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Keynote lecture

Macrophytes of the Danube River: aquatic plant ecology – and some outreach into 'real world' policies

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Keywords: Expert Group IAD, survey method, habitat features, biodiversity, climate change, EU policy

Introduction

In 1985 the IAD established the Expert Group 'Macrophytes' (EGM) who's members again joined the day before the opening of the 2012 IAD conference. Despite the fact that macrophyte work had started much earlier in Europe in many places this group especially focused on macrophyte research in the Danube Basin. Two activities centered EGM activities from the beginning: standardizing the survey method among members in all Danube Countries and assessing macrophyte life in the Danube River corridor and in tributaries of different character. EGM work produced many individual publications (e.g. Schütz et al. 2008, Janauer & Schmidt 2005, Hrivnák et al. 2010, Kuhar et al. 2011, Osimec et al. 2010, Sipos et al. 2003, Vukov et al. 2008, Valchev, Georgiev 2012 [web reference], Sarbu et al. 2011) and many more still unpublished results, but a concerted strategy combined forces on the 'Multifunctional Integrated Study Danube: Corridor and Catchment' (MIDCC 2012; see web references). All this information, and the participation of the Viennese Team under the lead of the author in several EU-projects of scientific - as well as applied content - form the background of many details described below.

Survey methodology

Alexander Kohler was the first scientist to realize, that the three-dimensional development of plant stands is an important feature of the aquatic vegetation. This is because this factor varies to a much wider extent in water than in terrestrial vegetation due to the influence of water depth and water flow. As 'cover'-based methods did not consider this vertical development and neglected the importance of the non-vegetated parts of survey units, Kohler developed an estimate-based assessment. This was the 'amount' of an aquatic plant species (in German: Pflanzenmenge) in relation to a defined survey unit in running water or in the littoral area of a still water body. A huge number of publications - albeit most of them in German - (starting with: Kohler et al. 1971) were produced until today. These provide a huge set of information on aquatic plant stands in many German rivers, with some more work done in Sweden and Hungary. Furthermore many more still waters were studied again in Germany (the working group of Melzer, starting with his own survey of the Osterseen-lake-ensemble: Melzer 1976a,b, 1992). Heindl at last provided numerical proof of the validity of the estimator scale developed by Kohler specifically for the aquatic macrophyte vegetation (Janauer, Heindl 1998).

Today this method is used for macrophyte assessment in all EU Member States along the Danube River. It is the method applied for the Joint Danube Surveys (in 2001 and 2007) and it is one of the methods described by European Standards for running and still waters, to be applied for assessment of ecological status of surface waters (CEN 2003, 2006).

The EGM group practiced the standardized survey method in workshops arranged almost every year, in running and still waters. In a pilot study (performed in several Danube countries (Janauer et al. 2003)) they demonstrated the ability to assess the macrophyte vegetation in the Danube river corridor and in its tributaries. This opened the door for the MIDCC project, in which the macrophyte vegetation of the whole main Danube channel length, the side channels and the floodplain water bodies was assessed (Janauer 2005).

Ecological processes

Water flow is usually the strongest environmental impact parameter for aquatic plants in running waters, but wave action can be of serious effect in still waters too. Janauer and Jolankai (2008) complied an abundance of information on environmental relationship between the aquatic environment and the macrophyte vegetation, including flow type preference and hydraulic resistance originally assessed by Haslam (2006). He showed how these two parameters define the range of habitat conditions that aquatic plants can cope with. This is mirrored in greater abundance of macrophytes in run-of-river power plant reservoirs than in river reaches with no impoundment (Pall, Janauer 1995). Consequently the aquatic flora of oxbow lakes is characterized by higher biodiversity and abundance than that of the main river channel (Janauer et al. 2010). However artificial running water bodies can support even higher biodiversity. In Stetak's survey of the Gemenc Danube Reach (Janauer & Stetak 2003) the following species' numbers were detected: Danube main channel – 12; oxbows – 23; canals – 28. Another limiting factor can be flood events when reaching beyond more "regular" ones: Strausz reported noticeable impact of the extreme flood of 2002 in an oxbow system near Linz (Austria) (Strausz & Janauer 2007), and similar effects were recorded by Schmidt (personal communication) for the same extreme event.

Connectivity

Connectivity is primarily seen as longitudinal connectivity, which is e.g. interrupted by hydro-electric power installations (Vannote et al. 1980, Ward, Stanford 1995). Of course, connectivity is overlapping with the phenomenon of water flow impact (Janauer et al. 2010), but several studies have pointed out an intrinsic component of lateral river channel connections, which are more often easier to assess than to cope with the high variability of water flow in a selected environment. Hydrobotanists pointed out as early as 1991 that lateral connectivity is a prime driver for macrophyte distribution in floodplain water bodies (Bornette, Amoros 1991). The '*Connectivity Concept'* (Petts, Amoros 1996) then formed a fundamental theory, which covers main river channel and floodplain water characteristics, relating habitat types with the "*strength, duration and frequency of their connectivity [with the] river channel*" (Petts, Amoros, p.6). Those authors also defined that *"…biota are seen to be distributed according to predictable environmental gradients…*". Later Herny et al. (1996) and Bornette et al. (2009) reported on flood disturbance and recolonization thereafter, and about succession processes in former river channels. Chovanec et al. (2005) based their "Floodplain Index" of oxbow-related fauna on the connectivity type of floodplain water bodies. With relation to the aquatic macrophyte vegetation of the eastern reach of the Austrian Danube Janauer et al. (2012) reported the highest species number for floodplain waters directly connected with the main river channel during only 5 days per year, at average (Fig. 1).

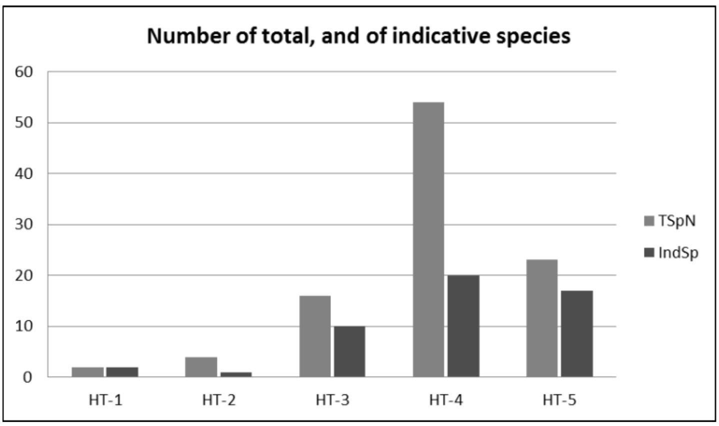

Figure 1. Total species number (TSpN) and number of Indicator Species in the eastern reach of the Austrian Danube. Floodplain Habitat Types, average connectivity with the main channel: HT-1: Cd > 330 days; HT-2: Cd < 330 days; HT-3: Cd < 120days; HT-4: Cd < 5 days; HT-5: temporary waters. Indicative species of HT-4 (statistically significant): *Nuphar lutea* (L.) Sm., *Myriophyllum verticillatum* L., *Sagittaria sagittifolia* L., *Hippuris vulgaris* L., *Najas marina* L., *Carex elata* All., *Potamogeton lucens* L., *Nymphaea alba* L., *Utricularia vulgaris* L., *Ranunculus* x *glueckii* A.Félix nom. nud., *Rumex* sp., *Sparganium erectum* L., *Schoenoplectus lacustris* (L.) Palla, *Potamogeton pusillus* L., *Lythrum salicaria* L., *Mentha aquatica* L., *Riccia fluitans* L. emend Lorb., *Potamogeton nodosus* Poir., *Sparganium emersum* Rehmann, *Veronica anagallis-aquatica* L. (order according to indicator strength).

The importance of the lack of high variability in discharge, which results in very constant flow conditions, can be seen in many feeding canals for hydro-power plants, and was shown for the Lower Hungarian Danube reach by Stetak (2003, Table 1). On a larger scale Sarbu et al. (2011) presented individual characteristics of the Romanian Danube River corridor, including the main channel, the large side channels and the main Delta channels.

Table 1. Species number in habitats of the Lower Hungarian Danube River Corridor. DRmain: Danube River, main channel; GFP: Gemenc Floodplain water bodies; CanB: canals and artificial water bodies near the town of Baja

DRmain	GFP	CanB
12	23	28

European Directives, river restoration, changes in biodiversity and Climate Change

Lateral connectivity relates to the aims of the EU Water Framework Directive (WFD 2000), but as well as to those of the Habitats Directive (HD): aquatic vegetation had developed over more than 100 years into remarkable richness in the oxbow ensembles of regulated river floodplains and reaches high conservational quality today. Yet, the reconstruction of permanent flow conditions in the process of re-establishing good ecological status *sensu* WFD will destroy these macrophyte assemblages and all aquatic fauna directly depending on it (Barta et al. 2009, Janauer et al. 2008).

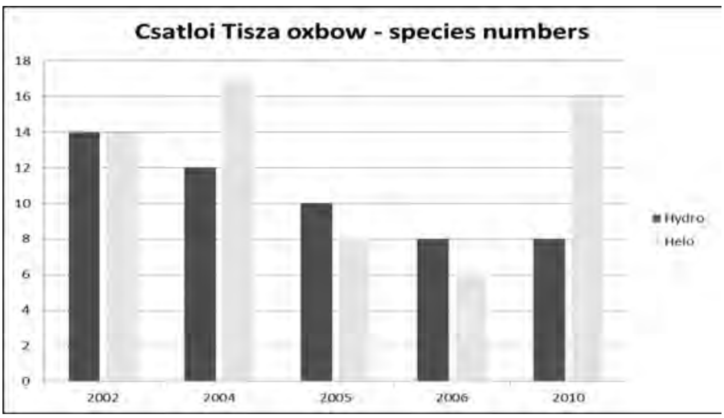

Figure 2. Species number of aquatic macrophytes and of helophytes in Csatloi Holt Tisza (Hungary). The number of hydrophytic species is decreasing due to longer and more intensive low discharge in the main channel of the Tisza River and the consecutive increase of *Trapa natans* L., which tens to cover all free water areas outside dense *Nymphaea alba* L. patches. The conditions for helophytic species seem to vary of a greater range, as there are gains and losses in this group of plants over the recorded time period.

Regarding studies on temporal changes in biodiversity and water quality in running and still water environments several studies are currently in progress, especially at the Neusiedler See/Fertő (AT/HU, 1997 – 2005; Magyar et al. 2012; Hatvani et al. 2012), at the floodplain waters between Vienna and Bratislava, at the Maly Dunaj (SK) and the Mosoni-Duna (HU), which represent the two bordering side-rivers of the Danube reach between Bratislava/Rajka and Gönyü, carried out by teams in Austria, the Slovak Republic (Oťaheľová 2007, Kovács 2007) and in Hungary.

An equivalent to possible climate change effects on oxbow lakes in the Tisza river corridor is under study at the Csatlói-Holt-Tisza since 2002 and will be soon, indicating the importance, and threat related to native plants turning into aggressive competitors where floating leaf or free floating macrophytes cover the total surface of still waters (Mandoki, Janauer, personal communication, Fig. 2).

Outlook and conclusions

This contribution covers several aspects of macrophyte research in the Danube River basin. Examples given show that not only scientific interest is met, but real-life drivers like regulations related to environmental pressures like e.g. water flow conditions or climate change, as well as European policy define the current and future conditions for aquatic plant occurrence. The Expert Group 'Macrophytes' of IAD will strive to devote even more effort in studying the macrophyte vegetation in the water bodies of the Danube river corridor and in important tributaries.

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Have sturgeons a future in the Danube River?

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*Keywords**:** sturgeons, historical evolution of stocks, essential habitats, migration barriers, genetic variability and supportive stocking*

Introduction

Several historical records indicate the importance of the sturgeons in nutrition of human populations along the Danube from the Palaeolithic age. Sturgeon fishery flourished in the Middle Danube between the 11th and 16th centuries, but over-exploitation caused a decreasing trend in catches in the following centuries and anadromous species became an occasional capture in the 19th century (Kriesch 1876, Károli 1877, Herman 1887, Khin 1957, Hensel & Holčik 1997, Guti 2006, 2008). Sturgeon populations spawning in the Lower Danube have declined considerably since the 19th century and this trend has persisted even during the last decades.

European human population has almost doubled since the end of the 19th century and its recent density is 70 inhabitants/km^2 (the second most populous continent after Asia). Ensuring the needs of mass of people has had several undesirable impacts upon river ecosystems, leading to the loss of half of Europe's wetlands and resulted many serious threats to freshwater fish species (Kottelat & Freyhof 2007).

Long-term downtrend of sturgeon populations indicates deteriorating state of large river systems. The main threats to sturgeon populations include habitat loss and alteration due to river engineering (in the Upper and Middle Danube in particular), the disruption of spawning migrations by dams, pollution (bio-accumulation of toxic substances), and potential degradation of the genetic diversity due to supportive stocking programs. Over-exploitation of populations is an additional threat, especially in the Lower Danube and the Black Sea (over-fishing linked with poaching and illegal trade), and the significant decrease in anadromous sturgeon populations in the Middle Danube was resulted by overfishing in the last three centuries (Reinartz 2002, Bloesch et al. 2005, 2006).

This study concentrates some questions of habitat and population issues of sturgeon conservation with special attention to the differences and similarities between the Middle and Lower Danube, as well as the reality of some restoration ideas and species conservation measures.

Habitat changes

Availability and integrity of key habitats is vital for the normal ontogeny and successful recruitment of fish populations. Sturgeons have special habitat requirements due to their particular life history and anadromous or potamodromous migration. Their spawning sites are usually characterized by hard gravel or clay substrate with many crevices where flow velocity near the bottom and bed shear stress is generally low. These areas are in the main river bed or in the larger eupotamic side arms (Holčik 1989, Reinartz 2002, Bloesch et al. 2006). Locations and environmental conditions of former spawning habitats are less known and most of these areas have been altered by extensive river engineering since the 19th century. Habitat loss and degradation is one of the most serious threats for sturgeons.

River engineering for improvement of navigation route and flood control (including channel straightening, narrowing and dredging, shortcutting of meander, blocking of side arms, etc.) adversely altered the typical hydro-morphological processes and hydraulic conditions, which maintained the natural fluvial landscape and habitat patterns in the main stream (Iványi et al. 2012). Information about locality and condition of sturgeon habitats is limited along the Danube, however modified flow and sediment regime can result degradation and areal decrease of spawning habitats, as it was demonstrated by long-term changes of sterlet catches in the Szigetköz floodplain. The Szigetköz section of the Danube (r.km 1850-1768) was one the most important historical spawning ground for sturgeons in Hungary. Annual catch of sterlet (*Acipenser ruthenus*) increased from 150 kg to 2000 kg in the 1980s (Jancsó & Tóth 1987), but declined sharply to 10 kg by the beginning of operation of the Gabčikovo hydropower dam in 1992. Running of the hydropower station resulted intensive sedimentation and accumulation of 400,000 km^3 silt in 10 years on former gravel substrate in a 4 km long side arm, which was the only and last spawning site of sterlet in the Szigetköz section of the river (Guti 2008).

The hydropower dams built at the Iron Gate in 1972 and 1984 have additional adverse impacts on natural habitats and ecological functioning of the Danube. The dams do not allow free movement of migratory fishes and remaining populations of anadromous sturgeon unable to move from the Black Sea to their former spawning grounds in the Middle Danube.

By modifying flow regime, constructions started in 2011 for improvement of conditions for navigation in Romania, on the Lower Danube River between Brăila and Călăraşi, Danube rkm 175 to rkm 375, are threatening spawning sites of stellate sturgeons recently described by both acoustic telemetry tracking (Hontz et al. 2012) and molecular biology analysis (Holostenco et al. 2012). Monitoring of sturgeon habitats on the Borcea branch in relation with these construction works revealed to be crucial for the survival of these last largest sub-population of Stellate sturgeons spawning in the Lower Danube River.

Population changes

Direct monitoring of sturgeons and their recruitment from natural spawning has been implemented only in the Lower Danube (Suciu et al. 2004; Paraschiv & Suciu 2005; 2006), however analysis of catch data of fishery provides an opportunity for indirect monitoring of populations (Guti & Gaebele 2009). The main advantage of this last approach is the large scale survey in time and space.

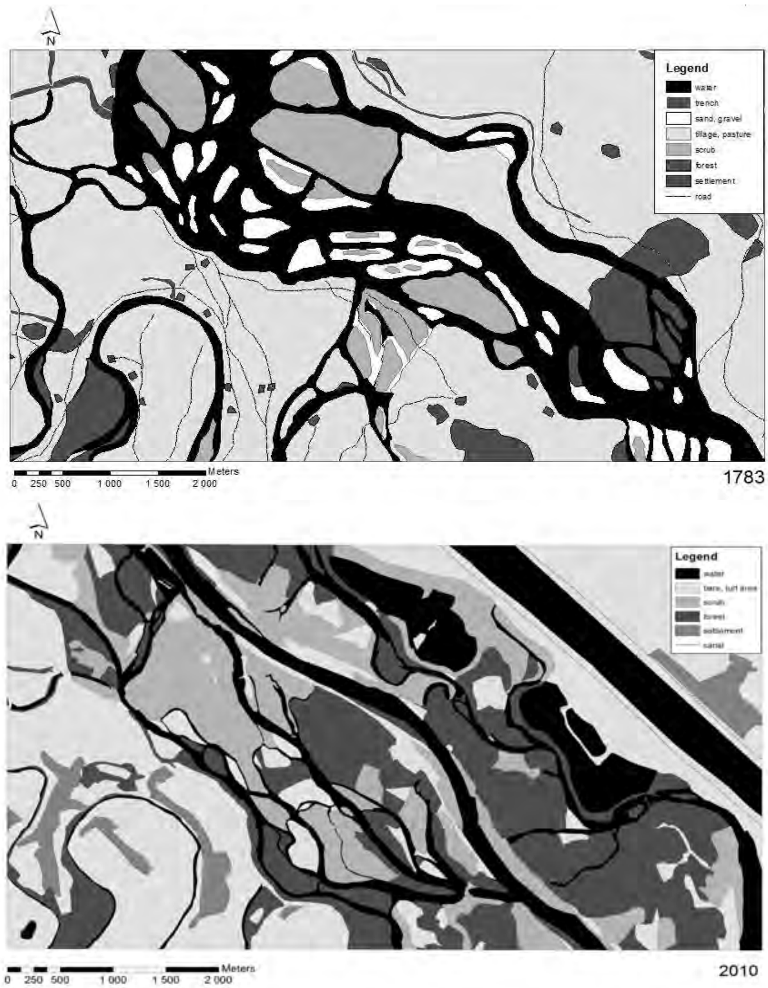

Figure 1. The Cikola branch system in the Szigetköz section of the Danube in the pre-regulation period (18th century) and recently. The river section was one of the most significant spawning ground of the anadromous sturgeons.

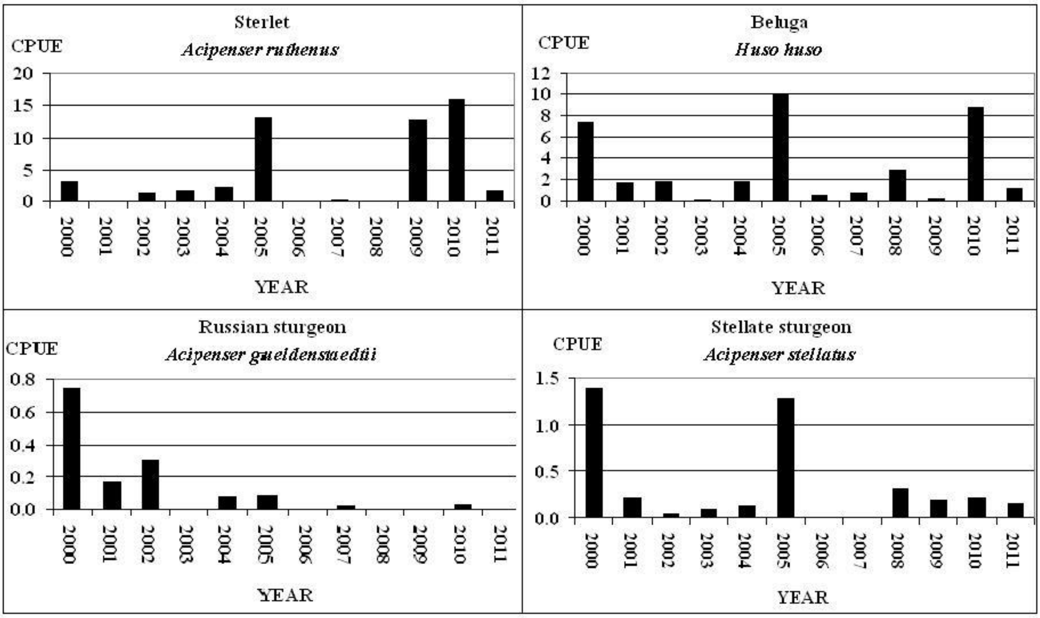

Figure 2. Recruitment from natural spawning of the four sturgeon species in the Lower Danube River during 2000–2011. CPUE (Catch Per Unit of Effort) = Number of young of the year sturgeons captured in one trammel net (90 m long, 2 m high, 20 mm mesh size) drifted every time over the same reach (850 m length; 6–14 m water depth) of the Danube at rkm 123.

According to the historical data, catches in the Middle and Lower Danube show significant difference. Sturgeon catches in the Middle Danube began to decrease much earlier, from the 16th century (Kriesch 1876, Károli 1877, Herman 1887, Khin 1957, Hensel & Holčik 1997, Guti 2008). In the 19th century, when the annual sturgeon catch was near 1,000 tons along the Lower Danube, the anadromous sturgeons (*Huso huso, Acipenser gueldenstaedti, Acipenser stellatus*) were rarely caught in the Hungarian section of the Danube (Guti 2008).

Recruitment from natural spawning of the four sturgeon species in the Lower Danube River monitored by DDNI Tulcea during 2000 – 2011 (Fig. 2) shows natural variation in Sterlet and Beluga sturgeon, with high/normal values in year 2000, 2005 and 2010. In Beluga sturgeons this seems rather the result of successful spawning of beluga females from the same generation, which escaped the intensive fishing and returned every 5 years to spawn again in the river.

In Stellate sturgeon the recruitment shows no visible pattern and is rather on a decreasing trend, while in Russian sturgeon this trend is extremely alarming.

On the Lower Danube River, in Romania, catches of Beluga sturgeons decreased from an average of 250 metric tonnes/year during 1950–1965 (Fig. 3) to only 8.4 tonnes in year 2005.

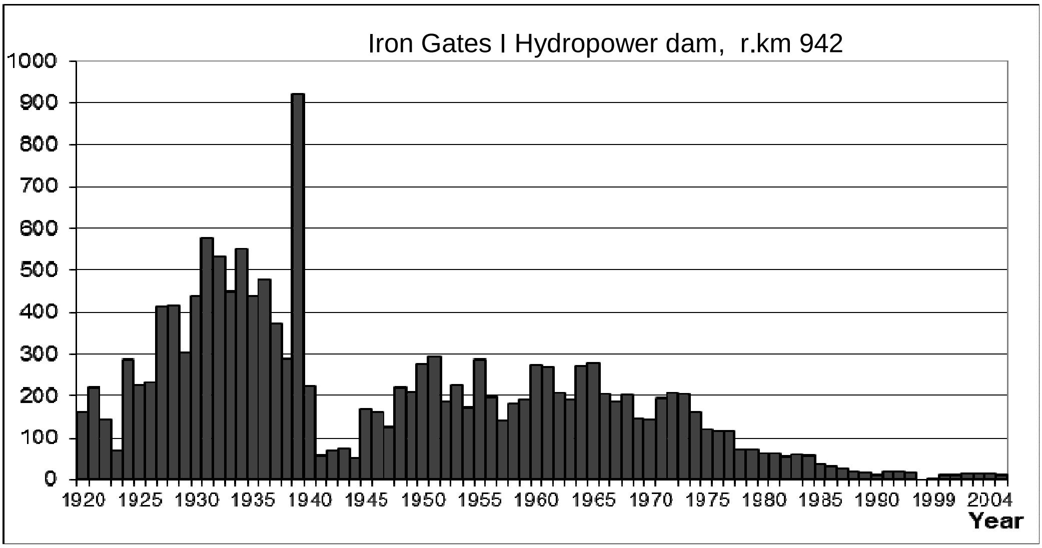

Figure 3. Decline of Beluga sturgeon catches (metric ton) in the Lower Danube (1920-2005) (from Paraschiv & Suciu 2006)

Even CITES regulations on sturgeon management and export implemented in the region since year 2001 (Suciu 2004) were not able to halt decline of sturgeons legally captured in Romania (Fig. 4).

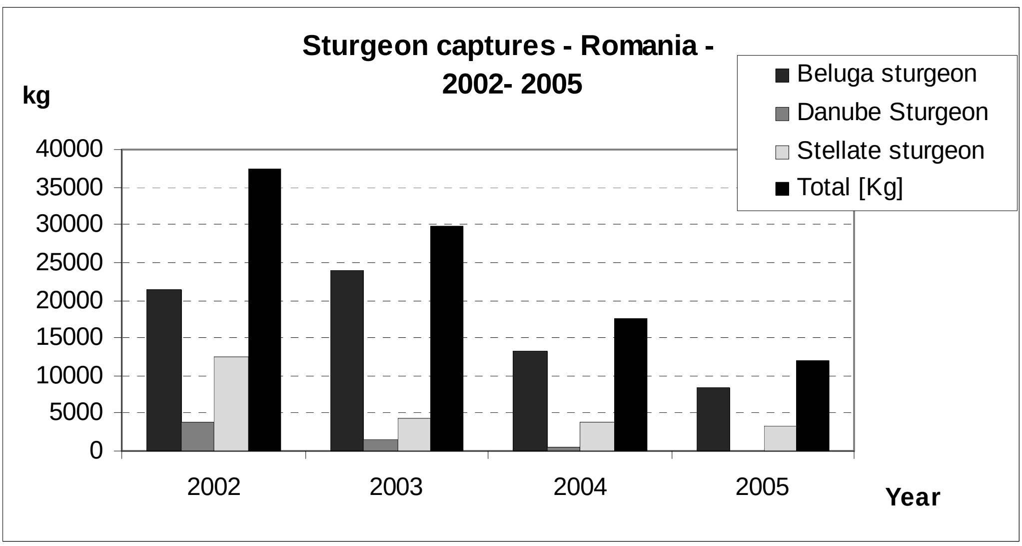

Figure 4. Decline of legally captured sturgeons in Romania during 2002–2005

Presumably, anadromous sturgeon species of the NW Black Sea used to spawn in the Danube forming a meta-population, which means individuals of different races (distinct genotypes?) of a species formed several sub-populations. Spawning grounds of the sub-populations were separated and located few hundred kilometres from each other. Sub-populations could be characterized by spawning site fidelity, that is spawning migration of individuals was controlled by homing behaviour. The homing behaviour of sturgeons has been known in some river systems of North America (Hurley et al. 1987, Stabile et al. 1996, Rusak & Mosindy 1997) and it can explain the existence of different races (e.g. vernal and winter races) within single species (Reinartz et al. 2002).

