is 20.6 $m^3\ s^{-1}$. Its flow regime fluctuates between 1.7 $m^3\ s^{-1}$ and 660 $m^3\ s^{-1}$. The first efforts of river regulation are known from the 17th and 18th century. Some meanders were cut off and several small tributaries were regulated in the 19th century. In the 1980s, six dams were constructed between Ipolytölgyes and Sahy (Mike 1991, Kabay 2007). The interventions resulted in channel incision and a decrease of mean and low water levels. The lower section of the river belongs to the Danube-Ipel National Park and an increasing effort is made to restore its ecosystem in the recent years. Our study was aimed to assess the deviation of the present fish fauna from its original reference state in the Hungarian section of the river. Analysis of ichthyologic literature and history of river regulation provided information for the judgement of former fish fauna.

2 Methods

The long-term changes of the fish fauna and occurrence of species were evaluated by literature data. Acceptable reports are available from the end of the 19th century (Herman 1887, Vutskits 1918, Vásárhelyi 1961, Kux & Weisz 1964, Botta et al. 1984, Botta 1993, Keresztessy 1993, Györe et al. 2001, Tóth et al. 2005). The description of the recent fish fauna was completed by the results of our fish surveys undertaken by electrofishing in the vicinity of Ipolytölgyes (rkm 18) and Szob (rkm 2) between July and October 2009.

3 Results

Our fish surveys detected 38 fish species and three of them (*Ameiurus melas, Neogobius melanostomus, Neogobius gymnotrachelus*) were new for the Ipel. According to results of literature analysis and data of our fish surveys the occurrence of 56 fish species has been proved in the Hungarian section of the river (sequence according to Table 1):

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Bream (*Abramis brama* Linnaeus, 1758): Common species, indicated in all fauna lists from the 1960s.

Sterlet (*Acipenser ruthenus* Linnaeus, 1758): It is an occasional migratory species from the Danube. All of the early publications (Herman 1887, Vutskits 1918, Vásárhelyi 1961) indicated its occurrence, but it has not been mentioned since the middle of the 1960s.

Spirlin (*Alburnoides bipunctatus* Bloch, 1782): Common species mentioned by all authors.

Bleak (*Alburnus alburnus* Linnaeus, 1758): Abundant species, indicated in almost all fauna lists.

Asp (*Aspius aspius* Linnaeus, 1758): Common species, listed in most of the publications.

Zopel (*Ballerus ballerus* Linnaeus, 1758): Its occurrence was mainly indicated in the early publications (Herman 1887, Vutskits 1918, Vásárhelyi 1961). It occasionally migrates from the Danube to the lower section of the river (Botta 1993).

Blue bream (*Ballerus sapa* Pallas, 1814): Rare species, recorded in the lower section (Botta 1993, Györe et al. 2001). It was detected by our surveys, too.

Stone loach (*Barbatula barbatula* Linnaeus, 1758): Common species. It is listed in most of the fauna studies.

Barbel (*Barbus barbus* Linnaeus, 1758): Abundant species listed in all publications.

Carpathian barbel (*Barbus carpathicus* Kotlik et al. 2002): Common species, particularly in the tributaries and the upper section of the river. It is listed in almost all publications from the 1960s.

Silver bream (*Blicca bjoerkna* Linnaeus, 1758): Rare species, listed in almost all publications from the 1960s.

Crucian carp (*Carassius carassius* Linnaeus, 1758): Rare species in the disconnected oxbows (Herman 1887, Vutskits 1918, Vásárhelyi 1961, Botta 1993).

Nase (*Chondrostoma nasus* Linnaeus, 1758): Common species, listed in all publications.

Spined loach (*Cobitis elongatoides* Bačescu & Maier, 1969): Common species listed in almost all publications.

Sculpin (*Cottus gobio* Linnaeus, 1758): Sporadic species drifted from the upper section of the river. One occurrence was only recorded at Hont in 1996 (Györe et al. 2001).