The faster decline of anadromous sturgeon populations in the Middle Danube can be elucidated by former occurrence of long- and short-migratory races (sub-populations migrating to the upper-middle or lower sections of the Danube). The fishing mortality rate (it refers to individuals are removed from the stock by fishing) of the long migratory race could be almost one order of magnitude higher than that of the sub-populations reproducing in the Lower Danube, due to higher number of sturgeon traps along the longer migratory route. The excessive fishing for centuries continuously reduced the number of fish that arrive in the spawning sites. Decrease of population recruitment resulted in the disappearance of the long-migratory races at the end of the 20th century.

Recent, unpublished work by Holostenco et al. (2012), using mtDNA markers, has demonstrated the existence of 10 genetically distinct groups of Stellate sturgeons, still spawning in the Lower Danube River. According to recent acoustic telemetry tracking and direct observation in June 2011 of Stellate sturgeon males branch while releasing milt at handling for implanting of acoustic transmitters on the Borcea, is pointing to the existence of a spring migrating group that is spawning very late, in early summer (Hontz et al. 2012). This group is genetically distinguishable by the most frequent *D-loop* mtDNA RFLP composite haplotype I (Holostenco et al. 2012). The fact that this group of Stellate sturgeons is the most frequent (70.21%) (Holostenco et al. 2012) can be explained by belonging to a short–migratory race (sub-population) which has its main spawning sites on the Borcea branch, only about 250 km from the Black Sea.

Habitat restoration ideas

Mitigating impact of migration barriers between the Lower and Middle Danube by adequate fish passages is now considered one of the keys for restoring longitudinal connectivity of spawning migratory route for sturgeons (Bloesch et al. 2005, 2006) (Reinartz et al. 2012), however existing knowledge about recent upstream movements of sturgeons is limited and clarification of several problems is necessary to make clear efficiency of this rehabilitation idea:

1) Impoundment of Iron Gate dams has changed hydraulic characteristics in a 200 km long section of the Danube and behaviour of sturgeons in the impounded river section is unknown.
2) Some sections of the Middle Danube are heavily modified and suitability of spawning and nursery habitats for sturgeons is unclear. The anabranching Szigetköz section was one the most important area of sturgeon reproduction, but recently 80 % of discharge is diverted to the bypass canal of the Gabčikovo hydropower dam. Alteration of hidraulic conditions resulted accumulation of fine sediment in the branches and it destroyed the former spawning sites.
3) If the hypothetical meta-population concept for Danube sturgeons and former occurrence of long- and short-migratory races is accepted, the extinction of the long-migratory race can be presumed. Forty years before construction of Iron Gate dams, in the 1930s, only two catches of great sturgeon was recorded in the Hungarian section of the Danube in ten years, but in the same time the annual sturgeon catches exceed 1,000 tons in the Lower Danube, and it indicates 3-4 order of magnitude difference in population density between the middle and lower river sections. Since the 1930s, annual sturgeon catches have decreased by 3 order of magnitude in the Lower Danube and recurrence of anadromous sturgeons would be uncertain in the Middle Danube, even in cases if the Iron Gate dams could be completely removed.

Construction of adequate fish passages at the Iron Gate dams can provide migratory way for several fish species, but the significant improvement of the habitat availability for sturgeons by this measure is doubtful and controversial. Despite all these risks a recent FAO appointed mission to the Iron Gates formally inspected the dam sites and declared the possibility of building here several fish passages (Comoglio 2011), based mainly on the recently constructed largest fish passage in Europe, at Geesthacht, on the Elbe River (* * * 2011).

Identifying, protecting and restoring of essential wintering, spawning and nursery habitats for sturgeons seems more important, but realisation of this task is difficult due to limited knowledge and information gaps concerning the key habitats (location, hydraulic specifications, hydro-morphological processes governing habitat development, etc.). Despite these difficulties essential wintering holes used by Beluga sturgeons during the winter 2011–2012 were located on the Bala branch at Km 7.7 and Km 5.4 using combined acoustic telemetry techniques (submerged acoustic receivers and a mobile tracking receiver) (Suciu et al. 2012).

After one year continuous monitoring of movement and behaviour of sturgeons in relation to the ongoing construction of bottom sill at Km 9 on the Bala branch (Danube River Km 345) using up to date acoustic telemetry equipment (Suciu et al. 2012), it turned out clearly that the Borcea and Bala branches are the main migration route towards the upstream reach of the Lower Danube River, were the main spawning sites for Beluga sturgeon are located along the rocky grounds of the Bulgarian bank (Vassilev 2003). To solve the problem of longitudinal connectivity for migratory sturgeons at this obstacle the Romanian Ministry of Transportation has announced recently (June 6th, 2012) that it will publish a tender for the feasibility study of a fish passage for sturgeons at the bottom sill on Bala branch. This means that if all goes according the preliminary schedule the construction of a first fish passage for sturgeons on the Danube River could be completed during the next 5-6 years.

Population conservation measures

Stocking from artificial propagation is one of the approaches have been used to restore endangered sturgeon stocks. Breeding methods for Danubian sturgeons have been developed and there are several facilities for propagation of sturgeons along the Danube (Reinartz 2002). Casual stocking actions for recovery of sturgeon populations were initiated in Germany, Austria, Hungary, Serbia, Bulgaria and Romania in the last decades, but their impacts are less known.

The supportive stocking programme with young sturgeons produced by artificial propagation using a certain number of brood fish captured from the wild and rearing of the offspring in aquaculture to a TL ≥ 10 cm started by Romania in year 2006 as measure of recovery of critically endangered species. This measure was accompanied by a ten year moratorium of commercial catches (Anonymous 2006), meant to allow recovery of populations by interdiction of legal landings for commercial purposes and supporting the recruitment of the ten weak year classes suppressed by the uncontrolled intensive fishing during 1990–2000, when Romania was not able to issue a new/revised law on fishery and aquaculture.

For the first time in the history of the Danube River most of the 430 thousand young sturgeons stocked in the Lower Danube River in Romania during 2006-2009 were tagged individually using Coded Wire Tags. Due to lack of funding to evaluate the survival and dispersion in the Black Sea of young sturgeons stocked in the river, the stocking programme was discontinued in year 2010. The evaluation project funded by the Fishery Operational Programme of Romanian, which will start in the second half of year 2012, is expected to provide critical information needed to improve and resume the stocking programme.

In general view of fishermen, stocking programs can contribute to the improvement of sturgeon catches. In the Hungarian section of the Danube, the quantity of stocked juvenile sterlet varied between 10,000 and 100,000 individuals from the middle of the 1970s to the end of the 1980s. The estimated result of this activity was about 150-1,500 kg annual additions to the total biomass of the adult sterlet population in the 1980s and 1990s. However rising trend of sterlet catches started between 1971 and 1976, before the beginning of the regular stocking program and the increase was more than 5,000 kg. This observation confirmed that the improvement of sterlet catches in the initial period was independent from stocking programme and the natural recruitment was significantly higher than the calculated contribution of the subsequent stocking activity (Guti & Gaebele 2009).

Genetically poorly organised and managed extensive stocking program was implemented for recovery of sturgeons in the Caspian Sea and the Volga River in the second half of the 20^{th} century. Annual quantity of released juveniles was 20-60 million specimens in the 1980s, but success of the massive stocking efforts was doubtful, sturgeon populations could not be stabilized (Secor et al. 2000).

As worldwide experiences confirmed, stocking programs can only provide provisional solutions, unless they are coupled plans for increasing level of natural recruitment of populations (Birstein et al. 1997). Protection and restoration of key habitats of sturgeons can contribute to improvement of natural recruitment, but direct observations are limited in this field. Development of complex programmes for sturgeon species conservation is challenging because of information gaps concerning abundance, age-distribution, habitat use and recruitment of populations.

Conclusions

The excessive fishing for centuries in the Middle Danube continuously reduced the number of fish that arrived in the spawning sites long before damming of the gorges at the Iron Gates. Ceasing of population recruitment resulted in the presumable drastic reduction or even disappearance of the long-migratory races at the end of the 20^{th} century. Therefore any feasibility study for fish passages at the Iron Gates has to be accompanied by genetic screening of specimens sporadically arriving at the Iron Gates II dams, to determine their genetic identity.

Damming of the Upper Danube and at the Iron Gates during the second half of the 20^{th} century induced radical changes of the sediment transport with unknown consequences on the essential habitats for wintering, spawning and nursery of sturgeons in the Middle and Lower Danube. Therefore mapping of actual situation of these habitats is a high priority for potential recovery of anadromous sturgeons and recovery of resident sterlet by habitat restoration projects.

Monitoring of effects of ongoing construction projects to improve conditions for navigation the Lower Danube has proved to be critical for avoiding severe impact on longitudinal connectivity of migration routes as well as functioning of habitats for wintering of fall migrant adults and nursery of young of the year born in the river.

Improvement and protection of the key habitats within river rehabilitation projects are essential prerequisites of successful conservation of the Danube sturgeons. Long-term supportive stocking programs are not able to generate self-sustaining populations at poor environmental conditions and permanent stockings threaten genetic diversity of populations.

The situation of the recruitment from natural spawning in the Middle and Lower Danube is totally different. While in four out of five sturgeon species surviving in the Danube River, natural recruitment still occurs almost every year in the Lower Danube, spawning of sterlet and ship sturgeon, as well as landlocked potamodromous Russian sturgeon in the Middle Danube is poorly documented or even lacking.

Following the successful example of recovery of salmon migration in the Middle Rhine River at the end of last century, the recovery of anadromous sturgeons to the Middle Danube River could be a “dream come true” only by joint effort of all stakeholders in the Danube basin, including fishermen communities, ensuring a future for the sturgeons in the Danube. However, this approach needs appropriate information on sturgeon habitats and ecology, as well as threats. No solution for the conservation of the Danube sturgeon populations can be found without multidisciplinary scientific support; therefore improvement of research capacities and activity in this area and development of regional as well as wider international cooperation are essential requirements.

Acknowledgment

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LECTURES

Topic 1
Ecological processes in riverine conditions

(dynamics and interactions between
the environmental conditions
and the living communities)

The distribution and abundance of genus *Potamogeton* in Slovenian rivers

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Keywords: Potamogeton, rivers, distribution

Abstract

This contribution reports about the presence and abundance of the taxa within the genus *Potamogeton* in Slovenian watercourses. The genus *Potamogeton* was the most abundant representing nearly 20% of total macrophyte biomass in surveyed watercourses. For the purpose of the study, we surveyed 40 rivers, which were divided into 1228 stretches. We determined 8 different *Potamogeton* taxa, among which *P. nodosus* was the most abundant exhibiting the highest relative plant mass. The second most abundant species was *P. pecinatus* and *P. natans* the third. Three hybrids were also found, namely *P. x salicifolius, P. x cooperi* and *P. x zizi*. Each of them was found at one location only. Species of the genus thrived in slow as well as in fast flowing waters with wide range of ecological status. Five species found in studied watercourses are listed on the Slovenian Red list; *P. berchtoldii*, *P. lucens*, *P. nodosus,* and *P. perfoliatus* are classified as vulnerable and *P. trichoides* as endangered. Indicator values of *Potamogeton* species are also discussed.

Introduction

Macrophytes are fundamental to the structure and functioning of river habitats (Baattrup-Pedersen & Riis, 1999), being involved in energy flow, nutrient cycling, and sedimentation processes. They affect water quality, provide food and refugia for aquatic invertebrates and fish, and are also valuable as indicators of water and sediment quality (Haslam 1987, Carbiener et al. 1990). Their presence and diversity depend on water quality, water depth, flow velocity, and substrate characteristics (Bornette et al. 1994, Baattrup-Pedersen & Riis 1999). Macrophyte species composition and abundance reflect the quality of an ecosystem as a whole. They are one of the biological elements required by the EU Water Framework Directive (WFD) (Council of the European Communities, 2000) for the assessment of ecological status of rivers.

The aim of our study was to examine the presence and abundance of the representatives of the genus *Potamogeton* in Slovenian rivers.

Materials and methods

In the survey, 40 Slovenian rivers divided into 1228 stretches of different length were examined. The distribution and abundance of macrophytes were assessed from the bank or using a boat. For sampling we used a rake with hooks. Species abundance was evaluated using a five degree scale: 1 = very rare; 2 = infrequent; 3 = common; 4 = frequent; 5 = abundant, predominant (Kohler and Janauer, 1995). On the basis of plant abundance a relative plant mass was calculated (RPM), which is related to true biomass with function x^3 (Pall and Janauer, 1995; Schneider and Melzer, 2003).

Results and discussion

Altogether 11 taxons of the genus *Potamogeton* were determined in survey of 40 Slovenian watercourses. No other genus consists of such a high number of species and hybrids. Among them *P. nodosus* reaches the highest RPM value followed by *P. pecinatus* and *P. natans* (Figure 1). Three hybrids were also found, namely *P. x salicifolius, P. x cooperi* and *P. x zizi*. Each of them was found at one location only. Species had the lowest RPM values from 0.011 to 0.013. *P. x salicifolius* was found in the Rak River, *P. x zizi* grew in the Obrh River and *P. x cooperi* thrived in the Dravinja River.

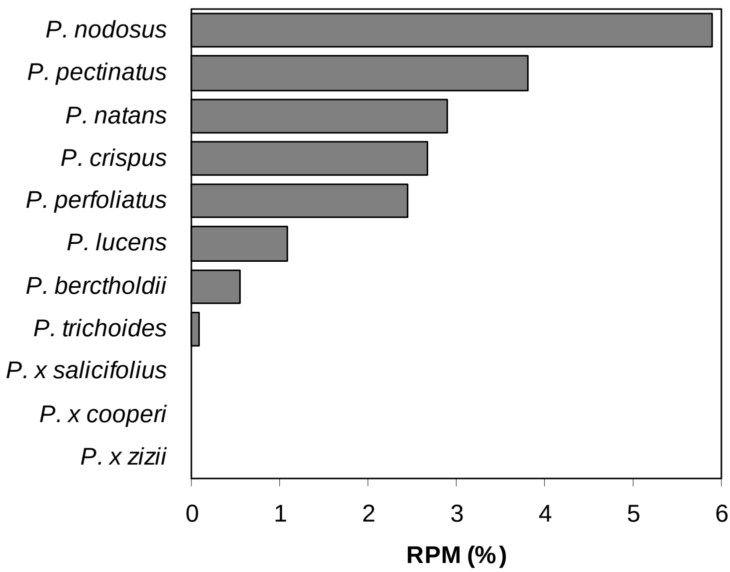

Figure 1. Relative plant mass (RPM) of the representatives of genus *Potamogeton* in Slovenian rivers, taking into account all present macrophyte species.

The representatives of the genus *Potamogeton* were found in a variety of environments, in slow as well as in fast flowing waters, with wide range of ecological status. The presence and abundance of different taxa reflected the conditions in the water body. Their relation regarding habitat characteristics revealed also from the analysis performed for the purpose of the development of River Macrophyte Index (RMI) for assessing river ecological status in Slovenia (Kuhar et al. 2011). We classified all macrophyte taxa into one of the six ecological groups. Taxa present only at the reference sites (percentage of natural areas >70 % in the catchment) were classified into group A, taxa present only at the moderately loaded sites (percentage of natural areas 30-70 % in the catchment) were classified into group B, and those present only at the heavily loaded sites (percentage of natural areas <30 % in the catchment) were classified into group C. Taxa present at both reference and moderately loaded sites were classified into group AB, and those present at both moderately and heavily loaded sites were classified into group BC. The taxa found at the heavily loaded sites and at the reference sites were classified into group ABC. *P. x salicifolius* was classified into group A, *P. crispus* and *P. lucens* were classified into group AB, *P. pectinatus* into B, and *P. nodosus* into BC. *P natans* and *P. perfoliatus* are found in group ABC showing that the two species have wide ecological valence as also reported by Preston (1995). Some species were found in habitats which differed from that described in literature. This is contributed to specific geomorphology and climate of the area. For example some species characteristic of eutrophic habitats, i.e. *Potamogeton crispus* and *Potamogeton lucens* (Haslam 1987; Szoszkiewicz et al. 2006), were found to be indicative for the reference and the moderately loaded sites. Schneider and Melzer (2003) report that *P. natans* is characteristic of waters with medium nutrient load, while *P. lucens* thrives in waters with medium to high nutrient load. *P. nodosus* is characteristic for eutrophic waters (Preston 1995). *P. crispus* and *P. pectinatus* can tolerate high concentration of phosphorus and ammonia (Dykyjová et al. 1985). Mackay et al. (2003) found out that *P. crispus* was associated with waters characterised by low total phosphorus, intermediate to low alkalinity and low riparian canopy cover.

The relatively high number of *Potamogeton* species and the low number and occurrence of hybrids are possibly a consequence of high morphological variability of Slovenian watercourses. Great differences in river morphology occur not only between different watercourses but also within single watercourse. *P. berchtoldii*, *P. lucens*, *P. nodosus* and *P. perfoliatus* are on the Slovenian Red list of Pteridophyta and Spermatophyta (Red list 2002) assigned as vulnerable. *P. trichoides* is classified as endangered. The present classification does not fit to the real situation therefore the study presents a basis for revising the list.

Conclusions

We determined 8 different *Potamogeton* taxa in 1228 stretches of 40 rivers surveyed. *P. nodosus* was the most abundant exhibiting the highest RPM value, followed by *P. pecinatus* and *P. natans*. Three hybrids, namely *P. x salicifolius, P. x cooperi* and *P. x zizi*, were also found. All present taxa thrived in slow as well as in fast flowing waters with wide range of ecological status. Five species that were found in studied watercourses are listed on the Slovenian Red list; *P. berchtoldii*, *P. lucens*, *P. nodosus,* and *P. perfoliatus* are classified as vulnerable while *P. trichoides* as endangered. The relatively high number of *Potamogeton* species and the low number and occurrence of hybrids are possibly a consequence of high morphological variability of Slovenian watercourses.

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Trophic structure of the ichthyofauna of the ripal zone of the Danube River and three adjacent wetlands in Bulgaria

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Keywords: Food webs, Qualitative modeling, Fishcenoses

Introduction

The knowledge of the trophic structure of zoocenoses is essential to understand how it influences the properties of the ecosystem, as a whole (Pimmet al. 1991; Warren 1994). The scientists used two main approaches to describe the fish trophic structure in the Lower Danube: reference data and gut content analysis. Florea & Gheorghe (2008) used a reference data for assessing the changes of the trophic structure of fish communities in the Romanian part of the Danube for a 55 years period.The authors payed attention mainly on the published data for the main trophic components in the diet and the feeding habits of the fish species.There are several studies on the fish trophic structure in wetlands alongside the Bulgarian Danube section such as Pehlivanov 2000, Pehlivanov et al. 2005, Pehlivanov & Pavlova 2008. Pavlova & Pehlivanov (2012) used the basic trophic attributes of ichthyocenoses in three Danube wetlands for modeling the trophic webs. Trophic attributes of the fish as terminal units in the trophic webs might be very usefull for revealing interrelationship among biocenoses in the ecosystems helping the uncover of some specific features. Thus the main goal of this study was to assess the trophic structure of the ichthyocenoses within the selected wetlands and the Danube River ripal along the Bulgarian Danube stretch, as integral part of a unified system of the riverplane.

Materials and methods:

The research was carried out within 2010 and 2011 in three wetlands adjacent to the Danube (Srebarna Lake, Malak Preslavets Marsh and Orsoya Marshland) and in September 2010 at some ripal sites along the Bulgarian Danube stretch (Table 1).

In the standing water bodies fish were sampled using gill nets, fish traps and hand net while in the Danube ripal area a seine net was used. After the species identification the fish specimens were preserved in 4% formalin for laboratory processing. As a standard recent methodology for analysis of the food composition of fishes was used. A volumetric analysis of food was done according to Hyslop (1980). Volumetric contribution the trophic components was used for the determination of fish species affiliation to a particular trophic group. The frequency of occurrence of the trophic components in the fish diets was used for calculating the Trophic index (Pauly et al. 2000), using the Troph Labtool (www. fishbase.org). Qualitative food web modeling using PowerPlay software for Loop analysis was done. Statistic packages “PAST”, “PRIMER v.6” were in use for processing the data. The principal component analysis (PCA) was performed according to Clarke and Warwick (2001).

Table 1. Geographic coordinates of the studied sites (WGS84 coordinate system)

	Orsoya	Zagrajden	Belene	Vardim Island	Vardim	Batin
N	43 47 39.69	43 45 09.52	43 39 09.65	43 37 25.52	43 36 44.64	43 40 18.59
E	23 06 05.05	24 32 51.31	25 07 54.54	25 27 13.38	25 28 31.68	25 41 13.76
	Ryahovo	**Babovo**	**Pojarevo**	**MalakPreslavets**	**Srebarna**	**Popina**
N	43 59 37.66	43 59 57.59	44 03 37.92	44 05 37.29	44 06 27.16	44 07 52.39
E	26 14 20.29	26 15 49.91	26 42 11.16	26 50 12.43	27 04 26.56	26 57 38.87

Results and discussion

Sixty-nine trophic components were found in the diets of studied fish species. Three types of trophic components were recorded:

- Animal food: zooplankton; zoobenthos; fish; eggs of invertebrates and fish eggs;
- Plant food: phytoplankton, macrophytes, seeds;
- Detritus and unidentified substance.

The four trophic groups were identified among the most common fish species in the studied wetlands and ripal sampling points that were characterized as they are given in Table 2. Variable trophic status was recorded in both the perch (*Perca fluviatilis*) and rudd (*Rutilus rutilus*) in the studied sites. The perch is found to belong to the omnivorous group in the Danubian ripal, and also in the Srebarna Lake lateral pools. The species was reported as trophic oportunist, of which diet composition is influenced by the water level in the lake (Pavlova manuscript). The rudd in the Srebarna Lake was found to be omnivorous or benthivorous depending on the habitat occupied, respectively the central open water body or the lateral pools (Fig.1).

In another fish species, the pumpkinseed (*Lepomis gibbosus*), a distinct feeding pattern was recorded in the Orsoya Marshland. It might be assumed that probably this is an effect of the high level of trophic niche overlap (Pavlova & Pehlivanov 2012), due to the limited space of the part of the marshland, where the pumpkinseed inhabits. Many authors (Johnson & Dropkin 1993; Blanco et al. 2003 etc.) indicate this species as zoobenthivorous. Nikolova et al. (2008) refer data about its omnivorous type of feeding. The obtained results suggest a relationship with the high level of trophic overlap with several zoobenthivorous fishes in the Orsoya Marshland also for the tench (*Tinca tinca*).

Table 2. Trophic affiliation of common fish species in the Srebarna Lake -SRBL, Orsoya Marshland - ORSM, Malak Preslavets Marsh- MPRM and the Danube River ripal - DNNR. Omni- omnivores, Pr- predaceous, Zbv- zoobenthivores, Hbv- herbivores.

Fish species	Abbreviation	Trophic affiliation			
		DNNR	ORSM	SRBL	MPRM
Perca fluviatilis	**Pflu**	Omni	Pr	Omni, Pr	Pr
Aspius aspius	**Aasp**	Omni		Pr	
Esox lucius	**Eluc**	Pr	Pr	Pr	
Rutilus rutilus	**Rrut**	Omni	Omni	Omni, Zbv	Omni
Rhodeus amarus	**Ram**	Hbv	Hbv	Hbv	
Scardinius erythrophthalmus	**Scer**	Omni	Hbv	Omni	Hbv
Abramis brama	**Abr**	Zbv		Zbv	
Carassius gibelio	**Cgib**	Omni		Omni	
Alburnus alburnus	**Aalb**	Zbv		Omni	
Perccottus glenii	**Pgle**	Zbv	Zbv		
Cobitis elongatoides	**Coel**	Zbv			
Neogobius fluviatilis	**Nflu**	Zbv			
Chondrostoma nassus	**Cnas**	Hbv			
N. melanostomus	**Nmel**	Zbv			
Benthophyllus stellatus	**Bste**	Omni			
Pseudorasbora parva	**Pparv**	Zbv			
Gobio albipinatus	**Galb**	Zbv			
N. kessleri	**Nkes**	Pr			
Tinca tinca	**Ttin**	Zbv	Omni		
Misgurnus fossilis	**Mfos**	Zbv	Zbv		
Zingel streber	**Zstr**	Zbv			
Sander lucioperca	**Sluc**	Pr		Pr	
Lepomis gibbosus	**Lgib**	Omni	Zbv	Omni	Omni
Gymnocephalus schraetser	**Gshr**	Zbv			

Figure 1. Represents the similarity of the diets of the fishes cought in the Danubian ripal and the forming trophic groups. The partition was found to be statistically significant (ANOSIM, with global statistic R= 0.72 and significance level p=0.0001 for 999 permutations).