Carp (*Cyprinus carpio* Linnaeus, 1758): Common species mentioned in all fauna studies. Its population was recently increased by stocking.

Pike (*Esox lucius* Linnaeus, 1758): Common species indicated in almost all fauna lists.

Gudgeon (*Gobio gobio* Linnaeus, 1758): Common species. It is mentioned in most of the fauna studies from the 1980s.

Ruffe (*Gymnocephalus cernuus* Linnaeus, 1758): Common species mentioned in most of the publications from the 1980s.

Danube ruffe (*Gymnocephalus baloni* Holčik & Hensel, 1974): Common species indicated by most of the authors from the 1990s.

Yellow pope (*Gymnocephalus schraetzer* Linnaeus, 1758): Rare species. It was found at some locations (Kux & Weisz 1964, Botta 1993, Györe et al. 2001).

Sun bleak (*Leucaspius delineatus* Heckel, 1873): Rare species in the disconnected oxbows, its occurrence was proved in the last decade (Györe et al. 2001, Tóth et al. 2005).

Dace (*Leuciscus leuciscus* Linnaeus, 1758): A rare fauna element in the Hungarian section of the river and its tributaries. Its first occurrence was recorded by Botta et al. (1984), since then it has been listed in most fauna descriptions.

Ide (*Leuciscus idus* Linnaeus, 1758): Common species, but its first record was only published in the 1990s (Botta 1993) and ever since then its occurrence has been verified by all authors.

Burbot (*Lota lota* Linnaeus, 1758): Common species mentioned by all authors.

Weatherfish (*Misgurnus fossilis* Linnaeus, 1758): Rare species in the disconnected oxbows (Herman 1887, Botta et al. 1984, Botta 1993, Keresztessy 1993, Györe et al. 2001).

Table 1. *The original and recent fish fauna of the Hungarian section of the Ipel River. Authors:* ***1*** *Herman 1887,* ***2*** *Vutskits 1918,* ***3*** *Vásárhelyi 1961,* ***4*** *Kux & Weisz 1964,* ***5*** *Botta et al. 1984,* ***6*** *Botta, 1993,* ***7*** *Keresztessy 1993,* ***8*** *Györe et al. 2001,* ***9*** *Tóth et al. 2005,* ***10*** *our data 2009.* ***Orig.*** *= original fish fauna (blue),* ***Nnat.*** *= non-native species (orange),* ***Rec.*** *= recent fish fauna (green), purple = atypical native species.*

	authors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Orig.**	**Nnat.**	**Rec.**
1	*Abramis brama*													
2	*Acipenser ruthenus*													
3	*Alburnoides bipunctatus*													
4	*Alburnus alburnus*													
5	*Aspius aspius*													
6	*Ballerus ballerus*													
7	*Ballerus sapa*													
8	*Barbatula barbatula*													
9	*Barbus barbus*													
10	*Barbus carpathicus*													
11	*Blicca bjoerkna*													
12	*Carassius carassius*													
13	*Chondrostoma nasus*													
14	*Cobitis elongatoides*													
15	*Cottus gobio*													
16	*Cyprinus carpio*													
17	*Esox lucius*													
18	*Gobio gobio*													
19	*Gymnocephalus baloni*													
20	*Gymnocephalus cernuus*													
21	*Gymnocephalus schraetzer*													
22	*Leucaspius delineatus*													
23	*Leuciscus idus*													
24	*Leuciscus leuciscus*													
25	*Lota lota*													
26	*Misgurnus fossilis*													
27	*Pelecus cultratus*													
28	*Perca fluviatlis*													
29	*Phoxinus phoxinus*													
30	*Rhodeus sericeus*													
31	*Romanogobio albipinnatus*													
32	*Romanogobio kessleri*													
33	*Rutilus pigus*													
34	*Rutilus rutilus*													
35	*Sabanejewia balcanica*													
36	*Salmo trutta*													
37	*Sander lucioperca*													
38	*Sander volgensis*													
39	*Scardinius erythrophthalmus*													
40	*Silurus glanis*													
41	*Sqalius cephalus*													
42	*Tinca tinca*													
43	*Vimba vimba*													
44	*Zingel streber*													
45	*Zingel zingel*													
46	*Anguilla anguilla*													
47	*Ameiurus melas*													
48	*Ameiurus nebulosus*													
49	*Carassius gibelio*													
50	*Lepomis gibbosus*													
51	*Neogobius fluviatilis*													
52	*Neogobius gymnotrachelus*													
53	*Neogobius melanostomus*													
54	*Onchorhynchus mykiss*													
55	*Proterorhinus semilunaris*													
56	*Pseudorasbora parva*													
	number of spp.	**17**	**18**	**16**	**21**	**27**	**46**	**33**	**49**	**33**	**38**	**43**	**10**	**54**

Razor fish (*Pelecus cultratus* Linnaeus, 1758): It occasionally migrates from the Danube. It was recorded in the vicinity of Ipolydamásd (Botta 1993).

Perch (*Perca fluviatlis* Linnaeus, 1758): Common species included in almost all descriptions of the fauna.

Minnow (*Phoxinus phoxinus* Linnaeus, 1758): Abundant species in the tributaries and the upper section of the river (Kux & Weisz 1964, Györe et al. 2001). Drifted individuals usually occur in the lower section (Vutskits 1918, Vásárhelyi 1961, Botta 1993).

Bitterling (*Rhodeus sericeus* Pallas, 1776): Abundant species, particularly in the slow flowing sections and backwaters. It is indicated by all authors from the 1960s.

White-finned gudgeon (*Romanogobio albipinnatus* Lukash, 1933): Abundant species, indicated in almost all fauna lists from the 1980s.

Kessler's gudgeon (*Romanogobio kessleri* Dybowski, 1862): Rare species, occurs mainly in the upper section of the river. Most of the authors mentioned it from the 1960s.

Danubian roach (*Rutilus pigus* Heckel, 1852): It occasionally migrates from the Danube. It was recorded once upstream of Szob (Botta 1993).

Roach (*Rutilus rutilus* Linnaeus, 1758): Widely distributed along the entire Hungarian section of the river, recorded in all fauna descriptions.

Balkan golden loach (*Sabanejewia balcanica* Karaman, 1922): Common species. Its occurrence was described in the 1980s (Botta et al. 1984), since then it has been listed in most fauna descriptions.

Brown trout (*Salmo trutta* Linnaeus, 1758): Rare species. Drifted individuals can be found in the lower section of the river (Györe et al. 2001). It was occasionally stocked in the tributaries and the upper section of the river.

Pikeperch (*Sander lucioperca* Linnaeus, 1758): Common species, but it was not mentioned in the early publications. Its occurrence was only described in the 1980s (Botta 1993) and since then it was listed in all fauna studies.

Volga pikeperch (*Sander volgensis* Gmelin, 1788): It occasionally migrates from the Danube. It was recorded at Ipolydamásd (Botta 1993).

Rudd (*Scardinius erythrophthalmus* Linnaeus, 1758): Common species in the backwaters and disconnected oxbows. It was recorded in the 1980s (Botta et al. 1984), since then it has been listed in most fauna descriptions.

Catfish (*Silurus glanis* Linnaeus, 1758): Common species listed in almost all fauna studies.

Chub (*Squalius cephalus* Linnaeus, 1758): Abundant species listed in all publications.

Tench (Tinca tinca Linnaeus, 1758): Rare species, it was mainly found in oxbows (Herman 1887, Botta 1993, Györe et al. 2001, Tóth et al. 2005).

Vimba (*Vimba vimba* Linnaeus, 1758): Common species in the lower section. It is listed in almost all publications from the 1990s, and also recorded in our surveys.

Zingel (*Zingel zingel* Linnaeus, 1758): Rare species. It was found at Ipolytölgyes and Tésa (Györe et al. 2001, Tóth et al. 2005).