Significantly greater number of fish species was found in the zoobenthivorous trophic group. This fact reflects the main resource available to the fish in ripalzone in the research season. Secondly, a relatively high degree of uniformity in the distribution of the number of species in trophic groups is typical on the wetlands surveyed in the same season due to the diverse habitats and zoocenoses.

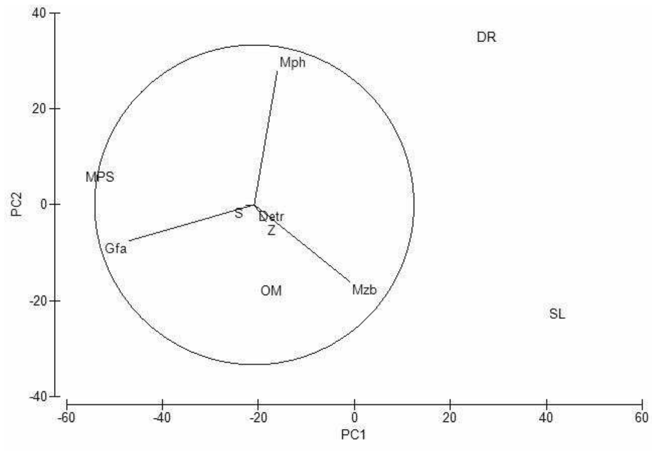

Figure 1. Diagram of PCA of the main trophic components in the diet of the rudd in the studied wetlands and the Danubian ripal. Legend: DR – The Danube River, OM – the Orsoya Marshland, SL– the Srebarna Lake, MPS- the Malak Preslavec Marsh, Mzb - macrozoobenthos, Z - zooplankton, Detr - detritus, Gfa – Green filamentary algae, S – higher plants seeds, Mph – macrophytes. (PC1 – eigenvalue 0.64, PC2- eigenvalue 0.02, significant at p=0.002)

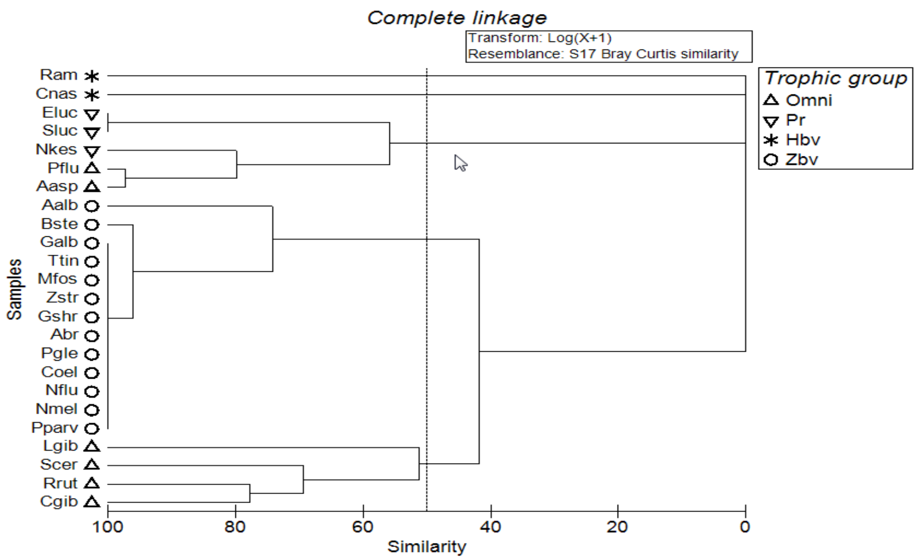

Figure 2. Dendrodram of an UPGMA cluster analysis of Bray-Curtis similarities in the diets of 24 fish species in the ripal zone of the Danube River in the studied sites.

The Trophic index values (Fig. 3) show more refined data from Table 2. There the diferences in the trophic level of the food of rudd and roach from the Srebarna Lake and the other sampling place is also well visible. The values of the index for the predaceous species (the pike, the pike perch and the asp) show high degree of conservatism.

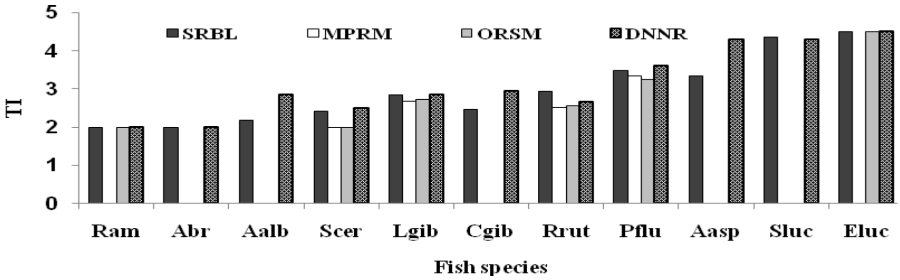

Figure 3. Trophic Index – (TI) values for common fish species in the three wetlands and the Danubian ripal, Legend: see Table 2.

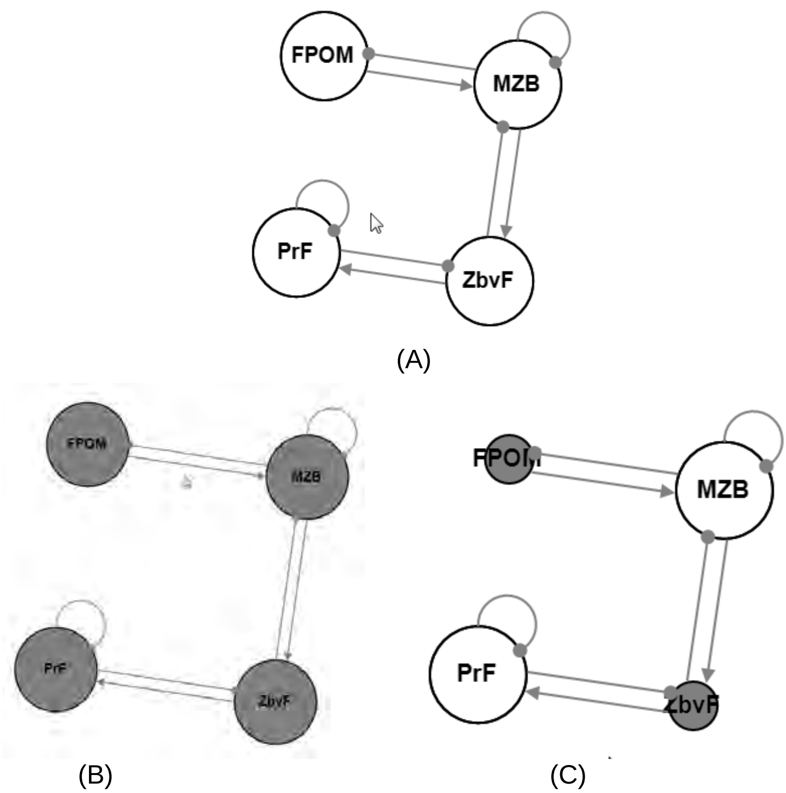

Figure 4. Danubian ripal trophic webmodel (A) with a prediction for development of the system while increasing the factor of Fine particulate organic matter (FPOM), relative importance (B) and decreasing the factor predatory fish (C). Legend: FPOM – see above, MZB - macrozoobenthos, ZbvF – Zoobenthivorous fishes, PrF – Predaceous fishes.

The Danubian ripal trophic webmodelled (Fig. 4) is significantly more simple than the reported one for the three studied wetlands (Pavlova & Pehlivanov 2012). The prediction function of the Powerplay software (Fig. 4,B) displays for whole the trophic web relatively high importance of the fine particulate organic matter, which is known as a pattern in the fluvial ecology (Vannoteetal., 1989). Furthermore, this result is a good demonstration for the reported high importance of the piscivorous fishes as a top predatory functioning level on the foodweb (Fig. 4, C).

Conclusion

The fish community of the Danube ripal zone is characterized with relatively simplier trophic structure than those were in the adjacent wetlands. The results obtained suggest that the difference was found, is mainly an effect of the species composition and the dominant structure of the fish communities as well as of the specific habitat features. Considering the specific life cycles, habitat preferences of fishes and the features of their feeding patterns, they can be summarized as the connectivity between the main river course and the adjacent wetlands, that plays an important role for the shaping the trophic structure of the fish communities maintaining their integrity.

Acknowledgments

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http://www.fishbase.org/search.php

Life table model of the Pontic shad (*Alosa immaculata* Bennet, 1835) from the Danube River and the Black Sea

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Keywords: Danube, Alosa immaculata, life table model, anadromous fish

Introduction

Pontic shad (*Alosa immaculata*) in the Lower Danube Region (LDR) still represents an economically valuable resource, despite habitat fragmentation, pollution and exploitation (Navodaru 1998*a*). Except a few scientific investigations within LDR countries, detailed analysis of this species and stock monitoring are still not established to a proper extent (Lenhardt et al 2012). Population abundance and consequently annual landings in Romania exhibit large fluctuations (5-10 times maginitude range), over periods characterized by a combination of short cycles of 3-4 years (Kolarov 1985) and long cycles of 10-11 and 30-40 years (Navodaru & Waldman 2003).

We developed a simple life stage model of the Pontic shad population in the Danube and Black Sea, in order to better understand the state of its population in this region. Such a deterministic model can simplify the population dynamics and makes a number of assumptions which are rarely met in nature. Nevertheless, it is also helpful as a tool for a preliminary population assessment, based on the limited data available. The model evaluated the population sensitivity to changes in different life history parameters as well as the impact of exploitation on shifts in sensitivity patterns. Obtained results are considered to be helpful for the evaluation of the Pontic shad fishery management activities within the region.

Methods

A life table model was developed as an Excel spreadsheet using a standard approach (Beamesderfer et al. 2007). The life history parameters were gathered from the literature. The population dynamics in the model were based on the species longevity, age at maturity, natural and fishing mortality, age-specific fecundity and spawning frequency. The model was adjusted to result in a fixed population growth rate (λ=1) and the sensitivity analysis was conducted by measuring the change in the population growth rate (λ), when each of the life history parameters was increased by a fixed proportion (i.e., +10%). The population dynamics was projected for a 50 years in order to allow for the population growth rate to stabilize.

Longevity of the Pontic shad is reported not to exceed 7 years and the age at first spawning of females is 2-5 years, with a dominance of the age classes 3 and 4 (Navodaru 1996, 1998*b*; Navodaru & Waldman 2003). Age-specific fecundity was based on the data from Navodaru (1992). Since the reported data were related only to the fecundity of the age 2-5 fish, fecundity of the age 6 and 7 were calculated by projecting an exponential function based on the available data.

The question whether shads are iteroparous or semelparous species is still unresolved (McDowall 2003). It is believed that few shad specimens experience a second spawning event (Navodaru 1998b), but that the repeated spawning occurrence generally increases with latitude (Leggett & Carscadden 1978). Reported spawning interval of the Pontic shad is between 1 and 2 years (Navodaru 1997). With a low proportion of repeated reproductions observed (Navodaru 1998b), it is likely that the 2 years interval is more frequent than the annual spawning. As a result, probabilities of 0.25 and 0.75 were assigned for the spawning intervals of one and two years, respectively.

Available sources and derived indices for natural and fishing mortality of the Pontic shad in the Danube and the Black Sea are highly variable. As a result, five different sets of age specific mortality estimations have been employed and the sensitivity analysis was conducted for each of them. The first data set originates from Prodanov et al. (1997), representing data of stock assessments in the Black Sea. Age-specific mortality, estimated from the change in abundances of each cohort, represented the result of both natural and fishing mortality. As a result, the model setup represents an exploited population. The second estimation of the annual mortality was based on Navodaru et al. (1992). With Z=1.63 and F= 1.32, representing a heavily exploited population. The third mortality estimation used the same data (Navodaru et al. 1992), but only the natural mortality (m = 0.3) was applied in the model setup to derive an undisturbed population development. The third and fourth model setups were based on the equations of Rikhter and Efanov (FISAT II 2000) and Hoenig (1983), which use the data on the age at maturity and longevity to estimate the natural mortality of a species respectively. The survival of the initial life stage (egg to age 1) was adjusted to let the population reach predefined population growth rate (i.e., λ=1). Life history parameters that were applied in the model are presented in Table 1.

Table 1. Population parameter estimates used in the Pontic shad life table model

Variable		Value		Source	
Longevity		7		Navodaru 1996, 1998b; Navodaru and Waldman 2003	
Age at first spawning		3-4 (total range 2-5)		Navodaru 1998b; Navodaru and Waldman 2003	
Spawning interval (years)		1-2		Navodaru 1997	
Fecundity (number of eggs)		43700 (age 2)–82000 (age 7)		Navodaru 1992	
Age-specific survival:					
Age	Model 1 (Prodanov et al. 1997)[1]	Model 2 (Navodaru et al. 1992)[1]	Model 3 (Navodaru et al. 1992)[2]	Model 4 (Rikhter and Efanov's equation)[2]	Model 5 (Hoenig's equation)[2]
1	0.70	0.19	0.70	0.63	0.55
2	0.69	0.19	0.70	0.63	0.55
3	0.48	0.19	0.70	0.63	0.55
4	0.28	0.19	0.70	0.63	0.55
5	0.24	0.19	0.70	0.63	0.55
6	0.03	0.19	0.70	0.63	0.55

[1] Survival comprises both the natural and fishing mortality
[2] Survival comprises no fishing mortality

Results and discussion

The evaluation of the population sensitivity to changes in different life history parameters, provided by the model, is presented in Fig.1..

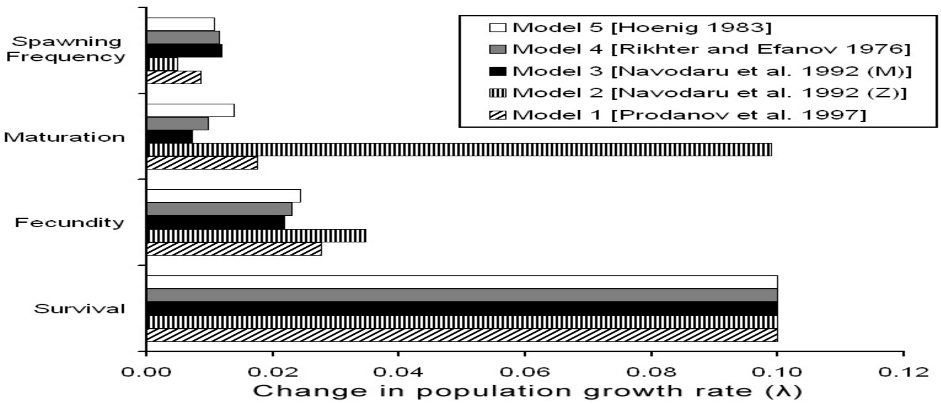

Figure 1. The change in the population growth rate (λ) when each of the life history parameters (survival, fecundity, maturation and spawning frequency) were increased by a fixed proportion of 10%.

Results indicate that the survival rate had the largest influence on the population sensitivity and this result was consistent across all model setups. Pontic shad population had a moderate sensitivity to changes in fecundity and the comparatively weakest sensitivity to the spawning frequency and age at first spawning. As can be seen in Figure 1, influence of the age at first spawning in the Model 2 (Navodaru et al. 1992) was substantially higher than in the other four model setups. As it was previously discussed, this population represented a heavily exploited population. In such a population, few fish survive long enough to spawn and contribute to the population growth, so the age of their maturation becomes a very important parameter. Results indicate that in highly exploited populations maturation represents one of the most important life history parameters. The selective pressure of fishery towards the earlier maturation is a widely observed phenomenon (Kuparinen et al. 2008), which requires attention of the scientific community due to the long-term negative effects it might produce on economically important fish species.

The age at first spawning and fecundity were more influential in the model setups representing exploited populations (i.e., those based on Prodanov et al. 1997 and Navodaru et al. 1992). Spawning frequency was more influential in populations without any fishery pressure (Fig. 1, models 3-5). This is probably a result of low number of fish surviving to their second spawning in exploited populations, which renders this parameter less important in the presence of fishery.

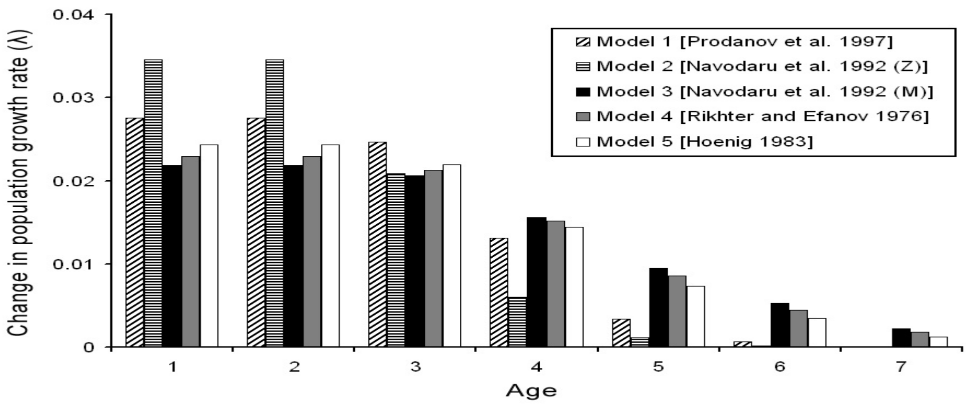

Figure 2. Change in population growth rate (λ) with increasing survival rate of each age class by 10%.

The change in the population growth rate (λ) based on the increase of survival rate of each age class is presented in Fig. 2. As can be observed in the Figure, general pattern was consistent among all models. It is evident that the influence of age classes before the first spawning (≤3) on population growth rate and population sensitivity is greater than the influence of subsequent age classes. This is a result of two distinct processes. Firstly, high mortality rates result in a low abundance of older age classes, which decreases their influence on population dynamics. Secondly, mature age classes have already reproduced and contributed to the population growth, which makes their continued survival less influential on the population dynamics.

Conclusions

To conclude, while the survival rate represents the most important life history parameter for population dynamics of the Pontic shad, age at maturity becomes another critical parameter in heavily exploited populations. Therefore, future research of the Pontic shad in the Danube and the Black Sea should be primarily focused on the research of age-specific survival rates and the age of maturation. Moreover, it would be important to conduct research that would reveal whether low percent of fish returning to spawn for the second time is a result of their physiology (i.e., similarly to some salmonid species), or an artifact of a high fishery pressure, which reduces the probability of their survival to the second spawning. Due to the present uncertainty and lack of knowledge regarding various life history parameters, caution is needed when interpreting results of the present study. With new knowledge gained through the future research activities, model precision and its reliability will be improved.

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Heavy metal accumulation in tissues of pikeperch (*Sander lucioperca*), European catfish (*Silurus glanis*) and common carp (*Cyprinus carpio*) from the Danube River

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Keywords: Danube, heavy metal, bioaccumulation, biomagnification

Introduction

The Danube River is the second largest river in Europe, and it is subjected to large amounts of wastewater input (Teodorović et al. 2000; Pawellek et al. 2002). The Serbian section of the Danube is approx. 20% of its total length. Its basin is the most developed and most populated part of Serbia, and includes the sub-basins of the rivers: Tisza, Sava, and Velika Morava (Milenković et al. 2005). The section of the river between the cities of Novi Sad and Belgrade receives large amounts of untreated or poorly treated communal and industrial wastewaters. Pollution brought by the rivers Sava and Tisza as well as by untreated municipal wastewaters is probably the reason for elevated concentrations of As, Cu and Hg in the Danube sediments (Babić-Mladenović et al. 2003, Crnković et al. 2008, Triebskorn et al. 2008). Heavy metals from natural and anthropogenic sources are continually released into aquatic ecosystems posing a serious threat due to their toxicity, long persistence, bioaccumulation, and biomagnification in the food chain (Papagiannis et al. 2004). Heavy metals are classified as toxic and essential, yet essential heavy metals can also become toxic when present in excess (Nabavi et al. 2012). The distribution of metals in fish tissues depends on the fish species themselves (Ney & Van Hasel 1983, Kidwell et al. 1995, Voigt 2004, Kenšová et al. 2010). Two piscivorous species (pikeperch and European catfish) and one omnivorous species (common carp) were used in this study. Various tissues accumulate heavy metals to different levels, depending on their biochemical characteristics (Farkas et al. 2000). Since muscles – major tissue of interest for routine environmental monitoring – are not always the best indicators of heavy metal contamination in fishes, the analysis of other tissues is recommended as well (Has-Schön et al. 2006). Testing of heavy metal accumulation in tissues of fishes from different trophic levels, including economically important species used for human consumption has been realized in scope of the project "Fish as water quality indicators in open waters of Serbia".

Materials and Methods

Ten pikeperches (length 38-59 cm; weight 437-2000 g), 11 catfishes (length 55-100 cm; weight 1190-6620 g), and 14 carps (length 29-82 cm; weight 405-8200 g) were sampled in the Danube River at the river kilometer 1170 kilometer where it confluences with the Sava River. During the sampling portable lift nets were used. Specimens were dissected with a plastic laboratory set and samples of liver and muscle were quickly removed, washed with distilled water, and stored at -18℃ prior to analysis.

All samples were dried by Freeze Dryers Rotational-Vacuum-Concentrator, GAMMA 1-16 LSC, Germany, and sample portions between 0.2 and 0.5 g (dry weight) were subsequently processed in a microwave digester (speedwave™ MWS-3+; Berghof Products + Instruments GmbH, Eningem, Germany), using 6 ml of 65% HNO_3 (Merck suprapure) and 4 ml of 30% H_2O_2 (Merck suprapure) at a food temperature program (100–170℃). After cooli ng the samples to room temperature the digested samples were diluted with distilled water to a total volume of 25 ml. The analysis was performed by inductively-coupled plasma optical spectrometry (ICP-OES, Spectro Genesis EOP II, Spectro Analytical Instruments DmbH, Kleve,Germany), comprising the assessment of concentrations of 8 elements (As, Cd, Cu, Fe, Hg, Mn, Se and Zn), expressed as $\mu g\ g^{-1}$ dry weight (dw).

Multivariate analysis of variance (one-way MANOVA) was applied to test the differences between concentrations of elements in the three sampled fish species and two tissues. The Mann-Whitney U test was applied to test the differences in concentrations of each element between three fish species, in each tissue separately.

Results

Mean values and standard deviations of the tested elements originating from the liver are presented in Table 1.

On one hand the results of the Mann-Whitney U test show that Cd, Cu, and Zn concentrations in carp liver were significantly higher ($p<0.05$) than in pikeperch or catfish liver (Figure 1). On the other hand, both predators (pikeperch and catfish) had significantly higher ($p<0.05$) concentrations of Hg and Se in liver than carp.Mean values and standard deviations of tested elements originating from the muscle tissue are presented in Table 2. The concentration of As and Zn in carp muscle was significantly higher ($p<0.05$) than the one in the pikeperch or catfish muscle, while the concentration of Hg was significantly higher ($p<0.05$) in both predators than in carp (Figure 1).

Table 1. Mean value and standard deviation of tested elements in liver samples (dw).

	As	Cd	Cu	Fe	Hg	Mn	Se	Zn
Pikeperch	0.497 ± 0.113	0.019 ± 0.028	6.183 ± 2.802	241.070 ± 157.460	1.656 ± 0.417	3.507 ± 1.560	0.835 ± 0.555	58.370 ± 10.382
Catfish	0.236 ± 0.139	0.023 ± 0.048	8.374 ± 3.881	396.158 ± 328.201	1.525 ± 0.540	1.651 ± 0.721	0.681 ± 0.359	41.518 ± 11.941
Carp	0.486 ± 0.245	0.282 ± 0.404	33.494 ± 13.498	141.444 ± 65.231	0.626 ± 0.181	2.206 ± 0.796	0.244 ± 0.503	325.374 ± 107.210

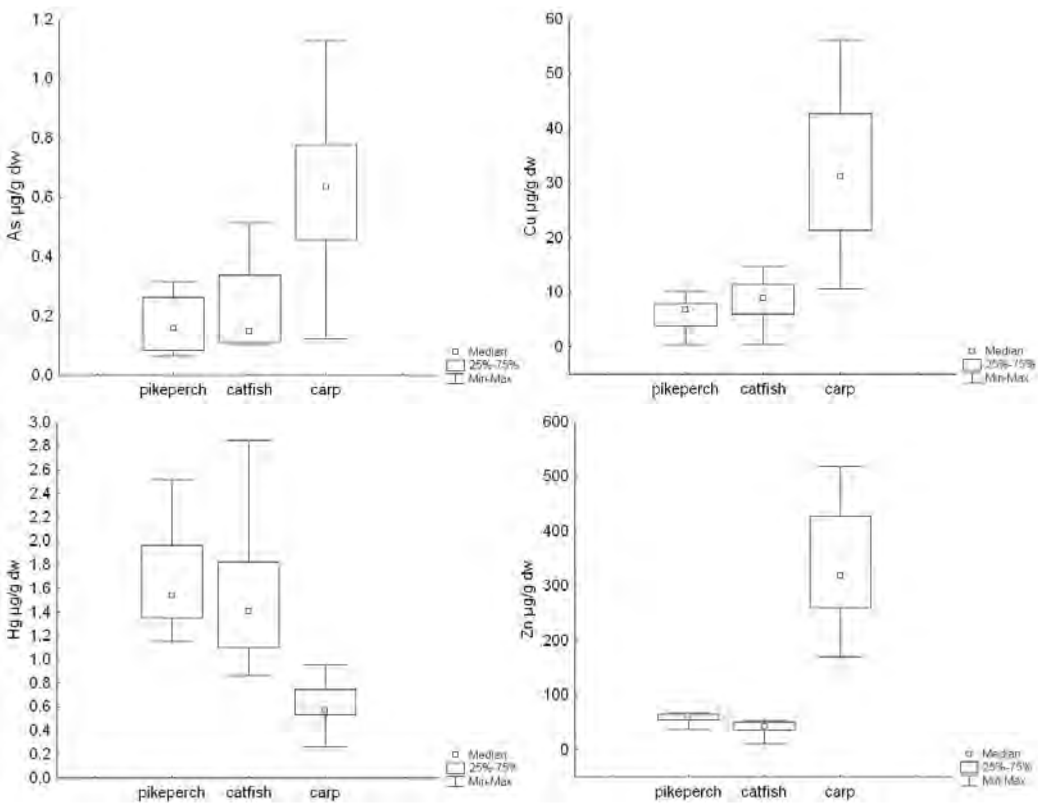

Figure 1. Concentrations of As in muscle, and Cu, Hg, and Zn in liver of three analyzed fish species from the Danube River.

Table 2. Mean value and standard deviation of tested elements in muscle samples (dw).

	As	Cd	Cu	Fe	Hg	Mn	Se	Zn
Pikeperch	0.174 ± 0.098	0.006 ± 0.001	0.749 ± 0.688	17.968 ± 30.471	1.320 ± 0.469	0.887 ± 1.808	0.069 ± 0.018	15.141 ± 11.535
Catfish	0.222 ± 0.137	0.006 ± 0.001	1.442 ± 1.793	27.058 ± 36.527	1.627 ± 0.510	0.443 ± 0.371	0.194 ± 0.345	20.806 ± 10.074
Carp	0.659 ± 0.279	0.005 ± 0.001	1.304 ± 0.979	19.622 ± 11.378	0.895 ± 0.217	0.130 ± 0.095	0.099 ± 0.046	59.012 ± 23.937

The element accumulation in liver tissue showed the following trend: Fe > Zn > Cu > Mn > Hg > Se > As > Cd in pikeperch and catfish, and Zn > Fe > Cu > Mn > Hg > As > Cd > Se in carp. The element accumulation in muscle tissue showed the following trend: Fe > Zn > Hg > Mn > Cu > As > Se > Cd in pikeperch, Fe > Zn > Hg > Cu > Mn > As > Se > Cd in catfish, and Zn > Fe > Cu > Hg > As> Mn > Se > Cd in carp.

Statistical tests showed that there is a significant difference in concentration of all 8 elements in the tissues depending on fish species and tissue types ($p<0.0001$). A one-way MANOVA revealed significant differences between fish species with regard to As, Cu, Hg, Mn, and Zn ($p<0.0001$), and Cd, Fe, and Se ($p<0.040$) in analyzed tissues. The significant difference between concentration of Cu, Fe, Mn, Se, Zn ($p<0.0001$), and Cd ($p=0.030$) was found between fish tissues.

Arsenic levels did not exceed the maximum acceptable concentrations (MAC), prescribed by the National Regulation of the Republic of Serbia (2 μg g^{-1} wet weigh). Mercury concentration only exceeded the MAC, prescribed by the European Commission Regulation (0.5 – 1 μg g^{-1} wet weight) in one carp muscle-, one pikeperch liver- and in 45% catfish liver- and 36% catfish muscle samples. The level of zinc exceeded the MAC of 30 μg g^{-1} wet weight prescribed by FAO legislation in 55% pikeperch muscle-, 91% catfish liver-, 82% catfish muscle-, and in 100% carp liver and muscle samples.

Discussion

The carp from the Danube had elevated concentrations of As, Hg, and Zn in comparison to samples from other European waterbodies (Has-Schön et al. 2006, 2007, Lavado et al. 2006, Kenšová et al. 2010, Mazej et al. 2010, Al Sayegh Petkovšek et al. 2011). Mercury concentration was only lower than the one measured in carp samples from the polluted Nitra River (Slovakia) (Andreji et al. 2006). Cd concentration was either similar (Mazej et al. 2010) or lower than in other studies (Doganoc 1995, Andreji et al. 2006, Has-Schön et al. 2006, 2007, Lavado et al. 2006, Kenšová et al. 2010).

The pikeperch had higher concentration of Hg and Zn than pikeperch in other studies from several waterbodies (Farkas et al. 2000, Kenšová et al. 2010, Mazej et al. 2010, Nabavi et al. 2012). The concentration of Cd in pikeprech was lower, the same as in case of the carp, in comparison to other waterbodies (Farkas et al. 2000, Kenšová et al. 2010, Nabavi et al. 2012).

The catfish had higher concentrations of Hg and Zn, and similar concentration of Cd in comparison to the catfish samples from Lake Velenje (Slovenia) (Mazej et al. 2010).

Elevated As and Hg concentrations in all three analyzed fish species from the Danube were probably the consequence of high levels of heavy metals present in the groundwater of the area where the fishes were sampled (Babić-Mladenović et al. 2003, Crnković et al. 2008, Kristoforović-Ilić et al. 2009, Rowland et al. 2011). Observed biomagnification of Hg in the sampled fish – from omnivorous to piscivorous – was expected, since it is well-known that Hg concentration increases through the food chain (Kidwell et al. 1995, Southward et al. 2003, Voigt 2004, Peterson et al. 2009). A number of studies revealed a strong antagonistic effect of Se on Hg assimilation in fishes (Chen et al. 2001, Peterson et al. 2009). The negative correlation between Se and Hg was also found in tissues of three species analyzed in this study.

Elevated Zn concentrations detected in this study could be the result of pollution of the Danube and the Sava River (Crnković et al. 2008), and tendency of Zn concentration to be inversely correlated with the trophic status of the fish (Papagiannis et al. 2004). Furthermore, Zn concentration in the digestive tract of carp is always >10 times higher than in most animal tissues due to its physiology (Jeng & Sun 1981, Liao et al. 2006).

The obtained results indicate that the section of the Danube near the confluence with the Sava River is polluted with As, Hg and Zn, but probably not significantly polluted with Cd. Concentrations of Hg in catfish and of Zn in all three species were higher than the MAC, accordingly posing a risk for the human consumption of these fish species.

Acknowledgements

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Topic 2
Longitudinal, vertical and lateral connectivity in riverine landscapes

(in main channel, side arms and active river-floodplain systems, effects of water regime)

Potamoplankton primary productivity in side-arms, floodplains and major tributaries of the Danube

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Keywords: Danube, floodplain, potamoplankton, productivity, species composition, chlorophyll-a

Introduction

Ecosystem health is one of the key issues in large rivers. Major improvement in the effluents from the catchment has shifted pollution from primarily organic to mainly inorganic. As a consequence, nutrient concentrations and river eutrophication became increasingly important. Changes in the climate will enhance this process in the near future (Dokulil & Teubner 2011). Photoautotrophic production is the essential parameter for the development of algal biomass ultimately defining the trophic status of the river (Dokulil 2012a,b). Through photosynthetic processes primary producers are important elements in the carbon cycle and in the oxygen budget. Since the autotrophic plankton is an essential quality element, the metrics required by the European Water Framework Directive (EC-WFD) will primarily evaluate the trophic status of rivers.

While an earlier study concentrated on the primary production of the main river (Dokulil 2012a), the focus here is to summarize and evaluate environmental variables, algal biomass and productivity of tributaries, side arms and floodplains.

Material and Methods

Qualitative and quantitative investigations were carried out as a part of JDS2 in larger tributaries and side arms with the aim to detect influences from the tributaries on the main river. Samples were taken in the mouth of the tributary or side arm from the surface with a black bucket (8 L) and used for all further analysis. A qualitative sample was taken with a plankton net (10 µm mesh size). Water Temperature (WT), Secchi-depth and incident PAR-radiation was measured at each sampling station.

Transparency was estimated from Secchi-depth (SD) using a white disk of 25 cm diameter. The disk was fixed to a stainless steel expandable pole to allow precise depth readings even when water current is high and is reported as the average of three measurements. Where does this belong? Photosynthetic available radiation (PAR, 400–700 nm) was measured above the water with a 2π flat Li-Cor sensor in units of µmol $m^{-2}s^{-1}$. Sub-surface PAR ($E_0´$) was calculated from the measurements in air assuming 10% reflection. Under-water PAR (E_z) was derived from an independent calibration of light measurements versus z_{SD} (on average 25% $E_0´$ at Secchi-depth). This information was used to calculate the vertical attenuation coefficient (K).

Total suspended solids (TSS) were immediately separated by filtering an aliquot, 0.2 - 1 L onto pre-combusted and pre-weighed glass fibre filters (GF/F) for gravimetric analysis. After drying the filters at 105℃ for 4 hours, TSS was calculated as mg $L^{-1}$from the difference in dry weight between the filter plus residue and the blank filter.

Chlorophyll-a (chl-a) concentration was analysed using the hot extraction technique (ISO 10260). Quantitative samples (100 ml) for phytoplankton counting and sizing were fixed with 0.4 ml Utermöhl's acetic acid Lugol solution, preserved with a few drops of formalin in brown screw cap glass bottles and stored in a cool dry place (Padisák et al. 1999). Biomass (B) was calculated from cell counts and cell volume. Samples were processed in the laboratory applying the sedimentation technique (Utermöhl 1958).

Primary production (PP) was estimated from active fluorescence measurements using surface samples and a commercial available Fast Repetition Rate (FRR)-Fluorometer (Fasttracka, Chelsea Instruments Co Ltd.). Conversion to carbon uptake rates followed the procedures outline in Kaiblinger and Dokulil (2006) and Dokulil & Kaiblinger (2008).

Photosynthetic rates, estimated by the oxygen light-dark bottle technique were converted to carbon uptake assuming a photosynthetic quotient of 3.

Results

Maximum Secchi disk visibility occurred in the River Vah (1.25 m) while Secchi depth was as low as 0.1 m in the River Morava, associated with highest TSS of 114.9 mg dry wt. L^{-1} (Fig. 1A). Both variables were non-linearly related [TSS = 8.16 + 124.35 exp (-4.38 SD), $r^2 = 0.67$, $p<0.0001$, N = 20].

Chlorophyll-a input from the tributaries (mean 14.5 µg L^{-1}) varied greatly from 0.6 µg L^{-1} in the River Jantra to 89.3 µg L^{-1} in Arges (Fig. 1B, black bars). Similarly, phytoplankton fresh-weight biomass varied from 0.11 mg L^{-1} in the Inn to 15.5 mg L^{-1} in the Arges. Both variables were highly correlated ($r^2 = 0.94$, $p<0.001$, N = 20), indicating that chl-a is a good estimator of phytoplankton biomass. Both variables however, were unrelated to either Secchi depth or TSS but are associated with soluble reactive phosphorus (SRP) concentrations in the tributaries ($r^2 = 0.48$, $p<0.001$, $r^2 = 0.37$, $p = 0.005$ respectively).

Hourly column production varied from a minimal rate of 0.29 mg C m^{-2} h^{-1} in the Sio canal to 43.2 mg C m^{-2} h^{-1} in the tributary Ipoly at river km 1706 (Fig. 1B, white columns). Side arms of the Danube such as Moson Danube or Szentendre arm were variable in their chl-a concentration and production rates. In both cases PP did not correspond to the low chl-a values (Fig. 1B).

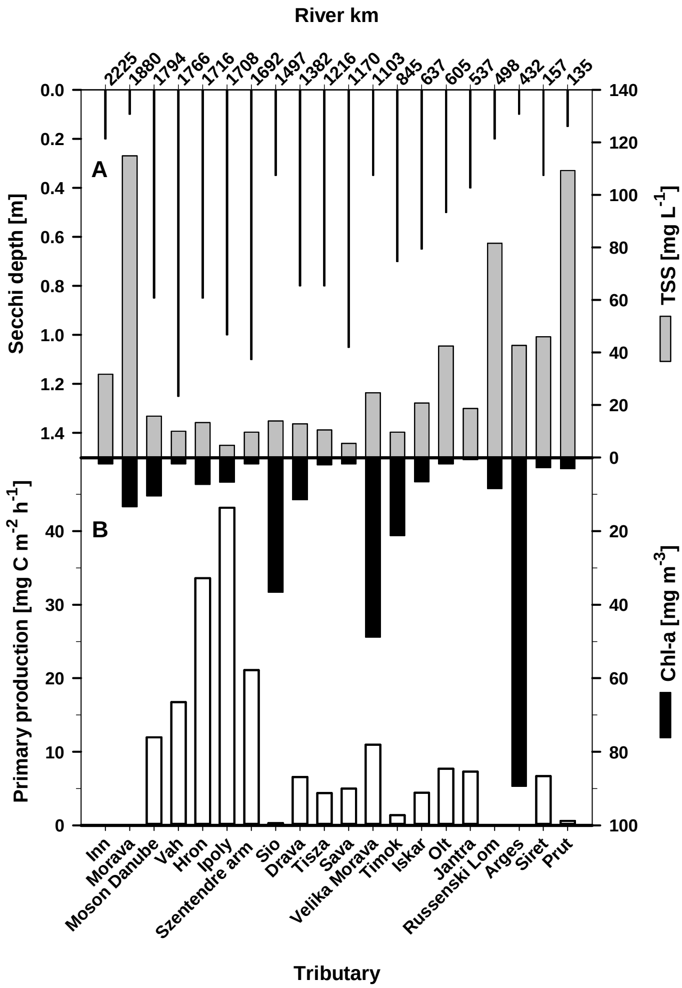

Figure 1. Secchi-depth and total suspended solids (A), chl-a and hourly column production (B) for the tributaries and side-arms indicated on the lower x-axis. River km for these sites are given at the top x-axis. All measurements were performed during the JDS2 in August and September 2007.

PP was significantly associated with subsurface PAR ($r^2 = 0.81$, $p<0.0001$) and water temperature ($r^2 = 0.44$, $p = 0.005$). The third likely component was discharge (Dokulil 1994, 2006) for which data were not available. Multiple linear regression, using E_0', WT, TSS, SRP, Chl-a and B as independent variables, indicated that variability in PP can be explained from light, temperature and either chl-a or biomass (0.94, p<0.001).

Phytoplankton biomass was the highest in Arges and Velika Morava (Fig. 2). Centrales contributed between 43 and 95% to diatoms, which together with cryptophytes, dominated most of the tributaries. Significant contributions of Cyanobacteria appeared in the Iskar (5%), increased further in the Olt, Jantra and Russenski Lom (Fig. 2) and became completely dominating in the highly polluted Arges (95%). Euglenophytes were the main component (>50%) in the Sio, Jantra and Russenski Lom. All other algal groups were far less important. In the River Olt, Dinophytes gained some importance (32%) at low total biomass of 0.38 mg L^{-1} (Fig. 2).

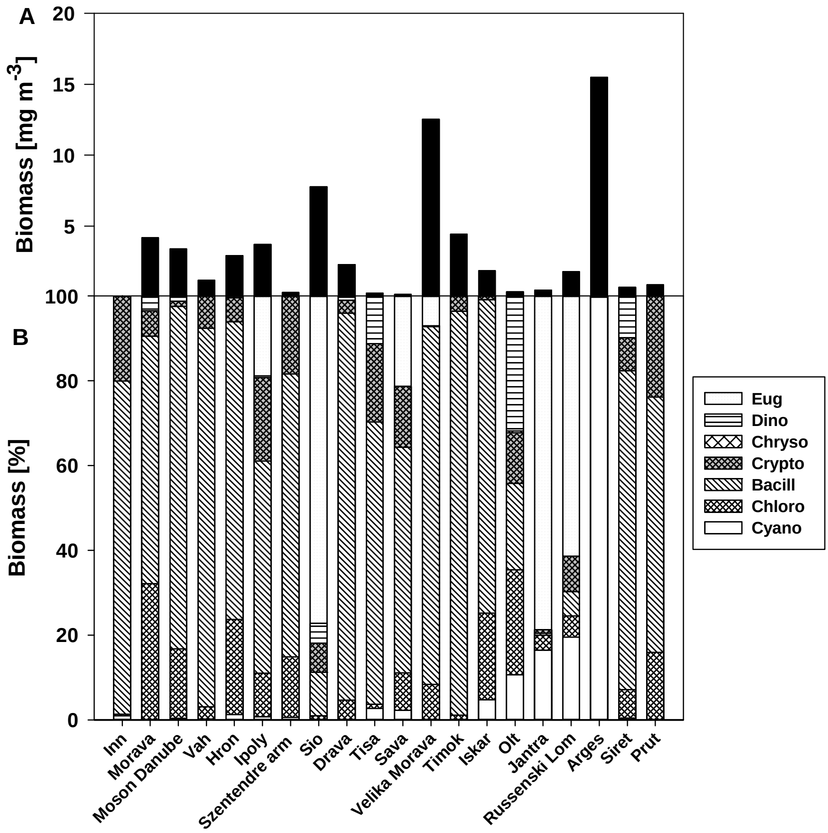

Figure 2. Phytoplankton fresh weight biomass (A) and percentage contribution of the algal groups indicated (B) for the tributaries and side arms indicated on the x-axis. Observations during the JDS2 in August and September 2007.

Discussion

Biomass concentrations, chlorophyll-a and species composition in the tributaries during JDS2 differed significantly from the observations during JDS1 in 2001. During JDS1 the highest biomass and chl-a concentrations occurred in the Sio, minimum values were observed in the River Siret (Németh et al. 2002). Biomass and species composition was very similar to the main river in most cases. Euglenophytes however were unimportant in all tributaries and side arms. Cyanobacteria gained significance in the Arges reaching 40% contribution to total biomass, which is much less then observed here. The high concentrations in many tributaries were assigned to their eutrophic status underlined by high nutrient concentrations and oxygen-hypersaturation. Several other streams such as e.g. the Siret and the Prut, although polluted with nutrients or biodegradable organic matter, had unexpectedly low phytoplankton biomass probably due to retarding or toxic effects. In contrast, much higher amounts of phytoplankton biomass could be observed in the Drava even though it contained comparably only low concentrations of nutrients (Németh et al. 2002).

Effects from the tributaries, even when dominated by euglenophytes or cyanobacteria on the main river, remained negligible during JDS2. Column production rates in the tributaries and side-arms were similar to those in the main river canal except from the reach between river km 1424 (Batina) and km 1200 upstream of the Tisza confluent, where production rapidly increased to 253 mg C m^{-2} h^{-1} near Novi Sad, declining thereafter (Dokulil & Kaiblinger 2008).

Interestingly euglenophytes dominated one of the investigated back-waters of the Gemenc floodplain, a part of the Danube-Drava National Park in Hungary. Chlorophyta and bacillariophyta (diatoms) were dominant in most of the other ox-bow lakes (Schöll et al. 2006).

Floodplain chlorophyll-a ranged from 1.1 mg m^{-3} to 8.6 mg m^{-3}chl-a in a number of oxbow lakes in the 'Lobau' region near Vienna. Production associated with 1.1 to 3.3 mg m^{-3}chl-a.was 4.1-9.5 mg C m^{-2} h^{-1} (Dokulil unpubl.). Much higher values of chl-a were observed in the backwaters further downstream (Stopfenreuther Au, Rosskopfarm), ranging from 18.1 to 99.4 mg m^{-3}chl-a. These concentrations were strongly associated with TP ($r = 0.69$), organic seston ($r = 0.53$) and algal biomass ($r = 0.70$). Hydrological connectivity was the main influential factor affecting the pelagic zone. The phytoplankton composition depended on water level. Diatoms dominated high water situations were similar to the main river because of the strong connectivity. Middle and low flow situations were characterised by either dinoflagellates or chrysophytes (Dokulil 2003).

Connectivity is proofed to be an essential parameter for primary production in a side-arm south of Vienna (Regelsbrunn). Phytoplankton photosynthesis was generally high at high and mean flow, contributing up to 90% of the system productivity (Preiner et al. 2008), which was stimulated by nutrient influx from the river and controlled by retention time (Hein et al. 1999). The daily autochthonous production was equivalent with about 20% of the allochthonous input (Preiner et al. 2008).

Photosynthetic and respiration rates in the Kopacko Lake, converted from oxygen light-dark bottle measurements, ranged from 70 mg C m^{-3} h^{-1} to 633 mg C m^{-3} h^{-1} between April and August 1984 (Gucuncki & Horvatic 1988). During the same period respiration varied from 27 to 400 mg C m^{-3} h^{-1}. The respective values ranged from 100 to 700 mg C m^{-3} h^{-1} gross production and 33-167 mg C m^{-3} h^{-1} respiration in the Mulova Canal (Gucuncki & Horvatic 1988). Similar results were reported from the Sakadascher Lake by Gucunski & Horvatiċ (1990). Gross primary production in a reservoir of the Sava near Belgrade ranged from 0.45 to 2.04 g C m^{-2} d^{-1} (average 1.4 g C m^{-2} d^{-1}). Due to the high and variable respiration of 3 gO_2 m^{-2} d^{-1} (=1 g C m^{-2} d^{-1}) daily net production was often negative despite of the high chl-a concentrations, varying from 33 to 229 mg chl-a m^{-3} (Brkovich-Popovich et al. 1997). Phytoplankton composition was highly variable in the Sava but was dominated by diatoms during the whole vegetation period. Green algae were subdominant during the summer (Čado et al.). Earlier data on the Danube, tributaries and adjacent lakes have been summarised by Sirenko (1990).

Conclusions

Autotrophic primary production, chlorophyll-a, biomass and species composition are highly variable in the tributaries, side-arms, floodplains and back-waters. This is not surprising considering the wide variety of the size, structure and flow regime of these ecosystems, their connectivity, water quality and pollution level.

Phytoplankton species composition can be very variable but it is most often characterised by the domination of centric diatoms. During summer, chlorophytes can co-dominate. Cyanobacteria or euglenophytes can become dominant when rivers are highly polluted.

Potamoplankton and primary productivity in the tributaries largely depends on the size of the river, its catchment and discharge as well as nutrient concentration and amount of suspended solids. Sub-surface light intensity, water temperature and either chl-a or phytoplankton fresh weight biomass (0.94, $p<0.001$) are therefore the best to explain production in the euphotic zone. Suspended solids, chlorophyll-a or SRP alone however, can not fully explain the integral production. Photosynthetic rates the tributaries are usually of the same order as in the main river, except from the middle stretch of the Danube where primary production is enhanced due to better light conditions and reduced flow.

Respiration in the water column often compensates daily (gross) production, particularly when it is calculated for a 24 hour period and at the whole water column. As a result, phytoplankton production is often negative, except perhaps in reservoirs or impoundments. River stretches, tributaries and parts of floodplains therefore might be sources rather than sinks for CO_2, at least during certain periods of the year or under specific flood conditions.

The degree of connectivity is an essential parameter influencing the amount and seasonality of plankton productivity in side-arms and floodplains. It also affects the species distribution in these habitats.

Comparing recent investigations, several of the main tributaries seem to have significantly improved in water quality.

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Morphological, topographical and physicochemical characteristics of Bulgarian Danube River wetlands

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Introduction

Some of the most important functions and services of riverine wetlands are related to their chemistry characteristics and especially to their ability to metabolize and remove nutrients coming either from the river or from surrounding territories surrounding it (Hatvani et al. 2011). Unfortunately till now these and some other mostly routinely studied environmental indicators of Danube wetlands on Bulgarian territory were rarely and not systematically investigated. The only exception was the Srebarna Lake for which a multitude of characteristics i.e. relatively long data series of soluble nitrogen, phosphorus compounds and other geological, chemical and soil characteristics were collected and published (Hiebaum et al. 2000, Kalchev et al. 2007). There are also data some of which taken sporadically during few years for wetlands on Belene Island (Management plan 2006, Ninov 2008, Kalchev et al. 2010) and some others of Kalimok-Brushlen protected area (Draft management plan 2006). Recent investigation presents a first attempt to provide coordinated, simultaneous snapshot of environmental characteristics regarding important wetland water bodies along the Bulgarian section of the Danube River. The complied dataset is a good basis for comparison, ordination and classification of wetland sites. This will help to guide wetland management into a new direction based on common rules and principles inline with world experience and practice, in order to fulfill their functions and utilize their services on local and global scale more efficiently.

Materials and methods

Nine wetland water bodies on the Bulgarian Danube section were investigated from west to the east on the Bulgarian Danube section (Fig.1). The Pischin, Murtvo blato, Dyulova bara (all three located on Belene Island), Maluk Preslavets and Srebarna are of lake type while the Brushlen and Kalimok sites are artificial canals from which only the first serves as the drainage of the surrounding area.

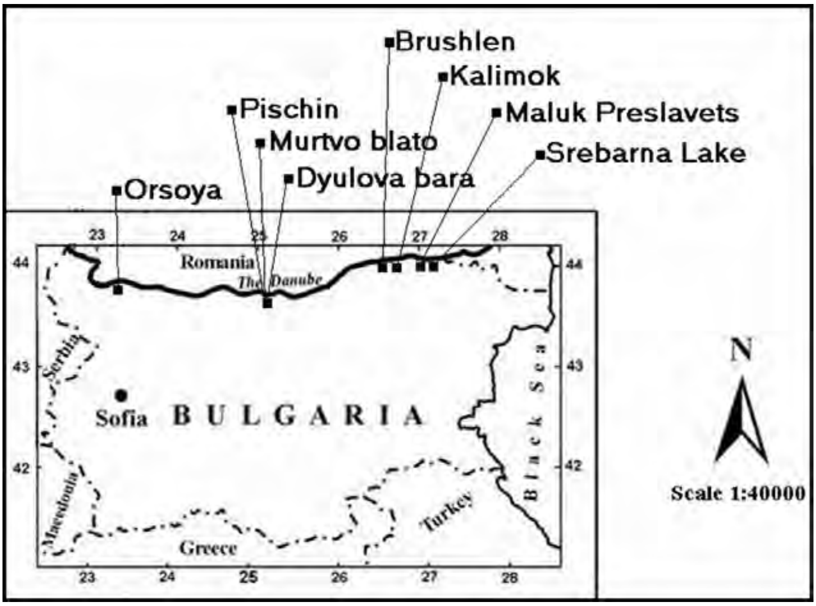

Figure 1. Schematic land map of Bulgaria with distribution of wetland sites along the Danube River.