Danube streber (*Zingel streber* Siebold, 1758): Rare species indicated in almost all fauna publications. Our surveys also verified its occurrence at Ipolytölgyes.

Eel (*Anguilla anguilla* Linnaeus, 1758): Sporadic species. The first occurrence was recorded by Botta at al. (1981). Further confirmations by Keresztessy (1993) and Györe et al. (2001). Its frequency increased in the Middle Danubian region due to stocking programs.

Brown bullhead (*Ameiurus nebulosus* Leseur, 1819): The occurrence of this non-native species was recorded at Vámosmikola in the 1990s (Botta 1993). It is assumed not to present viable population in the river.

Black bullhead (*Ameiurus melas* Rafinesque, 1820): The appearance of this non-native species was proved by our surveys at Ipolytölgyes in October 2009.

Prussian carp (*Carassius gibelio* Bloch, 1782): Abundant non-native species, mainly in the slow flowing sections and backwaters. Its first occurrence was recorded in the 1990s (Botta 1993).

Pumpkinseed (*Lepomis gibbosus* Linnaeus, 1758): Common non-native species. Its occurrence was proved in the 1990s (Botta 1993) and most of the publications indicated it since that time.

Monkey goby (*Neogobius fluviatilis* Pallas, 1814): Common non-native species in the lower section. Its first occurrence was recorded at Ipolytölgyes (Tóth et al. 2005).

Racer goby (*Neogobius gymnotrachelus* Kessler, 1857): The first data of this non-native species was verified by our survey at Szob in October 2009.

Rainbow trout (*Onchorhynchus mykiss* Walbaum, 1792): Rare non-native species. Drifted individuals can be found in the lower section of the river (Györe et al. 2001).

Round goby (*Neogobius melanostomus* Pallas, 1814): The first data of this non-native species was proved by our survey at Ipolytölgyes in August 2009. More specimens were found at Szob in October 2009.

Tubenosed goby (*Proterorhinus semilunaris* Heckel, 1837): Common non-native species. Its first records were verified between Ipolydamásd and Tésa in the 1980s (Botta et al. 1984), and since then it has been listed in all fauna studies.

Stone moroko (*Pseudorasbora parva* Temminck & Schlegel, 1846): Common non-native species. Its first occurrence was verified in the 1990s (Botta 1993.

4 Conclusions

Moderate change in the fish fauna is established in the Ipel River since the end of the 19th century. The number of observed species increased over time and the occurrence of 56 fish species has been reported up to now. Little information is available about the species composition of the fish fauna in the 19th century and beginning of the 20th century. Several remarkable species (*Rutilus rutilus, Leuciscus idus, Abramis brama, Gobio gobio, Gymnocephalus cernuus, Sander lucioperca*, etc.) are neglected in the early publications, due to the low intensity of fauna research. However, the historical data indicate the occurrence of typical rheophilic (*Acipenser ruthenus, Alburnoides bipunctatus, Lota lota, Zingel streber,* etc.) and limnophilic species (*Carassius carassius, Tinca tinca, Misgurnus fossilis*, etc.). Habitat requirements of these species are very different and high habitat diversity of the river-floodplain ecosystem can be inferred from their coexistence. Occasional occurrence of migratory fish (*Acipenser ruthenus, Ballerus ballerus*) from the Danube can be established. The estimated species number in the original fish fauna is 45 (Table 1), which is lower than in the recent fauna.

The occurrence of ten non-native and one atypical native species (Table 1) has been recorded since the 1980s and most of them have a permanent population. Some can be considered as invasive species and their spreading may be expected in the near future. Most of the original elements of the fish fauna occur nowadays, but presence of *Acipenser ruthenus* has not been verified since the 1960s due to disrupted migration by dams built on the lower section of the river.