The Orsoya wetland was represented by one marsh and one drainage canal site. In the particular year 2011, around all the wetlands of (except for Belene Island which showed weak flow-through during the spring visit) belonged to a stagnant water body type. Several geological, morphological, soil and physicochemical features were applied to describe and analyze the sites. The exact same chemical physicochemical features were applied to describe and analyze the sites. The exact same chemical measurements were conducted on samples from the Danube River branch in the vicinity of the town Belene in order to compare the river and wetland sites. The Geography of Bulgaria (1997) provided the geological and soil data of the wetland territories. Most of the morphological and physicochemical data were recorded during the three field visits representing the three seasons – spring (April-June), summer (August) and autumn (November) of 2011. During this year the Danube's water level was extremely low which caused strong shrinkage of wetland areas. Three of them dried-out completely (Pischin, Murtvo blato, Dyulova bara) in autumn. Thus, except for the lakes Srebarna and Maluk Preslavets - where the water shortage did not cause extreme events - the other studied sites in the Brushlen and Orsoya floodplains suffered from lack of floods and very strong water deficit and lack of floods in the Brushlen and Orsoya floodplains. Therefore we had to investigate small aquatic areas either marsh or canal type (e.g. only single puddles remained from Murtvo blato in the summer).

We measured the water column transparency using Secchi disk and turbidity using an on field photometer (Nova 60, Merck) with absorbance at 550nm. In certain cases because of high transparency the Secchi disk measurement was impossible to accomplish and all data were converted to absorbance with the equation: lnTurb=-1.6614lnSD-1.2671 with R^2=0.67 and n=22. The pH, conductivity and oxygen concentration were measured either by WTW - Multi 1970i or by GMH 3510, or Greisinger electronic (pH) and Winkler titration (oxygen). Surface samples were taken with a bucket, however, when the depth exceeded 0.5-0.6 m a Friedinger plastic water sampler was used. We determined NO3-N, NO2 –N, NH4-N and PO4-P colourimetrically (Nova photometer 60 and kits of Merck). The statistical treatment included principal component analysis (PCA), redundancy analysis (RDA) and detrended correspondence analysis (DCA) by Canoco 4.55 after ter Braak and Šmilauer (2002).

Results and discussion

Table 1 summarizes the geographical coordinates, geological, soil, morphological and hydrological characteristics of the wetland sites which were used during the multivariate analyses. The data describing the wetland area present rather its maximal size than the actual aquatic area corresponding to the extremely low water levels of 2011. The low water level separated the floodplains into several isolated water bodies, therefore two sampling sites (Torfata-marsh, Orsoya canal) represented Orsoya wetland and two other (Kalimok and Brushlen canals) the Kalimok-Brushlen protected area. Thus the sites Torfata -marsh and Orsoya canal have one and Kalimok and Brushlen canals have another common number corresponding to their aquatic area (Table 1). For these reasons we did not use the variable “wetland area” in the site analyses.

Table 1. Geographic position, geology, soil, morphology and hydrology characteristics of studied wetlands

Names of wetlands / Characteristics		Torfata marsh	Orsoya canal	Peschin marsh	Murtvo blato marsh	Dylova bara marsh	Brushlen canal	Kalimok canal	Maluk preslavets	Srebarna lake
position	Latitude	$43^0$46’	$43^0$46’	$43^0$40’	$43^0$40’	$43^0$40’	$40^0$0’	$44^0$01’	$44^0$06’	$44^0$07’
	Longitude	$23^0$01’	$23^0$06’	$25^0$13’	$25^0$14’	$25^0$14’	$26^0$20’	$26^0$29’	$26^0$50’	$27^0$04’
Geology	Gravels, sands, clays	+	+				+			
	Gravels, sands, clays,(alluvium)			+	+	+				
	Trachyite tuffs (cretaceous)							+		
	Pliocenne limes								+	
	Limestones covered with clay									+
Soil	Cherozems - gleyic	+	+				+	+	+	
	Fluvisols - calcaric			+	+	+				
	Gleyisols - eutric									+
Morphology & hydrology	Wetland aquatic area, ha	2460		182	123	81	3500		354	710
	Distance from Danube, km	2.56	1.5	1.23	0.41	0.62	2.13	1.8	0.07	1.0
	Surface & ground water connectivity	+	+	+	+	+		+		+
	Groundwater connectivity	+	+				+			
	Wetland type (canal)		+				+	+		
	Wetland type (lake)	+		+	+	+			+	+
	Permanent aquatic	+	+				+	+	+	+
	Temporal aquatic			+	+	+				
	Elevation above river level								+	

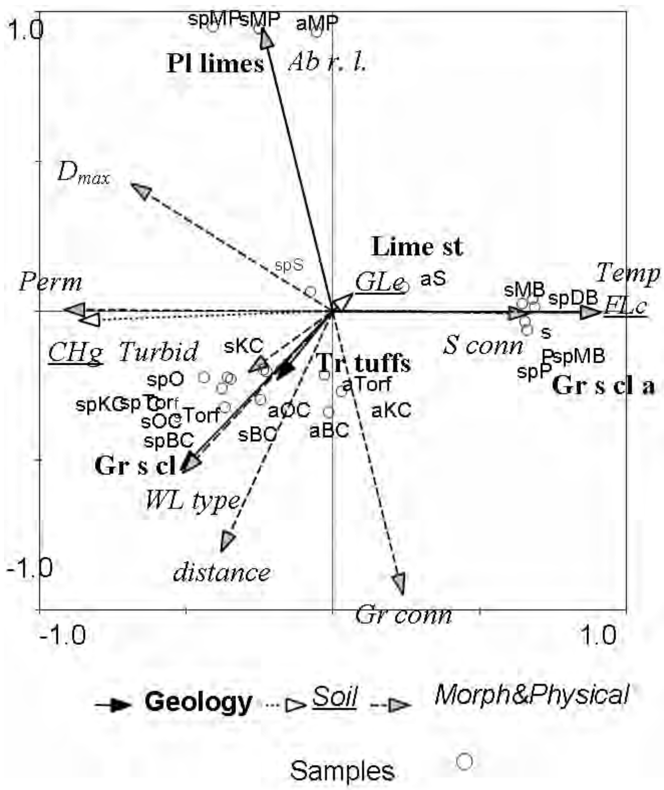

Figure 2. Wetland ordination according to their geological, soil, morphological, hydrological and physical characteristics by means of partial PCA to eliminate seasonal influences; eigenvalues of 1st axis 0.352 (37.3%) and of 2nd 0.247 (26.2%); abbreviations applied: Gravels, sands, clays (**Gr s cl**), Gravels, sands, clays alluvium (**Gr s cl a**), Trachyite tuffs (**Tr tuffs**), Pliocenne limes (**Pl limes**), Limestones covered with clay (**Limest**), Cherozems – gleyic (<u>*CHg*</u>), Fluvisols – calcaric (<u>*FLc*</u>), Gleyisols – eutric (<u>*GLe*</u>), Wetland type (*WL type*), Distance from Danube River (*distance*), Surface & ground water connectivity (*S conn*), Groundwater connectivity (*Gr conn*), Permanent aquatic (*Perm*), Temporal aquatic (*Temp*), Maximal depth (D_{max}), Water turbidity (*Turbid*), Elevation above river level (*Av r l*), spring samples of Torfata marsh (spTorf), summer samples of Orsoya canal (sOC), autumn samples of Brushlen canal (aBC), Peschin marsh (P), Murtvo blato marsh (MB), Dylova bara marsh (DB), Kalimok canal (KC), Maluk preslavets (MP), Srebarna lake (S).

The PCA ordination biplot (Fig. 2) presents the spatial site distribution obtained from almost all variables (Table 1). One geological (Gr s cl a), two soil (<u>*CHg, FLc*</u>) and other two hydrological variables (*Temp, Perm*) contributed strongly to the first main axis, while one geological (Pl limes) and three morphological (rather topography) ones (*distance*, *Gr conn, Av r l*) had the main influence on the formation of the second axis. The first axis separated the sites into two main groups. The first one contained the wetlands from Belene Island while the second included all canal sites together with the Torfata (marsh from Orsoya floodplain). The Srebarna Lake took an intermediate position while the Maluk Preslavets Lake was isolated far away due to its geological nature and distinct elevation above the Danube River level.

The spatial ordination of wetland sites and the Danube River samples by PCA regarding thetheir chemistry variables wetland sites and the Danube River samples distinguished between canal sites, lake sites and river samples according to their chemistry variables. The Danube samples have higher oxygen and NO_3-N concentrations and smaller variability (only due to seasonal differences) than the wetlands where more intense NO_3-N uptake and denitrification seemed to occur.

We do not present the last dDiscussed PCA ordination, first, due to space shortage and second because the RDA of the same data set (reduced by Danube samples) provided the same spatial separation between lake and canal sites for chemistry data significantly explained by variable “wetland type” (lake or canal) and macrophyte surface cover. The canal sites were more turbid, with a thick silt bottom layer, richer in nutrients and with lower oxygen than the sites of lake type (Table 2). This can be explained with both the canals location in proximity or within arable lands, and with their past and recent functionality as drains. In opposite, the lake type sites are either isolated from agricultural activity due to their protection status (Srebarna lake reserve), or they are located in the middle of the river (Belene island). The macrophytes had an obvious contribution in phosphate uptake and as a second explanatory variable they separated the wetlands to phosphate rich and poor.

Table 2. Arithmetic means (AM) and coefficient of variation (CV) of data from three main water types measured in spring, summer and autumn of year 2011

Water body type	Statistics	Oxygen g m^{-3}	Oxygen saturation %	pH	Conductivity µS cm^{-1}	NO3-N mg/l)	NO2 -N mg/l	NH4-N mg/l	PO4-P mg/l	Turbidity absorbance at 550nm
Lake	AM	8.798	94.981	8.444	598.651	0.126	0.048	0.405	0.167	0.230
	CV, %	38.727	33.169	6.646	47.758	75.161	100.917	104.289	104.713	55.057
Canal	AM	2.485	26.151	7.529	708.111	0.210	0.027	0.905	0.286	0.898
	CV, %	84.701	90.235	6.558	22.572	117.711	119.886	102.321	102.080	152.380
Danube River	AM	10.487	105.223	8.070	403.000	1.333	0.015	0.035	0.133	0.126
	CV, %	16.473	22.579	3.853	9.261	11.456	27.555	59.211	18.875	70.118

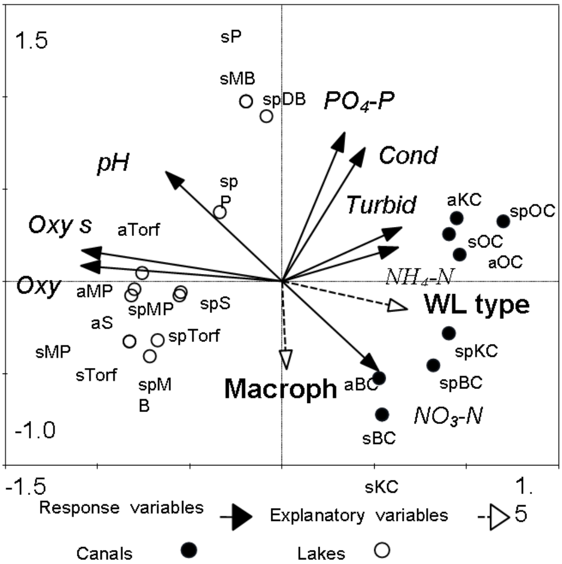

Figure 3. Triplot obtained from partial redundancy analysis RDA based on spatial variations of chemistry characteristics as response variables and wetland type and macrophytes as explanatory variables resulted in eigenvalues of 1st axis 0.271 and all canonical eigenvalues 0.329, both significant for P=0.002. The sum of all eigenvalues amounts to 0.907. For sample name abbreviations see Fig. 2.

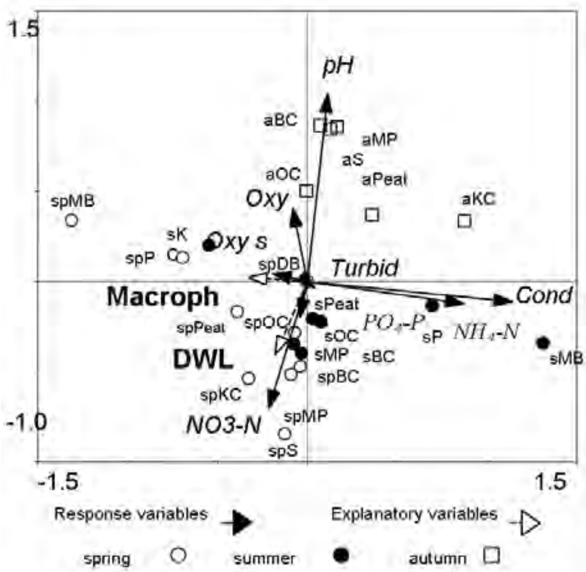

Figure 4. Triplot obtained from partial redundancy analysis based on seasonal variations of chemical characteristics as response variables and macrophytes and Danube River water level as explanatory variables with eigenvalue of 1st axis 0.073 and all canonical eigenvalues 0.124, significant for P=0.1220 and P=0.01 correspondingly. The sum of all eigenvalues reaches up to 0.428. For sample name abbreviations see Fig.2

Seasonal variability was much smaller than spatial (compare the sums of all eigenvalues from Fig. 3 and 4). Again the macrophytes along with Danube water level variations - recorded at town Ruse - were the variables explaining a significant deal of seasonal variations. Fig. 4 separated spring and autumn samples with the summer samples as a transition between them. The spring samples are characterized by high NO_3-N and low conductivity while the autumn samples have high pH, NH_4-N and conductivity mainly due to concentration effect of the drought.

Conclusions

The studied chemistry characteristics showed clear spatial differences between wetland water bodies of canal, -, lake type and the Danube River samples. The canal type water bodies' function was to collect ground water and transport it back to the river in order to prevent flooding of arable land. These acted also as depot and pre-filter for nutrients, especially in case of extremely low river water levels. On one hand the absence of high waters and floodplain flooding hindered the wetlands to fulfill their function as sinks for nutrients originating form the river. On the other hand the concentrations in the canal were considerably higher than the ones in the lake waters. These seemed to indicate a stronger ability in case of the latter to remove nutrients especially the PO4-P more efficiently. These substances were most probably was taken up by macrophytes in both water types. The geological and soil characteristics of wetlands did not influence the recorded chemical variables significantly. The same was true for wetland connectivity to the river. The connectivity is highly important and frequently studied (Tockner et al 1999, Mihalijec et al 2009) but its effect could hardly be revealed in our case due to its almost complete absence under the prolonged drought in 2011. The construction of various large scale hydrotechnical works in the upper sections of the Danube and its tributaries in combination with the advancing climate changes seem to present a growing danger for the existence and proper functioning of wetlands on Bulgarian territory.

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Composition and short-term dynamics of zooplankton and macrozoobenthos communities in two wetlands on the Bulgarian Danube floodplain.

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Keywords: Danube, flooding regime, zooplankton, macrozoobenthos, habitat diversity

Introduction

The aim of the study, intended to reveal two main tasks:

1. to compare the structure of both the zooplankton and macrozoobenthos communities in terms of changeable hydrological regime of two model wetlands located on the floodplain of the Lower Danube
2. and to identify the main environmental parameters, which affect the community forming processes on the specific habitats.

According to Junk et al. (1989) the floodplain areas with an intermediate level of flooding are expected to provide the highest biodiversity. Gruberts et al. (2006, unpubl.) is grouping the floodplain lakes of Daugava River based on their flooding regime to several types (Paidere 2009). Thereby the Orsoya marshland could be classified as repeatedly flooded (once or twice per year) and expected to have greater species richness than the Malak Preslavets, which is considered as not flooded at all, because of an artificial isolation during the last five decades. Malak Preslavets is not affected by the hydrological regime of the Danube.

The zooplankton communities are among the most influenced by the dynamics of hydrological mode. Pehlivanov et al. (2004) defined the fish predation, the import of organisms through biological drift and indirectly the flooding regime as the mayor factors influencing the zooplankton community structure in the Srebarna Lake (a wetland on Bulgarian Danube floodplain). Van den Brink et al. (1994) suggested the hydrological parameters as the most important for the macrozoobenthos communities in the frequently flooded lakes, whereas vegetation coverage and water temperature were the most important in the isolated, non-flooded lakes.

The two models studied wetlands that were situated on the right bank of the Danube. Both of them were isolated from the river by its embankments, constructed in the 1960-ies. The lake Malak Preslavets (Fig.1), located at the 414 rkm, is a former flooding marsh, transformed into a small reservoir by a dam which has raised the water level as well. Due to the continuous water discharge through the dike's overflow its almost constant water level remains higher than the river's flood pulses so inundation did not occur. The total surface of the water body is about 38 ha and the maximum depth reaches about 4 m. The Orsoya Marshland (Fig. 2) is situated between rkm 756 and 772 on a lowland of a more than 3000 ha area. During high Danube water levels, round 2/3 of the lowland is flooded, mainly by groundwater infiltration. A maximum depth of 2.5 meters was measured during the spring flood in 2010. Shortly thereafter, in the summer of 2010, the decreasing water level caused shrinkage of the water bodies within the wetland. As a result, three separated microhabitats occurred with a total water surface less than 10 ha: 1) Small natural marshes, 2) Abandoned fishponds and 3) Drainage channel system.

Material and Methods

The sampling points on each wetland were selected to cover the typical habitats. In the Malak Preslavets the sampling points (Fig. 1) were situated in the shallow tail area (MPO), in the middle part with maximum depth (MPS) and in front of the overflow near the dam (MPP). In the Orsoya Marshland the sampling points (Fig. 2) covered the Peat-marsh, the abandoned fishponds and the channels. The Peat-marsh (OTO) is an isolated water body fed only by underground waters, never drying and retaining constant water level.

Figure 1. Malak Preslavets

Figure 2. Orsoya Marshland

The abandoned fishponds (ORI) are part of a former fish farm. They have been flooded through the rest of the water supply facilities and directly by the Danube. The channel points (OK1) and (OK2) are situated in the drainage channel used for prevention of flooding during the high levels of the Danube. In 2001 an extremely decreased water level on Orsoya marshland caused drying up of the fishpond station (ORI). Therefore, it was replaced by another sampling point situated downstream along the channel (OK2).

Twenty three zooplankton and nineteen macrozoobenthos samples were collected during the spring, summer and autumn of 2010 and 2011. Sub-surface zooplankton samples were taken using a graduated 10 l bucket. Totally, 100 liters of water were filtered through a qualitative plankton net with a mesh size of 80 µm for each sample.

Samples were preserved for laboratory processing in 2-3% formaldehyde. Macrozoobenthos samples in the Orsoya Marshland were collected according the Standard EN ISO 7828:1994 and preserved in 4% formaldehyde. At the deeper stations in Malak Preslavets quantitative samples were collected according to EN ISO 9391:1995 using an Eckmann`s dredge sampler. In order to obtain an overall species richness of the macrozoobenthos in Malak Preslavets, two additional littoral samples were taken (MPL).

Together with the zooplankton and macrozoobenthos sampling the Secchi depth was measured. Water temperature, pH, conductivity and dissolved oxygen were measured by WTW - Multi 1970i set. The depth was measured each time along the sampling. The variation of the water level (i.e. the change of the depth) was used as a temporal parameter.

The laboratory process included species identification of both the zooplankton and the collected specimens of macrozoobenthos.

The total number of taxa and the recorded environmental parameters were used for statistical analyses using PAST software package (Hammer et al. 2001). Paired-group algorithm was used for Cluster analyses. Bray-Curtis similarity measure for the zooplankton and Euclidean similarity measure for the macrozoobenthos communities were used to explain the resemblance and differences between the wetlands. Canonical Correspondence Analyses were used for determination of the environmental parameters influencing the communities. The images of the maps were obtained using Google background.

Results and Discussion

In the spring of 2010, during the first sampling period in the fishponds (ORI) of Orsoya marshland, there was a surface hydraulic connection within the entire flooded area. Then, in the summer of 2010, the water level decreased drastically, when the fishponds (ORI) became isolated from the channel system (OK) and a total drought occurred in the summer of 2011. The Peat-marsh (OTO) also became isolated in the summer 2010, but the water level did not decrease significantly.

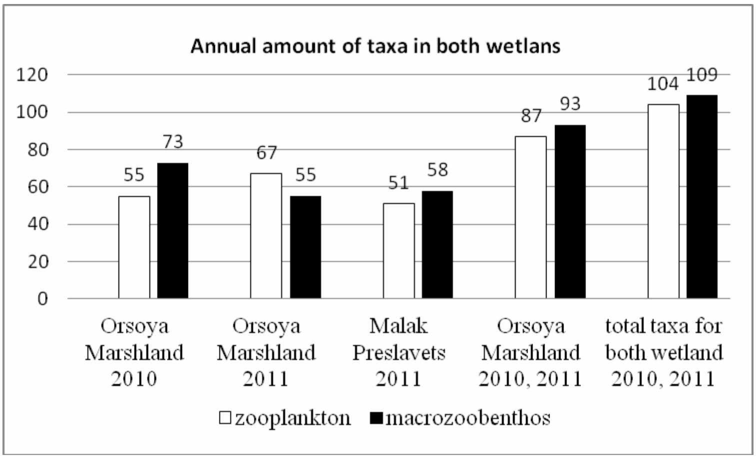

Figure 3. Macrozoobenthos and Zooplankton amount of taxa in the two wetlands (Orsoya Marshland and Malak Preslavets) for 2010 and 2011

Altogether 104 zooplankton and 109 macrozoobenthos taxa were found in the two wetlands all along the study (Fig.3). Greater species richness was found in the Orsoya Marshland with 93 macrozoobenthos and 87 zooplankton taxa.

Cluster analyses with species data were used to express the similarity of the zooplankton community among the habitats (Fig. 4) and the similarity of macrozoobenthos among the samples (Fig. 5).

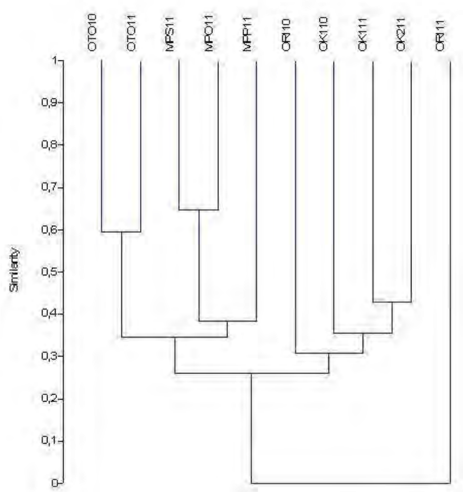

Figure 4. Comparison of the zooplankton composition in different habitats in 2010 and 2011, based on the similarity of zooplankton, summarized as total amount of taxa for each habitat. Coph. corr. = 0.915

The zooplankton community showed the highest similarity between the stations of Malak Preslavets (Fig.4). The fishponds (ORI) showed the greatest differences in the species richness in the both compared years 2010 and 2011.

The peat-marsh station (OTO) indicated, that communities are rather close to similarity for both years of the investigation. The channel system (OK1 and OK2) showed insignificant similarity. In the cluster analysis (Fig.5) all macrozoobenthos samples were compared, the Malak Preslavets (MPO and MPS) from the open water, formed an emphatic cluster, while the littoral samples of Malak Preslavets showed similarities with the Orsoya Marshland samples. This confirms the significance of the habitat's parameters, like submerged vegetation, for the distribution of the communities (Van den Brink et al., 1994, Varadinova et al., 2009). The impossibility for forming emphatic clusters of the Orsoya Marshland samples obviously reflects the high spatial and temporal diversity of the macrozoobenthic composition.

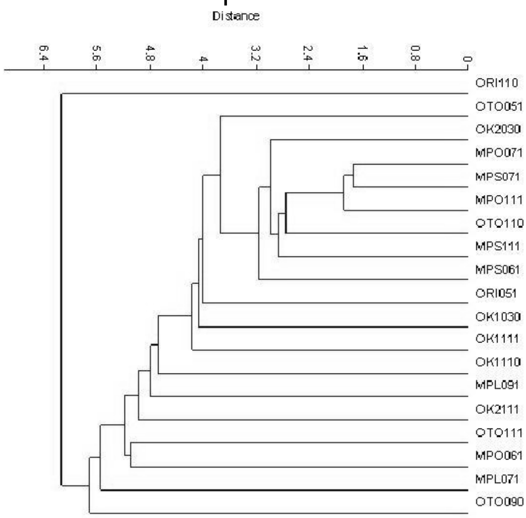

Figure 5. Comparison of the similarity between all samples of macrozoobenthos communities in 2010 and 2011. Coph. corr. = 0.9402

Seven par ameters such as temperature, pH, dissolved oxygen, oxygen saturation, conductivity, transparency, depth and water level variation were analyzed using Canonical Correspondence Analysis to describe the most significant environmental factors that influence on zooplankton community gradients (Fig. 6). The first two axes explained 51.26% of the total variation with eigenvalues 0.3826 for the first and 0.3248 for the second axis respectively. The biplot diagram shows a formation of three main groups of stations, based on the composition of the zooplankton community and environmental parameters. The first group is formed by the Malak Preslavets (MP), sampling points are located in the right part of the diagram and it shows that the depth and pH as are the most significant factors for the communities developed in this water body. Sampling points in the Malak Preslavets are characterized with higher range of depth between themselves than these in the Orsoya Marshland. Greater depth deprives the macrophytes overgrowth and allows phytoplankton blooms, inducing a sharper pH fluctuation. The second group is formed by the peat-marsh samples in the Orsoya Marshland (OTO), positioned in the middle bottom of the diagram, influenced mainly by the transparency and the oxygen concentration. An extreme development and extinction of macrophytes in the peat-marsh were observed annually. The third group, formed by the channels and the fishponds in the Orsoya Marshland, is located from the center along the axis of the temperature and the water level fluctuation. The channel system (OK) and (ORI) are the most decreased water level stations. This has caused shallowness of the channel system and higher temperature fluctuations.

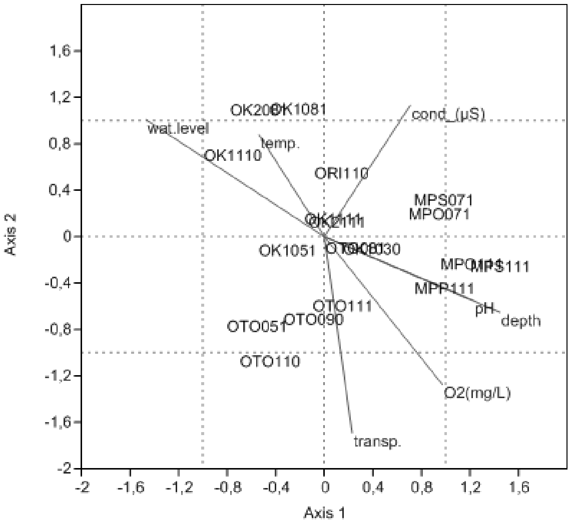

Figure 6. Correspondence between environmental parameters and zooplankton community structure. P-value = 0.009

The significance of environmental parameters on the different habitats of macrozoobenthos communities were analyzed (Fig.7). The first two axis explain 48.77 of the total variation with eigenvalues 0.526 for the first and 0.455 for the second axis respectively. The diagram (Fig. 7) showed that dissolved oxygen and oxygen saturation are the most significant factors that have influenced the communities in the habitats peat-marsh (OTO) and fishponds (ORI) of the Orsoya Marshland, just as like as for the littoral (MPO) and profundal (MPS) zones of Malak Preslavets. The oxygen values were influenced by the growth of the submerged vegetation, which was limited by the depth of the wetland. The sampling points from the channels (OK) showed correlation with the vectors depth, water temperature and conductivity. In the shallower sampling points of Malak Preslavets (MPO) the significant factors were dissolved oxygen, water temperature and conductivity. The samples (OK1030) and (MPS061) were gathered from the deepest points in each wetland, revealing the depth as significant factor here. While dissolved oxygen and saturation correlated as a main factor that determines the highest species richness of the macrozoobenthos.

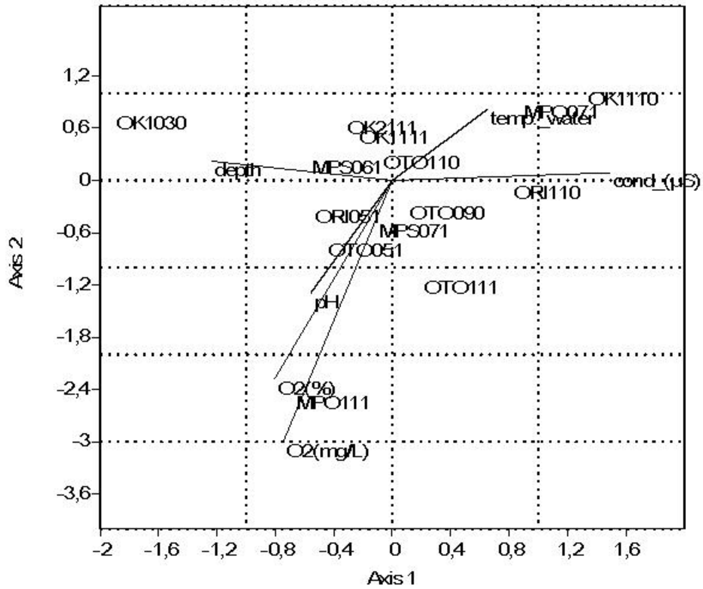

Figure 7. Correspondence between environmental parameters and macrozoobenthos community. P-value = 0.148

Conclusions

The greater depth of the Malak Preslavets is a prerequisite for the existence of two associated but completely different ecological niches. These are the littoral and the profundal zones for the macrozoobenthos, as well as the littoral and the pelagic zones for the zooplankton. Such spatially separated ecological niches allow the coexistence of variety of species. In general, the more stable water body is the more stable conditions support. Hence, the dynamics of communities is mainly promoted by the seasonal changes.

In the Orsoya Marshland the fluctuations of the water level with a smaller average depth and varied topography determined higher diversity of littoral habitats respectively maintaining a greater species variety.

The decreasing number of macrozoobenthos taxa in the Orsoya Marshland, was considered as a response to the drying out of the area and loss of microhabitats. Contrariwise, an increase of the number of zooplankton taxa occurred in 2011, when inundation did not occur and the isolation continued. In this particular case both the decreasing water level and prolonged isolation seems to function as main the factor for the impoverishment of the macrozoobenthos and in contrast benefits increase the species richness of the zooplankton in the variety of water bodies.

Acknowledgments

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Topic 3.
Changes in biodiversity

(interactions of metapopulations,
invasive species,
the Danube as ecological corridor,
status of nature conservation)

Historical Distribution, current Situation and future Potential of Sturgeons in Austrian Rivers

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Keywords: sturgeons, sterlet, Austria, alien, Danube

Abstract

Worldwide, the family of sturgeons is near extinction. Reasons are different human factors like energy production in rivers with the interruption of the river continuum, the pollution of water bodies and overfishing because of the valuable caviar.

The Danube has five native sturgeon species which partially used to migrate up to the Bavarian Danube for spawning. The exact distribution of the various species within the Danube remains still unclear. In the Austrian part of the Danube only small quantities of the sterlet (*A. ruthenus*) can be found, which are threatened with extinction. In the last years sturgeon stocking (accidentally and on purpose) and catches increased throughout Austria. Unfortunately many of these fish are of allochthonous sturgeon species. It is imminent to undertake steps for protection and support of the remaining population of sterlet and to evaluate other stretches regarding their potential of supporting a viable sterlet population. Measures for reintroduction have to be closely monitored as stocking programmes in the past didn't have a significant impact on catches.

The objective of this study was to summarize all available data about sturgeons in Austrian waters to get a picture of their historical and current distribution and to use the gained data to evaluate the potential of Austrian rivers for sturgeons.

Materials and Method

For the historical distribution various texts books and sturgeon preparations of the Museum of Natural History of Vienna have been analyzed concerning their species and the location of their catch. With the gained information a database and maps for the different sturgeon species were created, distinguishing actual catch reports and general statements.

Current catches and stocking were recorded through wanted posters in fishing shops and magazines as well as through contacting over 300 scientists, fishing organizations, governmental institutions and fishermen.

Because there is little to no knowledge regarding habitat use a very basic approach was used evaluating the potential. The criteria were: historic and current occurrence, condition of caught fish, signs of spawning activity, length of available river stretches/ impoundments/ connected tributaries, fragmentation and habitat heterogeneity. Functional fish passes for sturgeons are still in the early development stages therefore each impounded section had to be evaluated separately.

Historic records

Even through intensive research it is not possible to recreate the exact distribution of the five sturgeon species in Austria.

The sterlet occurred throughout the Austrian Danube and in Bavaria upstream to Ulm. It undertook spawning migrations up to 300 km of length (Holcik 1989). Keeping the species` range and the migration pattern in mind and combining it with records of catches, it can be stated that it was common in the Austrian Danube, even if it might have been only temporarily present in some stretches. It also occurred in the Inn along the Austrian - German border and in the Salzach upstream to Laufen (Heckel 1854). Although there are hardly any reports regarding the Traun, Enns and Ybbs, it can be assumed, that at least the lower 5 to 10 km were occasionally used by sterlets or other sturgeon species. The March was inhabited by sterlets along the Austrian - Slovakian border, and very likely also the lower sections of the Thaya (Heinrich 1856, Kraft 1874). In the Mura a catch near Graz (Mojsisivics 1897) states the occurrence of this species in this area, but due to hydromorphological characteristics it can be expected that it was more abundant in the border section of the Mura. There is no indication of the species present in the Austrian Drava, the next sporadic occurrence being 70 km downstream near Maribor (Woschitz 2006).

The ship sturgeon occurred in the whole stretch of the Danube, as catches near Vienna (Österreichs Fischereiwirtschaft 1936) and Regensburg (Jaeckel 1864) show. Although not abundant in the 19th century (Fitzinger & Heckel 1839) it is likely that the species was already overfished by then and was more numerous in earlier times. The situation is further complicated because most of the time fishermen didn`t distinguish juvenile ship sturgeons from sterlets and adults from Russian sturgeon. There are no reports for other rivers in Austria but looking at the distribution of the large migratory species it is possible that it occurred also in the Salzach, Inn, March and Mura. Also the most downstream sections of the Traun, Enns, Ybbs or Thaya might have had suitable habitat near their mouths into the Danube or the March respectively.

Russian sturgeons migrated up to the Bavarian Danube. It is also said to be rare by Fitzinger & Heckel (1839), but this might be the same situation as described with the ship sturgeon. A catch near Schärding (Brod 1980) shows the presence of this species in the Inn and it probably also occurred in the Salzach upstream to Tittmonig. In the March it is stated upstream to Hodonin (Weeger 1884). For other tributaries the same situation as for the ship sturgeon can be assumed. Some authors suspect the species in the Mura along the Austrian - Slovenian border (Zauner et al. 2000).

There are no reports of stellate sturgeons in Austrian waters, only two statements from the 19th century saying that it very seldom entered the Austrian Danube (Fitzinger & Heckel 1839) and that it rarely occurred in the Isar in Bavaria (Siebold 1863). It probably was more abundant in earlier times and used similar habitat and stretches as the other species. In the Ural River the spawning migration of the stellate sturgeon is considerably shorter than of Russian and beluga sturgeon (Lagutov & Lagutov 2008), which might be similar in the Danube, being an indication that the species might have been less frequent than others.

The beluga sturgeon occurred throughout the Austrian Danube and Inn. In the Salzach it migrated at least up to Tittmonig (Hochleithner 2004). Again this species was stated as rare in Austrian waters in the 19th century (Fitzinger & Heckel 1839). In this case the same authors state it was abundant in former times, which directly indicates overfishing in earlier centuries. For the March catches are stated as far upstream as Hodonin (Weeger 1884). For the other rivers the situation might be the same as with the Russian and ship sturgeon.

Stocking

Stocking is and was conducted in various Austrian rivers, especially in the Danube and the Drava. Most stocked fish are sterlets and there were also some stocking actions with extinct species like Russian sturgeon. Problematic is the high number of illegally stocked or escaped alien sturgeon specimens. In the Drava a high number of sterlets was stocked between 1982 and 1995 in various impoundments (Honsig - Erlenburg & Friedl 1999). In the Danube stocking efforts with sterlets concentrated near Vienna and in the Donau - Auen National Park area from 1994 to 2010.

Recent catch

In total 220 specimens from Austrian rivers could be included in the database. It can be estimated however that the real number is two to four times higher. Around 90 reported catches are sterlets, half of them from the Danube and the other half from the Drava. Over 100 fish could not be identified due to lack of pictures or usable morphological information. Most likely most of these fish are sterlets and Siberian sturgeon. 12 Siberian sturgeons could be reported. In river stretches not stocked with sterlets or not containing a sterlet population this species is by far the most abundant in Austrian waters. Other species are caught to a lesser extent, for example white sturgeon, Russian sturgeon, hybrids or paddlefish.

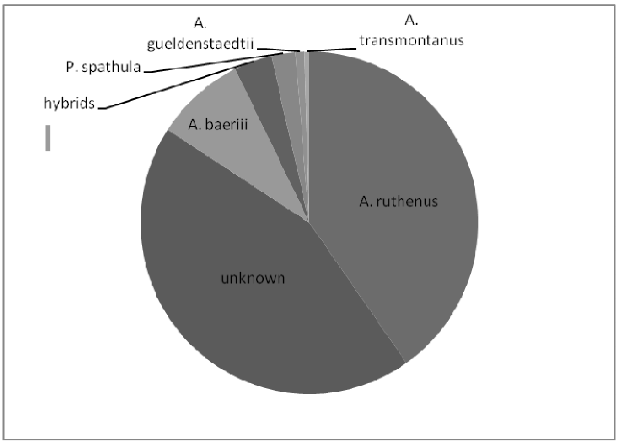

Figure 1. Sturgeon catches 1980 - 2011 in Austrian rivers (Credit: Author)

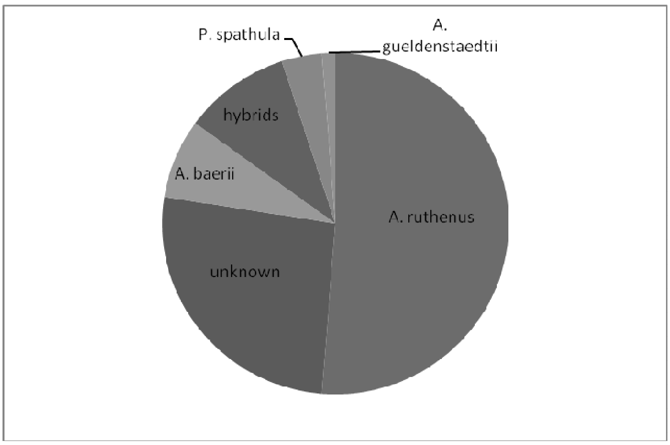

Figure 2. Sturgeon catches 1980 - 2011 in the Austrian Danube (Credit: Author)

Potential

In the Danube 80 specimens could be recorded. Around forty of these are sterlets, half of those being caught in the Aschach impoundment in the last 10 years. Catches of juveniles and adults are reported since the 1950's, therefore indicating the last remaining self- sustaining population of this species in Austria (Zauner pers. comm.). Other sterlet catches are from various stretches, most interesting being catches of leftover fish from former populations in the 1980ies and early 90ties near Linz, Wallsee, Altenwörth and Klosterneuburg. There is evidence of a reproduction near Klosterneuburg before the construction of the power plant Freudenau. Intensive stocking in the early 21st century didn`t have any impact on catches above the power plant Freudenau, whereas catches downstream of Vienna increased after stocking. Also many caught specimens remain unidentified but it can be assumed that most of those are sterlets or Siberian sturgeons. Alien sturgeon species and hybrids have been caught in nearly all stretches, with most fish caught below the power plant Altenwörth. An alarming discovery was the hybridization of native sterlets with alien Siberian sturgeon in the Aschach impoundment (Ludwig et al. 2009), posing a threat to this last sterlet population.

Although Austrian rivers suffer from various habitat alterations like channelization, migration barriers like power plants or weirs, deepening, etc., some stretches still have the potential to support a viable population of sterlets. Before any restocking takes place it should be tried to determine why the species disappeared in the first place and if suitable habitat is available.

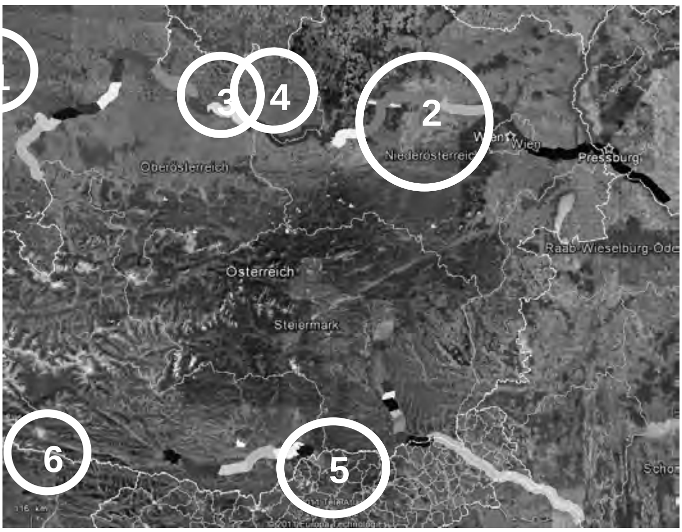

Figure 3. Potential hotspot areas in Austria for sturgeon restoration (Credit: Author/ Google Earth)

Special attention has to be paid to the last remaining population below the power plant Jochenstein (1). Protection of this population from various influences like habitat loss and especially hybridization with alien sturgeon species have to be top priorities. Fish from this stretch could be used to produce juveniles for restocking and more important to research the habitat use of this population which would make it possible to identify or reconstruct similar habitat in other Austrian river stretches.

The river system with the most potential regarding reintroduction is the Danube downstream of Vienna (2), connected with the March and Thaya, in total offering around 200 km of free flowing river. The last two rivers have relatively few human impacts on hydromorphology and the Danube flows mostly through the protected area of the Donau - Auen National Park. The system offers high habitat variability with both epi- and metapotamal characters. Various issues regarding successful restocking activities have to be assessed, especially habitat availability, quality of stocking material and predation.

Other stretches that should be evaluated are the second free flowing section through the Wachau (3) and the impoundment of Greifenstein (4). As sturgeon individuals caught in the latter show a very good condition at least available food resources seem to be adequate.

Another river with potential is the Mura along the Austrian - Slovenian border (5). Even if there is only a very short stretch on Austrian territory, it is connected to over 1000 km of free flowing Mura, Drava and Danube. If spawning and nursery habitat is available it could be restocked with fry and juveniles of sterlets and later maybe even with juvenile ship sturgeons or anadromous sturgeon species once the Iron Gate dams become passable. One factor that has to be kept in mind is the high density of aquaculture plants and the widespread distribution of alien sturgeon species within these in the area.

In the Drava habitat is limited due to numerous impoundments. The reports about juveniles in the impoundment Annabrücke and the finding of a sterlet larva in the impoundment Völkermarkt (Honsig-Erlenburg & Friedl 1999) are the only two indicators of spawning after the stocking in the 1980ies and 90ies. Therefore any efforts in the Drava regarding sterlet restoration they should concentrate on these two stretches (6).

The lower Salzach and Inn system is also very small - fragmented and shows many hydromorphological alterations. The only interesting stretch is a combined stretch of Salzach and Inn of around 60 km length (7). All recent sturgeon catches have been in this area near the mouth of the river Salzach.

As the most important stretches are along borders to other countries all efforts regarding protection and reintroduction have to be bi- or multilateral. Any actions taken have to be scientifically monitored to examine their success.

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Topic 6
Environment and infrastructure in the European Strategy for the Danube Region (EUSDR): harmonisation of ecological needs and effects of different water usages

(drinking water, irrigation, navigation, hydro-power, dredging, fishing, reed management, recreation)

Sturgeon Conservation in the Danube River Basin: How to implement the Sturgeon Action Plan 2005

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Introduction

The over-exploitation and increasing loss of habitats and longitudinal connectivity have gradually pushed sturgeon species to the edge of extinction: all but one of the eight European species are now classified as Critically Endangered on the IUCN Red List (http://www.iucnredlist.org/), making conservation actions mandatory in order to ensure their survival.

Despite some recent progress in sturgeon research and protection in the Danube River, there is evidence of continuous need to endorse the full implementation of the "Action Plan for the conservation of sturgeons (Acipenseridae) in the Danube River Basin" (SAP, Bloesch et al. 2006), a legally binding document under the Bern Convention, signed by all Danube countries. Current information reveals that several main issues listed in the SAP such as location of key habitats, reference conditions, current status of sturgeon species (completion of the life cycle), migration patterns, and the state of ex situ brood stock to sustain sturgeon populations remain largely unknown. The analysis of the post SAP period shows little progress in sturgeon protection and management, although it is prominently mentioned in the documents of the International Commission for the Protection of the Danube River (ICPDR) and the new EU Strategy for the Danube Region (EUSDR) (ICPDR 2005, 2007a, 2007b, 2009; EUSDR Action Plan, Priority Area 4: Action “To reduce existing water continuity interruption for fish migration in the Danube River Basin”; Priority Area 6: Action “To secure viable populations of Danube sturgeon species and other indigenous fish species by 2020”).

In January 2012, a group of sturgeon experts, NGO delegates, and representatives of the ICPDR, the EUSDR and national governments conducted a workshop on the status of and needed actions for Danube sturgeon protection. Aim of this workshop was to reactivate SAP implementation and to find means to coordinate and foster conservation of native sturgeon species in the Danube River Basin (DRB) and the adjacent Black Sea, making best use of the frameworks provided by the EUSDR and the ICPDR. The main result of the workshop was the creation of the Danube Sturgeon Task Force as a promising tool to propagate urgent sturgeon conservation measures in this region.

State-of-the-art of Danube and Black Sea sturgeon populations

Apart from many **pressures** addressed in the SAP, new potential threats for sturgeons were identified. Accumulative environmental pollutants impairing individual health will impact overall health of stocks (Poleksić et al. 2010). The introduction of exotic species into the aquatic ecosystem may be detrimental for sturgeons, by altering the food web and habitat structure (Karatayev 2007). Climate change is likely to increase temperature and alter the hydrological regime of rivers, affecting important sturgeon life cycle events such as migration and spawning (Xenopoulos et al. 2005, Ficke et al. 2007).

Detailed knowledge or reliable estimates on the **population status and trends** are still not available for Danube River sturgeons. In the *Upper Danube* the sterlet (*Acipenser ruthenus*) is the only native sturgeon species surviving in natural waters. Proofs of natural reproduction are scarce in this part of the river system; its occurrence depends mainly on stocking (Reinartz 2002, Ludwig et al. 2009). Two sturgeon species have been documented in the *Middle Danube* and its tributaries since 2005, the sterlet and the potamodromous form of the ship sturgeon (*Acipenser nudiventris*). Ship sturgeons are extremely rare (Guti 2006, Holčík et al. 2006, Ludwig et al. 2009). Populations of sterlet in the Upper and Middle Danube are either declining, threatened by hybridization or show unstable population structure and overaging (Guti 2006, Holčík et al. 2006, Lenhardt et al. 2008, Ludwig et al. 2009, Guti 2011), which was not known during the formulation of the SAP in 2005. Four species of sturgeons have been documented in the *Lower Danube* (*Huso huso*, *Acipenser gueldenstaedti*, *Acipenser ruthenus*, *Acipenser stellatus*) since 2005 (Suciu et al. 2011). The large migratory sturgeons have become very rare, which is true especially for *A. gueldenstaedti* (Paraschiv et al. 2006). Sturgeon migration in the Lower Danube is still confined to the free flowing river stretches below the Iron Gate dam II (rkm 863). A monitoring station for migratory fishes was established at Isaccea (rkm

100) and a monitoring system for YOY beluga (*H. huso*) sturgeons (juveniles: **Y**oung **O**f the **Y**ear) was successfully established at rkm 118–119 by Romanian researchers, documenting the differences in reproductive success of all four species (Paraschiv et al. 2011). The threatened status of sturgeon species in the DRB, the diminished access to sturgeon populations due to the increased scarcity of individuals and limited access to catches has stimulated studies involving **population viability analysis** (PVA). These studies revealed strong sensitivity of the Danube sturgeon populations to environmental changes reflected by changes in natural mortality, fecundity, age at maturity, and spawning frequency. Population models also confirmed that sturgeons are highly susceptible to even moderate levels of commercial fishery, and that their recovery is a multi-decadal process (Jarić et al. 2010).

The location of current **key habitats** for sturgeons in the Danube River is still mainly unknown as well as the **reference conditions** for their conservation and restoration. According to Guti (2011) important spawning habitats for sterlet in the Hungarian Szigetköz floodplain area were destroyed by river construction works. Researchers from Romania and Bulgaria were able to identify a few spawning, nursery and wintering sites for beluga sturgeon and sterlet in the Lower Danube River as well as some basic parameters such as substrate and water level conditions as prerequisites for successful spawning (Vassilev 2006, Onara et al. 2011, Suciu et al. 2011).

Some research has also been done on the determination of **migration** and **dispersal** patterns for Danube River sturgeons (Holostenco et al. 2011, Onara et al. 2011, Suciu et al. 2011). The barrages at Gabčíkovo and the Iron Gate are obstacles impassable for sturgeons as well as other fishes. A feasibility study for the restoration of river continuity, in particular for sturgeons, is urgently needed and planned (ICPDR 2007b; Danube Declaration (http://www.icpdr.org/icpdr-pages/mm2010.htm), Comoglio 2011); however, there is still a lack of political willingness and solidarity to fund and perform such a project. Moreover, some 500 km downstream of the Iron Gates dams, the navigation projects planned along the Lower Danube may result in a new migration barrier in the form of an underwater sill for water diversion (www.afdj.ro).

Catches by anglers and researchers show an increasing presence of **exotic sturgeons and sturgeon hybrids** in open waters, mostly resulting from intentional and unintentional release/escape of fishes from the pet-/ornamental fish trade and aquaculture (Holčík 2006, Holčík et al. 2006, Lenhardt et al. 2006, Masar et al. 2006, Simonovic et al. 2006, Ludwig et al. 2009, Guti 2011). Danube River sturgeon species can be found in a large number of **hatcheries** in the DRB. The origin of this brood stock in aquaculture is not always clear and unfavourable allochthonous origins could be documented in some cases (Reinartz 2002, Reinartz et al. 2011).

There is still no coordinated approach for the **ex situ-conservation** of sturgeons and the release of offspring into aquatic ecosystems of the DRB. Stocking of sterlets into the Danube River and some tributaries has been conducted occasionally in Germany and Austria, but regularly in Slovakia (Holčík et al. 2006). Stocking of sterlets in Hungary has become an occasional measure (Guti 2006, Guti 2011). Recently a few beluga juveniles were released in the Hungarian Danube and occasional stocking of juveniles of migratory species has also been conducted in Bulgaria and Romania. A confirmed ship sturgeon, caught on 2 December 2009 in the Danube River near Mohács (rkm 1440), is currently being kept in a live gene bank in Hungary as the basis for a conservation-breeding program.

In **policy**, sturgeons are species under the EU Habitats Directive (92/43/EEC) and under Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention). Some species are listed in Appendices II or III of the Bern Convention, yet Danube River sturgeon conservation is not high on the political agenda and there is no coordinated basin-wide approach to implement the SAP. A 10-year moratorium on the catch of sturgeons was issued by Romania in 2006, while Serbia banned the sturgeon fishery in 2009. Also Bulgaria declared the catching of wild sturgeons illegal in 2011, with a 4-year extension in 2012. Countries like Serbia and Bulgaria have issued national action plans for sturgeon conservation. Investigations made by TRAFFIC and WWF documented persisting sturgeon catches and a still flourishing black market for caviar and sturgeon products in the Lower Danube region, thus documenting the importance of this facet of the sturgeon issue (Kecse-Nagy 2011).

Socio-economic measures to sustainably tackle this issue have not been undertaken so far. Actions to raise **public awareness** like the preparation of flyers and documentaries (films) have been made, yet the problem of sturgeon conservation does not have basin wide attention in the public. The natural history museum collections of live sturgeons, such as the one recently established in Tulcea, may enhance public awareness.