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New manual on integrated planning of waterways as a tool for river management

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Keywords: navigation, planning process, integration, river management, Danube

1 Introduction

Public discussions on the protection versus economic development of European rivers have led in recent years to a growing understanding that there is a strong need to guide future actions to reconcile conflicting interests. Some innovative measures have shown that it is indeed possible to create win-win solutions for environment, transport and other river uses.

Inland waterway transport (IWT) is one of the strongest drivers exerting new pressures on large rivers, notably the Danube (Zinke Environment Consulting 2002; Haskoning 2005; Habersack et al. 2009). While various waterways in Western Europe have been developed in the 20th century into an intensively used network, the Danube and some of its tributaries (Sava, Tisza) are still ecologically largely intact. Beside some well-known conflict cases of the Upper Danube (Straubing-Vilshofen; section east of Vienna), several major IWT projects are currently under preparation (Hungarian Danube, Middle and Lower Sava, Romanian-Bulgarian Danube: Zinke 2007; Birdlife 2008; Weller & Zinke 2009).

Even though waterway transport may be considered a rather environment-friendly transport mode, these plans are conflicting with the EU Water Framework Directive and the growing Natura 2000 network. As a response, the concept of integrated planning was jointly discussed and endorsed in 2007 by Danube Basin governments and various stakeholders in form of the "*Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin*" (JS 2007), under the lead of the ICPDR (International Commission for the Protection of the Danube River), the Danube Commission for Navigation (DC) and the International Sava Commission (ISRBC).

It was clear that the Joint Statement as a key tool for the planning and implementation of waterway projects needed further illustration and explanation. This became subject of a new "*Manual on Good* Practises in Sustainable Waterway Planning" (ICPDR 2010) within the EU PLATINA project (see www.naiades.info). The manual should explain the needed scope, organisation and implementation of a planning process that aims at providing security for waterway planners and river protection managers at local and international levels of European rivers.

2 Material and methods

The preparation of the Manual was executed in the PLATINA SWP 5.3 project (2008-2010) which included desk studies, expert reflections within the SWP 5.3 team and several stakeholder consultations. The Manual was prepared as a coordinated effort by the PLATINA SWP 5.3 partners, i.e.

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- via donau, Vienna;

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- University of Natural Resources and Applied Life Sciences (BOKU) - Institute of Water Management, Hydrology and Hydraulic Engineering in Vienna;
- Inland Navigation Europe (INE).

Methods applied included:

- a screening of available European references and sources (publications, workshops of other organisations, other manuals etc.);
- the use of the general planning guidelines of the *Joint Statement (2007)*;
- the input from various experts and stakeholders on occasion of Joint Statement meetings on 29-30 January 2009 in Budapest and on 9-10 March 2010 in Zagreb;
- discussions of the early draft Manual by the participants of the two PLATINA SWP 5.3 training workshops on integrated IWT planning (9-10 June 2009 in Zagreb/Croatia; 15-16 September 2009 in Ruse/Bulgaria).
- numerous expert comments and text contributions to the advanced and final draft versions.

3 Results

This extended abstract constitutes a short presentation of the key elements and basic guidance that is provided in detail and with various background information in the manual (ICPDR 2010). The new manual is based on the new legal framework of the EU as well as on available experiences and recommendations from various infrastructure developments. This refers to the EC policy (EC 2006a) and technical papers (EC 2006b) , ECMT (2006), to case studies related to WFD implementation (EC 2006c), to the PIANC guidance documents on sustainable inland waterways (PIANC 2003), *´Working with Nature´* (PIANC 2008, 2009), to the planning experiences gained in the IWT projects on the Danube east of Vienna (OIAZDI 2009) and on the Scheldt (its Lys and estuary waterways – Maes et al. 2006) as well as to many engineering projects along waterways aimed at restoring river ecology (notably at the German and Dutch Rhine and the Austrian Danube: BfG 2009, Herpertz & Esser 2009).

As a result, this Manual offers **general advice** on organizing and implementing a balanced and integrated planning process. However, project developers should also consider national, regional and local aspects and requirements when developing an inland waterway transport (IWT) project. The early integration of stakeholders (including those representing environmental interests) and of environmental objectives and a wide communication are essential for a successful planning process.