While there is some knowledge about sturgeons in the Danube River, the information about the **Black Sea sturgeons** as the basis of Danube sturgeon populations is almost a black box and coordinated research on this issue is urgently needed.

Conclusions and outlook

The implementation of a “Sturgeon 2020” program, similar to that of “Salmon 2020” in the Rhine River (www.iksr.org/index.php?id=124&L=3), to bring the anadromous sturgeons back up to Austria and Germany by 2020, requires intensive efforts and cooperation at basin scale to make the vision become true. The biological traits of highly endangered sturgeon species imply a slow recovery process that was certainly not greatly supported by the few scientific and political actions undertaken since the adoption of the SAP. Hence, the overall status of Danube sturgeon species has deteriorated even more since 2005, bringing them closer to ultimate extinction.

In particular, the lack of public awareness and governmental involvement to implement legal requirements and coordinated measures was a major draw-back as such commitment is crucial also for the effective implementation of moratoria and other conservation measures on the executive level. While research must be intensified and better coordinated, a key role is given to the harmonization of national legislation, control of poaching and the domestic caviar market, management of hatcheries, and economic incentives for local fishing communities. Transboundary cooperation in the Danube River and Black Sea sturgeon conservation can only be effective, if based on a basin wide solidarity to solve the common problems.

The following concrete and immediate measures are proposed for further implementation of the SAP, to be fostered by the new Danube Sturgeon Task Force, founded in January 2012:

- a well coordinated transboundary research plan and population monitoring (road map) by leading organizations and institutes with focus on sturgeon stock status, habitat, migration, genetics and the establishment of competence centres for fish and fisheries (including sturgeons);
- supporting and coordinated PR actions (raising public awareness and participation, fundraising for sturgeon projects) by authorities and NGOs (e.g. WWF and IAD);
- continuous and intensified pro-active support of ICPDR and EUSDR to promote sturgeon policy, management and legislation; this includes, amongst others, the enforcement of migration aids at the Iron Gates and Gabčíkovo dams and an increased cooperation with CITES (Convention on International Trade with Endangered Species)/TRAFFIC (the Wildlife Trade Monitoring Network)/FAO (Food and Agriculture Organization of the United Nations) to positively influence the socio-economic aspects of sturgeon conservation and to ensure a sound basis for coordinated ex situ conservation measures.

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Topic 8
Technical aspects and the implementation of the EU WFD: ecological effects of water engineering facilities *(barrages, object of flood protections and bed regulations)*, navigation, hydro-power *(direct and indirect effects, short and long term observations)*

Virtual reality – is it just a game? Towards in-door training of aquatic plant mass estimation proficiency

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Keywords: virtual reality, aquatic macrophytes, Water Framework Directive, training tool

Introduction

3D games are state-of-the-art nowadays in the games industry, but applying game techniques for serious training purposes is still very rare. One reason might be the lack of economic background, another one is the complexity of the setup and difficulties in programming such tutorial games. This fact is also reflected in the very low numbers of publications and realisations of 3D game engines used in training methods (Amory 1998, 2001). So far applications in architecture and in medical environment are the only fields with serious development (Scheiblauer 2004, Mohd 2007). This is in contrast to the fact that appropriate technology exists for a long time and computers are capable of challenging power to calculate and simulate complexity in virtual environments.

The quantification of aquatic macrophyte plant mass in running and still waters are based on estimating aquatic plant abundance according to the European standards (EN 14184 and EN 15460). This method is accepted throughout the Danube River Basin for assessing the ecological status according to the EU Water Framework Directive. Despite the easy application of this method, training of experts is needed to get comparable results. We are designing a game-based tool for training experts in a three dimensional virtual reality. The experts can do their estimates on different scenarios (running and still water), which can be generated with different plant types in a randomized environment. The situation and the plant mass estimates, elaborated by the trainees, can be stored and used for evaluation of results also they can be compared, validated and discussed to improve the assessment skills. The tool is produced in co-operation between TGM (Höhere Lehranstalt für Informationstechnologie, Vienna) and the University of Vienna, Department of Limnology.

Materials and Method

A 3D model of the river Fischa (located in Austria) was derived from the online Austrian Map (AMAP web reference). 3D data for still waters were derived from a hydro-acoustics project (carried out by First Author) at Kollersdorfer See, from a gravel pit lake (Exler 2012).

Unity 3D (Unity Technologies, San Francisco, USA) was used to design the 3D virtual environment described in more detail by Grau 2010.

Autodesk Maya 2012 (Autodesk Inc., San Francisco, USA) has been used for designing the 3-dimensional full functional plant models.

Aquatic macrophyte abundance was assessed according to Kohler's method (Kohler 1978, Kohler & Janauer 1995), which is an intrinsic content of the European Standards (EN 14184 and 15460) and it has been used in the two Joint Danube surveys (JDS 1 and 2), conducted by the International Commission for the Protection of the Danube River (ICPDR). This method applies a five level estimator scale for abundance assessment, which respects the 3D-development of plant stands (a recent application: Janauer et al. 2008)

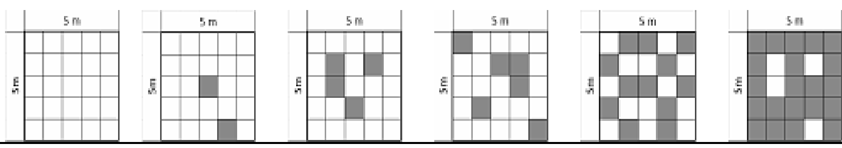
Application flow

After starting the game, the user can enter his/her name. Next step is choosing either 'running water' or 'lake'. Then the user can either load a previously stored, existing scenery or generate a new one (which can be stored for later use). When creating new scenarios, the process of inserting plant into the virtual environment is the next step, otherwise the user opens an already existing scenery and starts with mapping.

Inserting plants into the virtual scenery

Individual 'graphic species type' plant stands are stochastically distributed into the water body. They are located in 'seeding areas' of 5x5 m randomly arranged across the whole water body. Seeding areas are subdivided into 25 squares for setting plant individuals. As a next step a species is selected and a Kohler value between1-5 is randomly assigned to it or planted individually by the trainer. The Kohler values are representing the following corresponding values for the number of sub squares, which will be filled with plants.

Kohler Value	0	1	2	3	4	5
Description	nothing	rare	occasional	frequent	abundant	very abundant
Subsquares filled with plants	0	1-2	3-5	5-9	10-18	>18
Example						



Mapping of the virtual scenery

Next step is navigating through the virtual landscape either by boat or by walking around. Survey units in the river reach can be selected by pushing a button. For a selected survey unit the species have to be identified (selected out of a list) and the appropriate Kohler value has to be entered via a dialog menu (Figure 6). The state of the game can be saved at any time in a XML Format for later usage and / or for further statistical comparison.

Save and restore sceneries and mapped data

In case of using the same situation by several trainees, the individual XML files (with survey units, selected species, Kohler values) can be compared offline a later stage and statistical analysis is possible.

Results

As a start of this project two water bodies and a first set of representations of five different plant species (water lily – Figure 3, submersed European bur reed – Figure 4, bulrush model-Figure 5) were modelled.

This project is the first ever attempted to model aquatic habitats and their equipment of aquatic macrophytes in a virtual game environment. The river and lake sample are developed close to the natural status regarding their hydro morphological setting (Figure 1+2). At present, the modelling of the river and lake environments has progressed close to final versions. The plant models are still need to be adapted to a more natural format, as the flexibility and shaping of individual stems and the form of complete plant stands is one of the greatest challenges in this project.

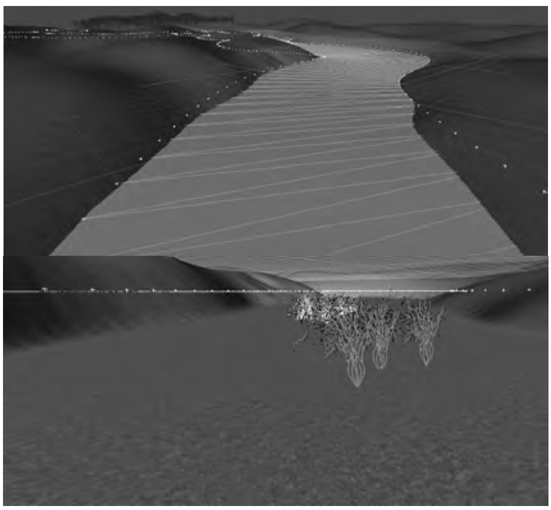


Figure 1. River morphology (left) and semi-submersed look towards the plant stands (right).

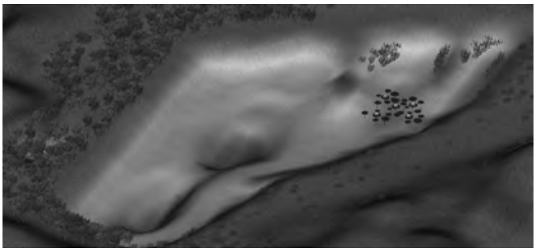


Figure 2. Lake environment and sparse macrophyte distribution. Lake basin shape is constructed on the basis of a dense hydro-acoustic survey.

Figure 3. Water lily model

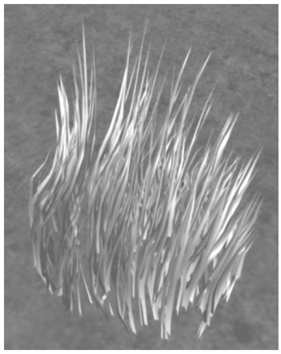


Figure 4. Submersed European bur reed stand

Figure 5. Bulrush model (bank species)

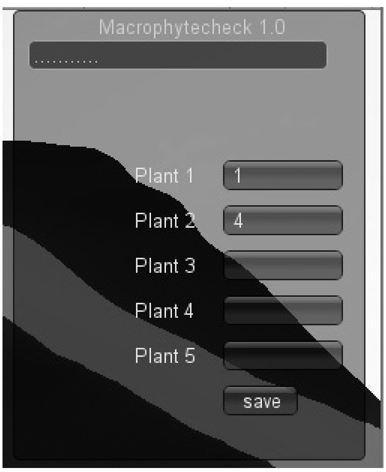


Figure 6. Plant species selection window

Outlook

The major problems and the step stones are the proper modelling of species and the complexity of programming the camera of the 3D engine in the virtual landscape. In a later stage of development it shall be possible to switch the water surface reflexion on/off during the walk through the virtual landscape. This simulates the usage of polarized sun glasses and helps trainees to get used to the difficulties of field survey situations where reflexions cannot be avoided at all time. The validation of the program will include test runs with students as well as with established experts to get feedback for adaptation and improvement of the plants and habitat representation. As a final step this virtual reality tutorial game should become a part of a standardized training method ensemble. It will be available on the homepage (www.biogis.net) in a later stage, which should include download and also the use on tablets running with Android or iOS.

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A novel hydro-acoustic approach on assessing aquatic macrophyte biomass data

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Keywords: hydro-acoustics, biomass assessment, aquatic macrophytes

Introduction

An assessment of submerged macrophytes by means of echo sounders has been suggested for more than ten years. Winfield et al. (2007) used a commercially available special hard- and software for the assessment of the macrophytes. Haga (2007) tried to calculate biomass at Lake Biwa in Japan. In his study he was using a colour echo sounder connected to a differential GPS-plotter, the image signal was recorded to a videotape for later manual evaluation of still images. The observation areas were usually 50x500m big. For all these studies either a rough resolution by large grid and/or expensive and very special dedicated equipment was used.

We developed an efficient method using conventional low-priced fishery sonar to map submersed macrophytes in surface water bodies. Further we aimed to distinguish between solid ground, muddy sediment and the “volume” of submersed macrophyte vegetation. As the hydro-acoustic signal was stored together with GPS coordinates, this information was further used to build a three dimensional model that provides the numerical basis for assessing the biomass of the aquatic macrophytes. This method reduces the measurement of aquatic macrophyte biomass to echo sounding the water body, mapping the shorelines and sampling the species distribution, on which the biomass can be calculated.

Kohlbauer (2008) used a special software developed by the first author (Exler, unpublished report) to derive macrophyte heights from recorded echo sounding to calculate biomass data for some different species of macrophytes. Exler & Janauer (2010) showed that a 3-dimensional model also can be obtained with a conventional low-priced sonar in a small side channel of the Danube River. This method has been used and validated now in different water bodies in Austria. Results of detailed seasonal mappings were obtained over a full year in a gravel pit pond near Vienna, the Kollersdorfer See, and are shown in this study.

Study Site and Methods

Study Site

Kollersdorfer See is a gravel pit pond about 60 km west from Vienna near the Danube (Figure 1), which is now used as a local recreation area.
Surface area is about 7 ha, maximum depth reaches about 6m and there is permanent groundwater connection. The surrounding landscape is characterised by intensively used agricultural areas.

Figure 1. Survey site “Kollersdorfer See” based on maps from www.wikipedia.org and bing.com.

Sonar

The sonar used is a standard low-price fish detecting instrument, LMS-480M Sonar (Lowrance Inc). This sonar works with single frequency (50/200 kHz depending on the detected depth) with 500W RMS and can detect a depth range from 0.5 to 400m. It is connected to a 12 channel WAAS, compatible GPS receiver and can store the depth profile geocoded in an internal format with 256 bit resolution.

Abiotic measurements

Secchi depth was measured once in course of each survey. Water temperature, pH and salinity were measured with a combined ExStik™ EC-500 instrument (ExTech Instruments).

Software

Extraction of ground line (GL) and top of macrophyte stands (TOM) from the stored data were done by original software (written in C++, Microsoft Visual Studio 2010 Express Edition, © Exler, 2011) and further calculation of data and visualisation was carried out by means of Matlab R2010b (Mathworks) with tools developed by the first author (Exler, unpublished report). The data gridding size was 1 x 1m.

Results

Sonar surveys have been done in April, June, August, September 2010.
Secchi depth varied over a considerable range, but it was typical about 4m. pH values ranged between 8–8.5. Conductivity values were approximately 750µS/cm for most of the year.

The most dominant submerged macrophyte species were *Myriophyllum verticillatum* L. and *Chara vulgaris* L. A reed belt of *Phragmites australis* (Cav.) Trin. ex Steudel covered the shoreline and also inhabited parts of the sand banks in the open water of the pond.

Figure 2 shows an example of an extracted echogram from survey from 29.7.2011. It shows the ground line, the upper limit of a layer of muddy sediment and the top of the macrophyte stands.

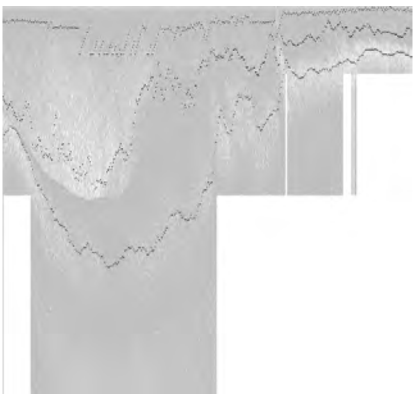

Figure 2. Sample of echogram with ground line and top of macrophytes.

Figure 3. Path of echo sounding, July 29th, 2011.

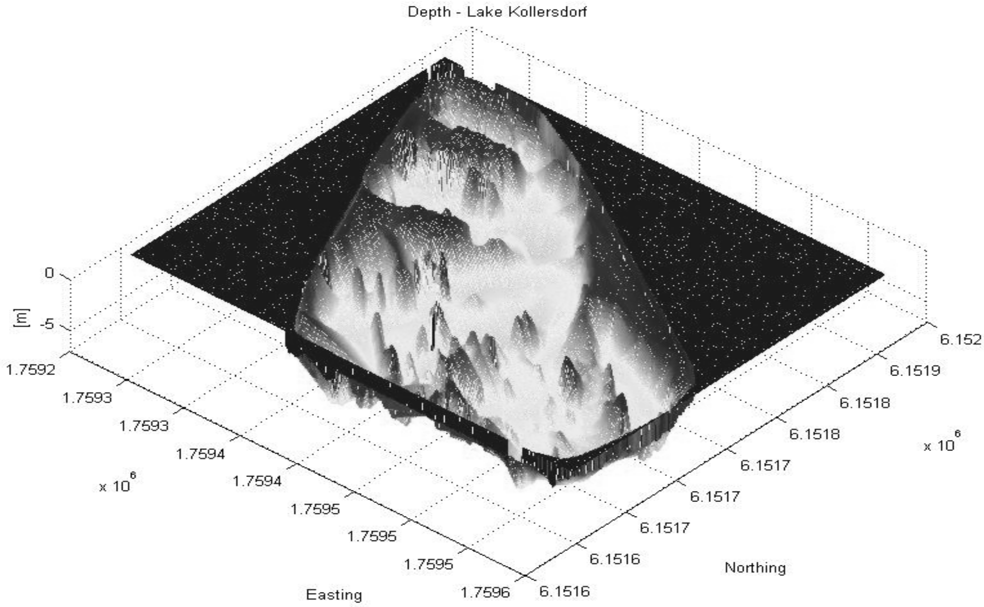

Figure 4. 3D View of the "empty lake bottom" derived by echo sounding

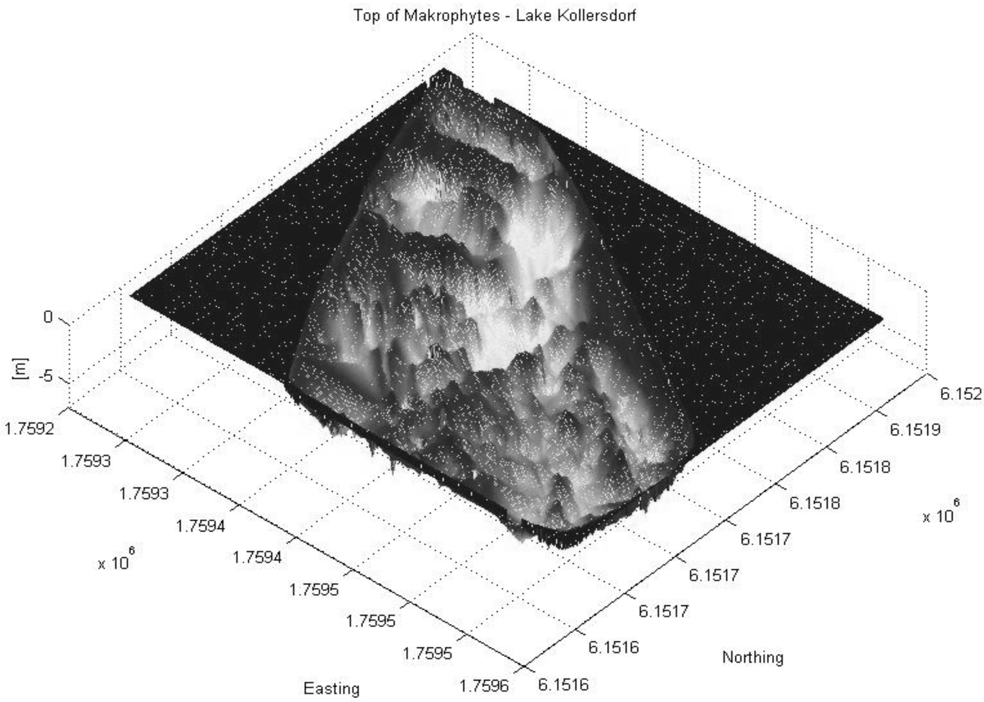

Figure 5. 3D Model of the lake with marcophytes recorded

Figure 3 shows the path in its total length of 5434m recorded by echo sounding on July 29th, 2011. The whole pond was surveyed by meandering loops to cover the whole open water. Due to the limits of the sonar, only depths with more than approximately 0.5m could be measured. Therefore the shoreline delineation was not highly exact and on account of this the volume filled by the plant stands needs further improvement.

Based on the recorded data 3-dimensional models were generated about the shape of the pond basin. One model shows the "empty" lake (Figure 4). Figure 5 shows the result from a model of the pond with submersed aquatic macrophytes. By means of intersection of these two models the volume of the aquatic macrophytes was calculated, resulting in about 139480 m^3. The average height of submersed macrophytes was 1.86m, mainly due to *Myriophyllum verticillatum* L.

Outlook and conclusions

The method applied is a very rapid possibility of estimating the plant biomass in a lake as compared to conventional methods of harvesting.

A next step will be an improved model of the shoreline of the pond. It will include aerial photography in order to improve the representativeness of the shoreline, automatic detection of the muddy sediment surface derived from the sonar data and it will hence also improve the resolution of data for estimating the plant infested volume and its related biomass.

In the next step in summer 2012 plant mass will be assessed by harvesting submersed macrophytes by scuba divers to evaluate the results of Kohlbauer (2008) and Haga (2007) and also the calculated biomass of aquatic macrophytes.

The seasonal data obtained in 2011 will form the basis of further studies of plant mass and the assessment of growth rate during a full vegetation period.

Other detailed studies will be carried out to compare calculated plant volume with plant mass, estimated as described by the Kohler Method (Kohler 1978, Kohler & Janauer 1995).

Acknowledgements

The authors thank Dr. Jens Hartmann, Scuba Diving Club Krems-Langenlois, for enabling the access to the lake, for the friendly permission for carrying out this work and the approval for harvesting macrophytes. We thank Dr. Katrin Teubner for assisting in the fieldwork and for discussing the manuscript. Reviewers are thanked for their effort in improving the language quality.

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Topic 9
Restoration ecology, landscape ecology, land use

(restoration needs and plans; planned and realised projects along the Danube; experiences and observations)

Restoration potential in the Danube River Basin, with focus on lower river courses of Danube, Mura and Drava

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Keywords: Floodplain and river restoration, prioritisation

Introduction

This article present the framework and first results of studies commissioned by WWF (since 2009, three studies with increasing spatial resolution were carried out, for the whole Danube basin and for the lower Danube as well as for the Mura and Drava rivers by Schwarz 2010, 2011, 2012). The aim of the projects is the assessment and prioritisation of potential restoration areas to support national and international activities in respect to nature protection (FFH), the ecological status improvement under WFD and flood mitigation under the umbrella of the European Floods Directive. Aside of the review of existing and planned major restoration projects including those officially proposed in the Danube Management Plan (ICPDR 2009), new areas are proposed based on continuously available data sets including land use, spatial configuration, the degree of hydromorphological intactness, overlapping protected areas and different floodplain types.

Methodology

The restoration potential of former floodplains is firstly based on a deep analysis of morphological and active floodplains (compare method of floodplain delineation, BfN 2009). Secondly landuse or better detailed habitat information is necessary to assess the former floodplain (infrastructure and settlements represent “no go areas”). Thirdly main hydromorphological conditions in the respective river stretch and its active floodplain should be assessed to estimate the lateral connectivity. Each individual potential restoration area is delineated according the available space and spatial configuration (minimum size was set for the overview study by >500 ha) fulfilling basic hydraulic requirements. Finally the overlay with protected areas (following international directives and conventions) indicates the ecological status and potential of a certain area (compare figure 1) and should be used for the further prioritisation. Further indicators such as dike and drainage canal length and related costs for restoration measures or land ownership were initially omitted for the overview but partially included for the more detailed studies.

Aside of already accomplished restoration projects and those officially planned in the active and former floodplain, the focus was set to the proposal of floodplain areas in the former floodplain. The final delineation of individual restoration areas as such is an interactive expert approach from upstream to downstream supported by basic modelling steps (GIS overlays, statistical calculations of continuous available parameters).

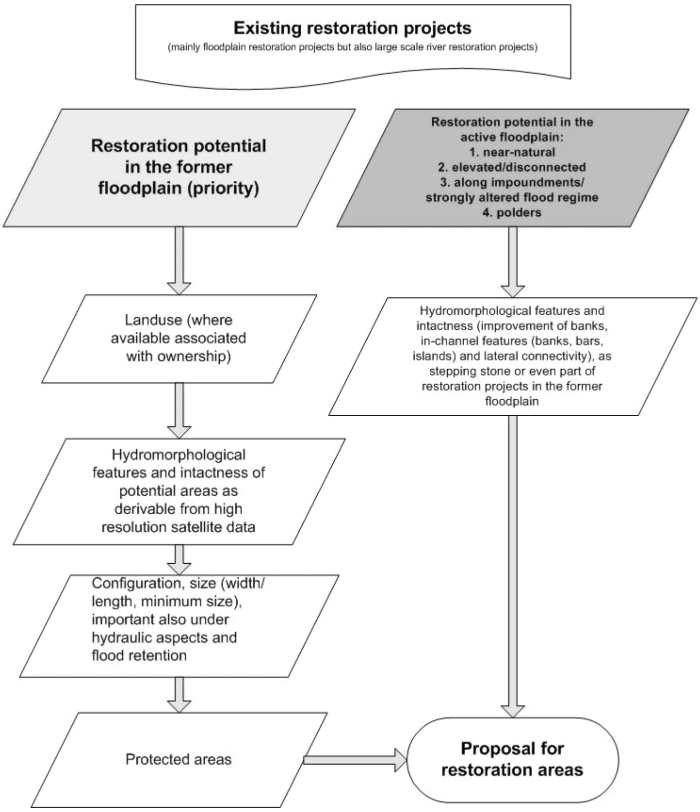


Figure 1. Proposal of new potential restoration areas

The following main steps further describe the approach how to delineate, assess and prioritise the restoration potential:

a) The continuous floodplain delineation gives a rather good defined working base for the active floodplain (between the current flood protection dikes) and the former floodplain (as part of the morphological floodplain delineated by natural terraces and steep banks/cliffs).

b) An initial floodplain typology according to main hydromorphological characteristics was prepared to find out differences in size and structure of potential restoration sites and to discuss initially restoration measures. For the overview study the initial step was to define “technical types” for floodplains (figure 2). The ecological typology of floodplains (e.g. according to the WFD surface water typology) will remain an important research topic.