To develop a **sustainable waterway infrastructure project** that does not (further) damage the river system and may even have a positive impact on the current state of environment, IWT planners need to understand and incorporate the wider environmental aspects and fully respect the legal environmental requirements.

Therefore, general planning objectives and principles should clearly prevent any deterioration of ecology (Natura 2000 and water status) and contribute to the legal needs (nature and water management objectives) to maintain and improve or restore ecological quality. The **River Engineering Criteria** elaborated in the *Joint Statement (2007)* should be taken into consideration as a general guide.

Preparing and executing an integrated planning process requires a more substantial investment into planning than was needed in the past, but it results in a number of **measurable benefits**: greater certainty that the IWT project planning will successfully pass environmental permit hurdles (EIA procedure); development of innovative technical solutions; better financial feasibility; reduced environmental damage costs and better use of the river ecosystem services; an improved public image of the project and the institutions responsible for planning and operating IWT infrastructure.

The **four essential features for integrated planning** are:

- Identify integrated project objectives incorporating IWT aims, environmental needs and the objectives of other uses of the river reach such as nature protection, water management and fisheries;
- Integrate all relevant stakeholders from the initial scoping phase of a project;

- Carry out an integrated planning process to translate the IWT and environment objectives into concrete project measures securing, where possible, win-win results;
- Conduct comprehensive environmental monitoring prior, during and after the project works, enabling an adaptive planning and implementation approach as well as securing an evaluation of project success.

This Manual suggests **five general stages** for preparing, executing and sustaining the integrated approach to be applied and interpreted in each IWT project: Scoping, organising the planning process, executing the integrated planning, monitoring and project implementation (Figure 1). For each stage, two to seven activities and steps are specified.

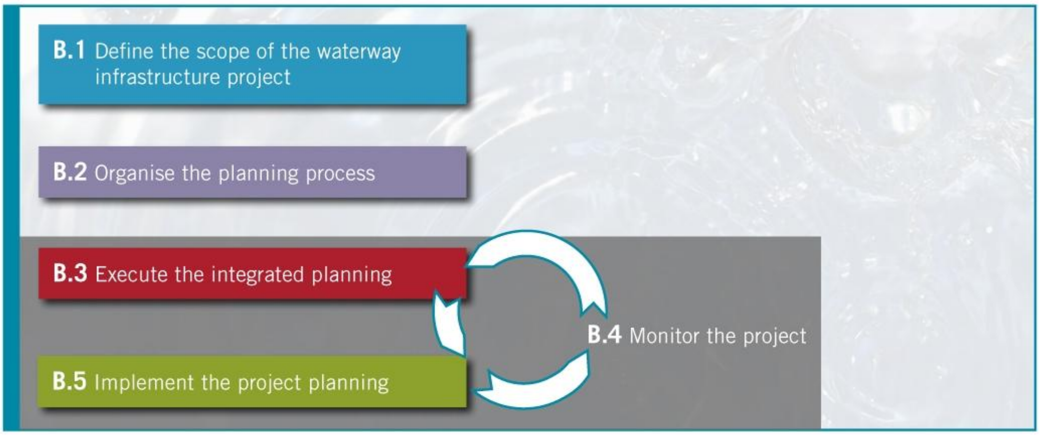

Figure 1. *The general stages of an integrated planning process of a waterway project.*

Especially the 2nd and 3rd stage require a much more comprehensive approach than taken in many infrastructure projects in the past.

The **integrated planning process** (B.3) itself covers four main planning steps as a *general guide*. There is no strict timeline, and the order of the steps may depend on the specific requirements and progress of a concrete IWT project:

Step 1 Define joint Planning Objectives and Principles

Step 2 Carry out the detailed planning of measures

- technical and ecological *options*
- plan *alternatives*
- *variants* of chosen alternatives
- local *examination* and/or *testing of measures*
- priority *ranking*

Step 3 Conclude the integrated planning process (communicate and adopt results)

Step 4 Execute the EIA process and apply for environmental permits.

Project developers can use these steps to create a dedicated *Road Map* for the entire planning process of their IWT project.

Before beginning the concrete planning work, several organisational activities are recommended to facilitate efficient work and concrete results. The Manual recommends setting up **several types of planning bodies.** Figure 2 presents the role, suggested members and functions of such actors within the integrated planning process:

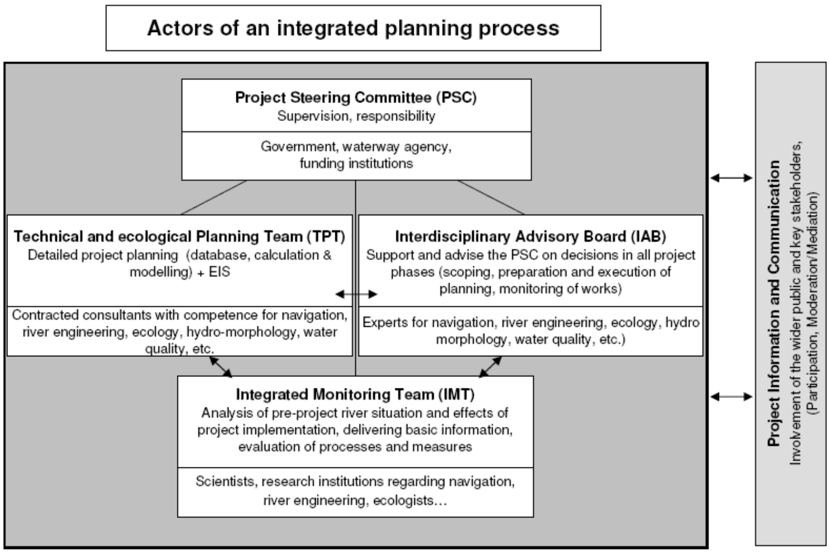

Figure 2. *Role, suggested members and their functions within the integrated planning process.*

While detailed planning has to be carried out by the *Technical and ecological Planning Team* (TPT), the *Integrated Advisory Board* (IAB) should be closely involved in this process to critically assess and optimise the proposed solutions. The joint planning results should be presented publicly and commented on by other stakeholders before they are finalised and endorsed. The completed set of integrated measures must be submitted to the responsible environmental authorities with all the required information (technical design, environmental aspects) in the Environmental Impact Study (EIS) to receive environmental and other permits.

The *Project Steering Committee* (PSC) executes overall supervision and assures that the planning results are implemented accordingly during further project phases. This may include the need to specify or amend certain details later upon conditions set by the permitting authorities.

The **environmental monitoring** should be executed by an independent *Integrated Monitoring Team* (IMT). This should also be connected to the adaptive planning and implementation of measures to allow for a feedback process, and any new findings have to be assessed by all planning bodies.

If the planning is properly done, the results are fully coordinated and compatible with other development plans, both in the transport sector and with other management affecting the river area (e.g. WFD, Natura 2000, flood control, agricultural and recreation development).

Even though integrated planning and its related implementation are rather new methods, there is already a wide range of experience and practical examples in Europe demonstrating Good Practices, some of which are presented in Part C of the Manual. This section also gives a comprehensive overview of relevant policies and the legal framework to be observed, of modern waterway management concepts and of the new management tasks of waterway administrations in line with EU environmental directives.

4 Conclusions

The *Joint Statement (2007)* has created a new foundation for combining the needs of transport with those of environmental protection. The new Manual provides practical guidance on how to achieve this. Success overall in integrated planning, however, depends on how well these planning tools are applied and interpreted in individual river infrastructure cases by all parties, i.e. governments, waterway agencies and relevant stakeholders. There is no best practice that can be easily copied elsewhere but there is the general understanding that waterway developers should respect multiple interests and requirements beside transport.

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