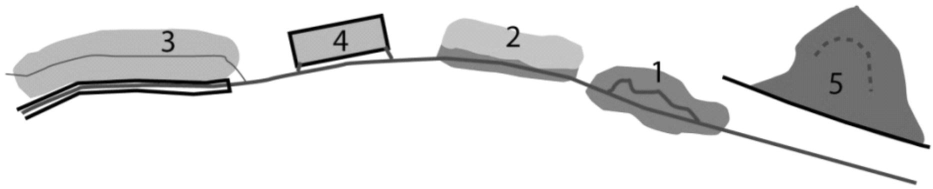


Figure 2. Floodplain types (visualized from left to right in order as they mostly occur along the Danube). Active floodplain: 3. along impounded reaches/backwaters or tributary confluences, 4. flood polder, 2. floodplain elevated by aggradation, 1. near-natural, 5. former floodplain (disconnected by dikes and dams, shown by black lines

c) The main working step was the mapping and proposal of potential restoration sites (compare figure 1).

d) The final step is the prioritisation of restoration proposals (prioritisation approaches are popular to stipulate planning approaches and measures e.g. under the WFD). Only continuous available data sets can be used for the prioritisation (metrics such as the landuse and protected areas overlay percentage, hydromorphological status classes 1-5, size classes or ratio of dike/canal length to area diameter. Based on the purpose (nature protection, ecological status under WFD and flood mitigation aspects) the prioritisation initially tries to integrate only nature protection and flood mitigation purposes (which can be evaluated individually or later extended to ecological status, e.g. for nutrient reduction in floodplains). The integration of main technical feasibility such as costs (cost benefit analysis) and land ownership were excluded so far from the prioritisation.

Based on the first study for the whole Danube basin (Schwarz 2010) and its methodological framework a second study was prepared for the lower Danube (without delta) in 2011 increasing the spatial scale of information for base information namely land use, habitats and existing infrastructure. Several areas in particular on lower tributary stretches were added and the prioritisation approach was extended now including better land cover and infrastructure data such as flood defence dikes and drainage canals. The third most detailed project (Schwarz 2012) is related to the recently established Transboundary Biosphere Reserve Mura-Drava-Danube and includes a detailed hydromorphological assessment of the river banks and the potential of bank reinforcement removal to initiate lateral erosion as well as in its extended variants the reconnection of floodplains.

Results for the Danube

Originally Danube basin floodplains would cover an area of 26,500 km², which is equal to about 3.3% of the total catchment. In recent history, 80% have been cut off by dikes and dams for flood control, hydropower generation or to improve navigability. River regulation, rectification and floodplain loss changed the hydromorphological conditions for many major rivers and cause the loss of large water retention areas, the acceleration and unfavourable superimposition of flood waves, the local increase of flood peaks and the loss of functional wetlands and their ecological services.

The loss of floodplains is in particular high on Upper Danube (in total 75%, but more than the half of the remaining areas lay in backwater stretches along the chain of hydropower plants, therefore the loss of ecologically functioning areas can be estimated with nearly 90%), Middle Danube (79%) and Lower Danube (73%). Only the delta lost only 35% of its originally flooded area (Schwarz 2010).

For the Danube itself in total 196 areas are identified amounting to 810,228 ha in total (compare figure 3). Detailed figures can be obtained from figure 4 and 5.
For an initial prioritization approach only parameters with sufficient data coverage, such as land use, overall hydromorphological intactness, protection status and area size were analysed. Of the planned and proposed areas, 33 (19%) receive a "very high" restoration potential rating, 98 (56%) a "high" and the remaining 45 (25%) only a "moderate" rating.

The total proposed area would have a significant effect on flood mitigation. A total capacity volume of about 13.5 billion m³ can be estimated.

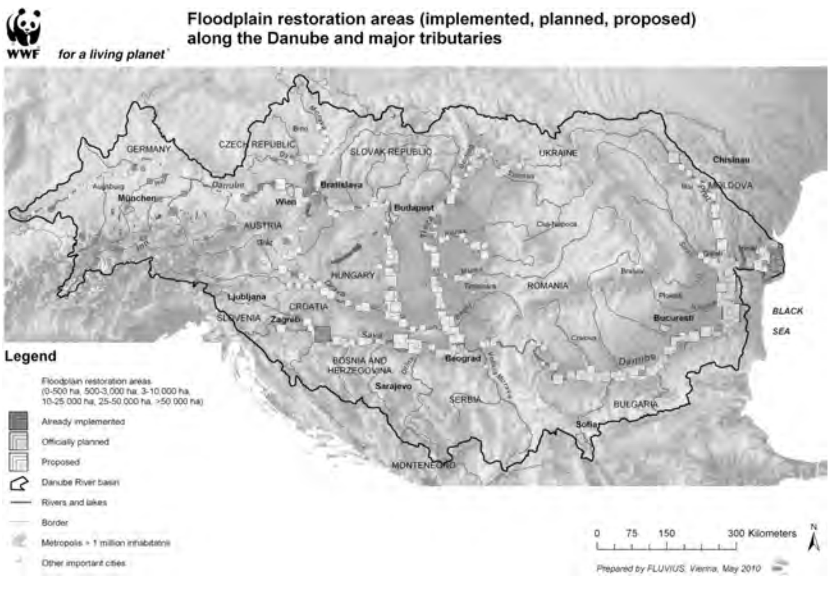
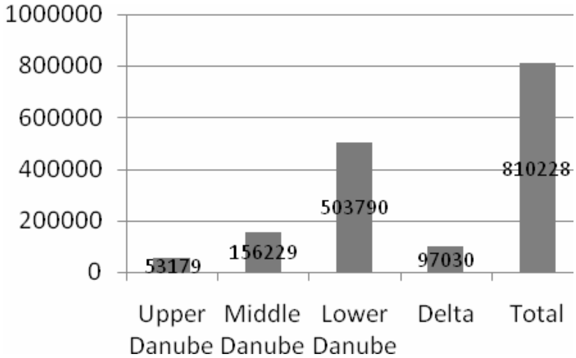


Figure 3. Map oft he Danube River Basin showing the potential restoration areas



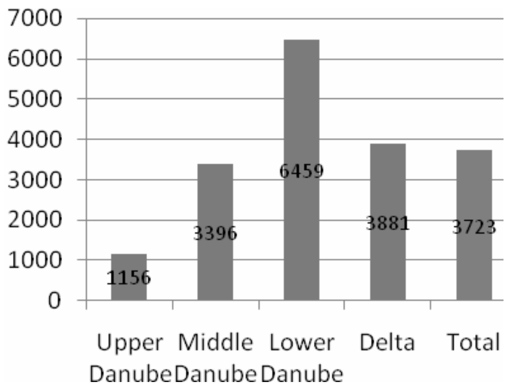


Figure 4 and **5.** Total area (left) and mean area size (right) of potential restoration areas in ha (explanation: boundaries for “Middle Danube” are Bratislava and the Iron Gate in Serbia, all other sections are self-explaining)

Conclusions

The applied methodology enables an overall proposal of potential floodplain areas suitable for reconnection and restoration for large rivers in general. This work doesn’t substitute the systematic preparation of inventories, the protection and often necessary specific restoration of still active floodplains (Schwarz 2008). The distribution and a basic typology of floodplains in the DRB should be used to define more type specific restoration targets and measures in the future.

The combination with technical aspects and feasibility (land owner, costs for measures) can further improve the prioritisation of projects. However the practical experiences of large scale river restoration projects in Europe indicate the importance of a strong local activity of stakeholders and public awareness, but also complex and long lasting planning process, missing data and funding opportunities.

Research targets should be a better understanding of different floodplain types, their hydromorphological conditions and intactness as well as ecology (in particular a better understanding of ecological processes related to the biological and physio-chemical quality elements of the WFD and vulnerability based on comprehensive floodplain inventories across the Danube basin.

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POSTERS

Topic 1
Ecological processes in riverine conditions

*(dynamics and interactions
between the environmental conditions
and the living communities)*

Linking sediment mineralization processes with nutrient dynamics of a Danube oxbow (Gemenc, Hungary)

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Keywords: microbial activity, sediment, oxbow, Danube

Introduction

Sediments play an important role in mineralization of organic matter and as a consequence in the nutrient dynamics of the aquatic ecosystems (Wetzel 2001). The mineralisation of sediment organic matter with allochthonous or autochthonous origin is realised by microorganisms, which release nutrients to the water column. These processes are regulated mainly by the physico-chemical properties of the water and sediment and by the substrate quality and availability for the sediment associated microbiota.

In sedimentological studies the measurement of microbial activity and biomass are commonly used techniques for determination of the intensity of organic matter mineralization (Håkanson & Jansson 1983). Numerous studies have investigated the metabolic activity of the sediment by using the ETS (electron transport system) activity method (Zimmerman 1975, Olanczuk-Neyman & Vosjan 1977, Trevors 1984, Broberg 1985, etc.), which is based on the reduction of an artificial electron acceptor (INT: 2-p-iodophenyl-3-p-nitrophenyl-5-phenyl tetrazolium chloride) by homogenate samples in the presence of electron donors (NADH, NADPH, succinate) added in excess and gives the maximal rate of respiration (Packard 1971).

The main objective of the work were: (1) to study the organic matter content and the carbon, nitrogen, phosphorus concentrations and stoichiometry, (2) the mineralization of sediment organic matter, (3) the possible linkages between the organic matter mineralization and the nutrient concentrations of the sediment and water column and (4) to identify which among the investigated factors influence the mineralization of sediment organic matter of Nyéki-Holt-Duna (Nyéki Danube Oxbow Lake).

Study area and sites

Gemenc is the largest natural forested floodplain of the Danube situated in southern part of Hungary (rkm 1489-1460). In 19th century the river regulation processes at this reach of the Danube shortened the length of riverbed, which resulted in increased flow velocities, river bed erosion, increase of drying processes, weakened lateral interactions, lower water supply and gradual silting-up of the oxbows (Szlávik et al. 1995). At this section of the Danube the average water discharge is 2449 m^3 sec^{-1}, the mean velocity is 0.5-1.2 m sec^{-1} and the stream gradient is 5 cm km^{-1} (Schöll et al. 2009).

Nyéki-Holt-Duna is situated on the right bank of the Danube in the active floodplain area of Gemenc (Danube Drava National Park) (Fig. 1). Its water regime depends on the water level fluctuations of the Danube; at high water levels: at 520 cm (Danube, rkm 1478, Baja gauge station), the hydrological connection of the Nyéki-Holt-Duna with the main arm is established through the Vén-Duna, Cserta-Duna, Sárkány-fok hydrological system, and at 570 cm water level (Danube, rkm 1478) also through the Felső-Címer-fok, when the lentic character of the oxbow changes to lotic (Schöll et al. 2009).

The investigations were carried out at two sampling sites: NYHD2 (46°11.563'N 18°50.834'E) and NYHD3 (46°11.489'N 18°50.937'E), prior (10.02.2009) and at the end (06.10.2009) of the vegetation period, when the water level of the Danube was below the annual average level (354 cm in 2009) (Fig. 1, 2).

Material and Methods

Sediment analyses

Sediment cores were collected with Gilson sampler (long: 40 cm, diameter: 5 cm) and sliced in the following depth classes: 0-1, 4-5, 9-10, 14-15, 19-20 cm.

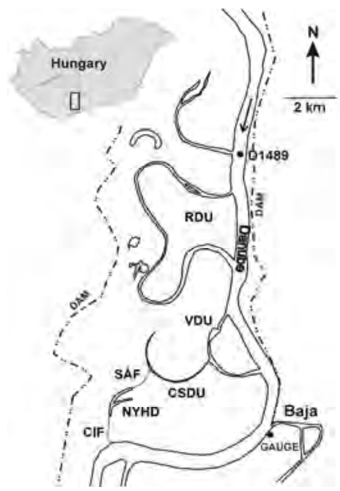

Figure 1. Sampling area (D1478: Baja station; NYHD: Nyéki-Holt-Duna, VDU: Vén-Duna, CSDU: Cserta-Duna, SÁF: Sárkány-fok; CIF: Felső-Címer-fok

All sediment samples were dried at 105 °C for 24 h for the determination of moisture content, then combusted at 550 °C for 4 h for determination of the organic matter content as the loss on ignition (LOI) (Sutherland 1998). The total carbon (TC), total nitrogen (TN) concentrations were determined by elemental NCS analyser (NA-1500 Fisons Instruments). The inorganic phosphorus (IP) was determined from dried and the total phosphorus (TP) concentration from combusted subsamples by molybdenum blue complex method after digestion with 1M HCl (Aspila et al. 1976). The organic phosphorus (OP) was calculated from OP=TP-IP. The electron transport system (ETS) activity was determined from fresh sediment subsamples taken from the above mentioned sediment layers by using the tetrazolium reduction test introduced by Packard (1971) and modified by Broberg (1985). The fungal part of the microbial biomass was estimated by extracting and quantifying the ergosterol content from the fresh sediment subsamples following the procedure of Gessner & Newel (1997) and Bååth (2001).

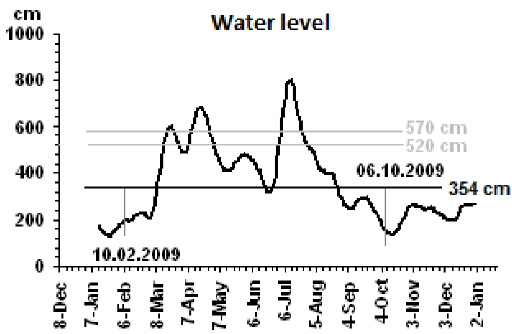

Figure 2. The water level of the Danube (rkm 1478)

Water chemical analyses

The temperature, redoxpotential, electrical conductivity, pH was determined *in situ* with WTW 340i Multi instrument. The TOC, DOC, TN, DN concentrations were determined by TOC analyser (Elementar liqui TOC) and the NH_4-N, NO_3-N, PO_4-P, TP, DTP, SPM concentrations by standard chemical methods (Golterman et al. 1978).

Statistical analysis

Pearson product moment correlation analyses of the data were performed by using the PAST statistical program package (Hammer et al. 2001).
The Danube water level data (at gauge of Baja rkm 1489) were obtained from http://www.hydroinfo.hu.

Results and Discussion

Hydrology

According to the hydrograph (Fig. 2), which presents the water level fluctuations of the main arm, three high magnitudes floods occurred between the two sampling dates.

Water chemistry

The main chemical parameters of the water are presented in Table 1.

Table 1. Chemical parameters of the water (NYHD: Nyéki-Holt-Duna)

Sites, data	Redox mV	Cond. µScm^{-1}	pH	T C°	NH_4-N µg l^{-1}	NO_3-N mg l^{-1}	TN mg l^{-1}	DN mg l^{-1}	PO_4-P µg l^{-1}	DTP µg l^{-1}	TP µg l^{-1}	TOC mg l^{-1}	DOC mg l^{-1}	SPM mg l^{-1}
NYHD2, Feb.	313	1380	7.6	3.6	20.3	0.2	2.9	2.8	1.6	32.8	71.1	14.0	13.9	7.3
NYHD2, Oct.	205	500	7.4	16.5	21.7	0.2	3.3	1.6	19.4	61.2	270.6	24.1	14.2	48.4
NYHD3, Feb.	291	785	8.3	4.0	44.1	0.1	3.9	4.0	3.7	31.5	137.0	14.3	13.8	11.3
NYHD3, Oct.	199	482	7.4	16.3	109.2	0.3	2.4	1.5	14.8	58.2	200.2	20.0	15.2	17.6

Sediment chemistry and microbial activity

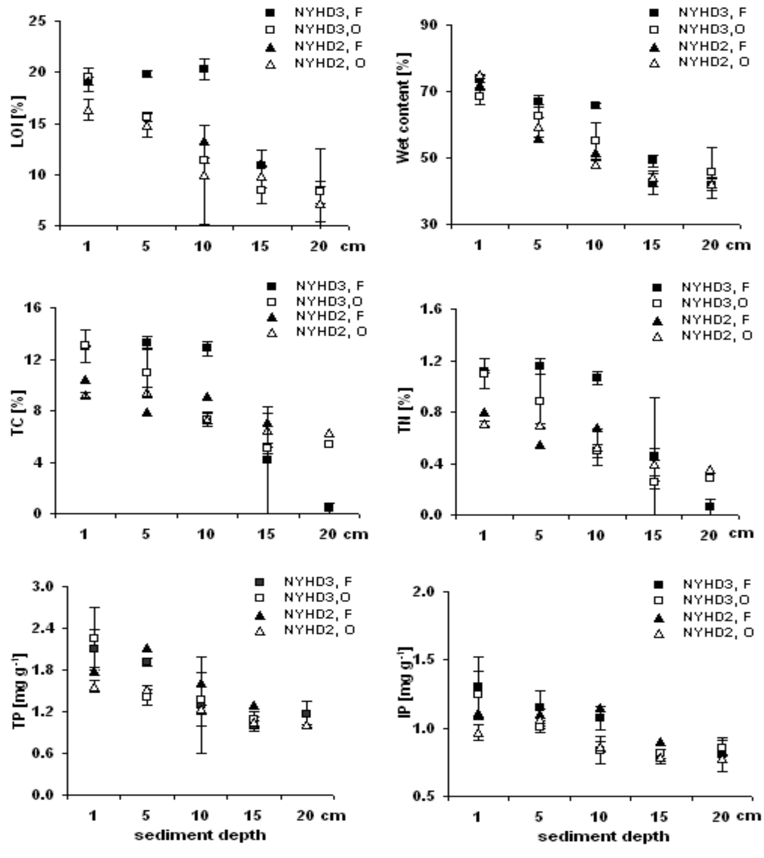

Figure 3. The organic matter (LOI) and wet content, the total carbon (TC), total nitrogen (TN), total phosphorus (TP) and inorganic phosphorus (IP) concentration of the sediment (error bars are SE for replicate measurements, n=3, except NYHD2 in Feb.)

TC concentrations were the highest in the top 5 cm sediment layer (i.e. NYHD3: 11.0-13.2%; NYHD2: 7.9-10.4%) and decreased remarkably below 10 cm of the sediment (except NYHD2 in Feb.) (Fig. 3). LOI concentrations were also high in the top 5 cm (14.9-19.8%); while in February at site NYHD3 it remained high as well to 10 cm depth (20.3%) and decreased in deeper layer. TN concentrations in the upper 5 cm sediment layer of site NYHD3 (0.88-1.15%) were higher than at site NYHD2 (0.54-0.80%) and decreased with sediment depth at both sites and date (Fig. 3). TP concentrations of the top 5 cm sediment layer were highest and varied between 1.4-2.3 mg g^{-1} then decreased in deeper layer (Fig. 3). In the top 5 cm sediment layer the IP concentration represented 52-72% and the OP content 28-48% of the TP, while in the deeper sediment layers the IP was 61-83% and the OP 17-98% of the TP, respectively. The TP in the top 5 cm sediment of Nyéki-Holt-Duna was higher than the TP in the paleopotamal sediments (top 4 cm) of River Havel (TP: 1.35 g kg^{-1} Knöscher 2006). Sediment C:N ratios were similar among the sampling sites and dates. The C:N:P stoichiometry of the sediment samples differed from the Redfield ratio (C:N=6, C:P=106; N:P=16) ranging from 14-17, 105-188, 7-14 in the top 5 cm sediment layer and from 19-23, 72-163, 4-8 in the 20 cm depth, respectively. The higher C:N and lower N:P ratio than the Redfield ratio suggested a N limitation.

The ETS-activity varied from 0.10 to 0.19 µl O_2 mg_{AFDM}^{-1} h^{-1} in the upper 1 cm sediment layer and decreased exponentially with increasing sediment depth (Fig. 4). Decrease in ETS-activity with sediment depth has also been observed in previous studies (Broberg 1985, Trevors 1985, etc). At NYHD3 the ETS-activity measured in 20 cm sediment depth represented 15-31% of the sediment surface activity and at site NYHD2: 13-18%, respectively.

The ergosterol concentration of the upper 1 cm sediment layer varied from 90.3 to 171.8 µg g_{AFDM}^{-1}, with the highest concentration at site NYHD2 in October. At both sites and dates it decreased in deeper layers. The lowest ETS value was measured in the 15 cm sediment depth in February (Fig. 4).

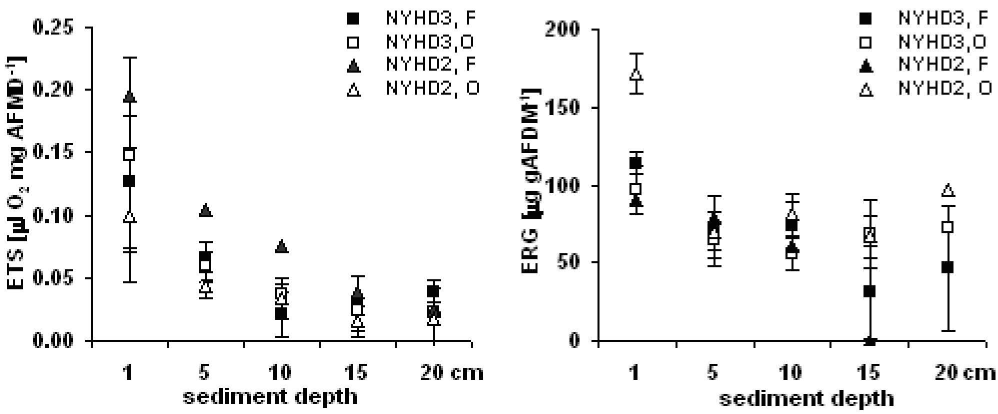

Figure 4. The ETS-activity and the ergosterol concentration of the sediment (error bars are SE for replicate measurements, n=3, except NYHD2 in Feb.)

Correlations between the examined parameters

The sediment ETS activity positively correlated with TP, LOI, TC, TN concentration and negatively with the C:N ratio of the sediment (Tab. 2). The ergosterol concentration positively correlated with the LOI (Tab. 2). The ETS activity and the ergosterol concentations did not correlate significantly with either the C:P or N:P ratio of the sediment.

Table 2. Pearson's correlation of the ETS activity and ergosterol (ERG) concentration with the chemical parameters of the sediment (r - correlation coefficient, p - two-tailed probability)

N=19	ETS-ERG	ETS-TC	ETS-TN	ETS-TP	ETS-LOI	ETS-C:N	ERG-TC	ERG-TN	ERG-TP	ERG-LOI	ERG-C:N
r	0.46	0.52	0.54	0.80	0.53	-0.30	0.39	0.36	0.39	0.47	0.03
p	0.05	0.02	0.02	0.00	0.02	0.21	0.10	0.13	0.11	0.04	0.90

Significant positive correlation was found between the LOI and OP (r=0.48, p=0.03). Zehetner et al. (2008) found positive correlation (r=0.51, p=0.021) between the organic carbon and organic phosphorus in the Danube floodplain soils at the Donau-Auen National Park east of Vienna.

Among chemical parameters of the water, ETS activity of the upper 1 cm sediment layer was positively related with TN concentration (r=0.97, p=0.03, N=4); while the ETS of the 4-5 cm sediment depth was negatively correlated with the NO_3^-N (r=0.98, p=0.02, N=4). In the upper 1 cm sediment layer the ergosterol concentration positively correlated with the SPM concentration of the water (r=0.95, p=0.05, N=4).

Conclusion

The sediment surface was characterised by high metabolic activity, organic matter, carbon and nutrient concentrations, which decreased with sediment depth. The intensity of mineralization was mostly influenced by the sediment organic matter content, C, N, P concentrations, C:N ratio and by the TN, NO_3^-N and SPM concentration of the water. The C:N:P stoichiometry indicated the N limitation of the microbial metabolism. At Gemenc floodplain these are the first results which link the intensity of mineralization with the organic matter and nutrient concentrations of sediment and water and with the sediment stoichiometry. Our results may contribute to understand the relationship between the sediment metabolism and stoichiometry and between the organic matter mineralization and nutrient dynamics of Nyéki-Holt-Duna.

Acknowledgements

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Nutrient dynamics in ecological systems of Sfântu Gheorghe branch (Danube Delta)

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Keywords: Danube Delta, nutrients, aquatic ecosystems

Introduction

A unique territory in Europe due to its great biodiversity, the Danube Delta was declared a Biosphere Reserve in 1990 and included in the world Natural Heritage List, the RAMSAR Convention List and the UNESCO program Man and Biosphere (Osterberg et al. 2000, Tudorancea & Tudorancea 2006). However, the socio-economic development in the Danube River Basin affected its evolution, especially in the last decades.

The hydrotechnical works carried out along the River Danube and its tributaries as well as within the Danube Delta, have significantly influenced the river water and sediment discharge and as a consequence the particle flux in the North-Western Black Sea (Noaje & Turdeanu 2008, Popa 1997). The first hydromorphological alterations along the Danube River consisted of floodprotection works in Austria and Hungary, in the 18th century (Jipa 2010). After the establishment of the European Commission of the Danube in 1856 in Sulina (Danube Delta), the Sulina arm was channelized and nine meanders were cut to shorten the navigation route. After two barrages were complete on the Lower Danube (Iron Gate I, rkm 943 in 1970, Iron Gate II, rkm 864, in 1983), sediment discharge, -particularly the bed-load flux of the River Danube- diminished by 25-35% (Popa 1997).

On its turn, Sfântu Gheorghe arm was subject to hydrotechnical alterations since the beginning of the 20th century: between 1903-1940, 1941-1961, 1961-1970 several large channels were built and dredged to improve water circulation within the delta (Ovejanu 2011). Moreover, between 1980-1992, six meanders were cut to meliorate navigation on Sfântu Gheorghe arm, shortening the navigation route by about 32 km (Ovejanu 2011). All these changes induced further alterations in the water and the sediment flow transported by the Danube to the sea.

The study conducted between 2008 and 2010 investigated the changes that occurred in the aquatic biocenoses of three different types of ecosystems resulted along Sfântu Gheorghe arm as a consequence of the hydrotechnical alterations: the newly formed channels, the disconnected meanders and the free flowing sections. The paper presents the physico-chemical characteristics of these aquatic ecosystems, with focus on their nutrient dynamics; future work will analyze the interrelations with the biotic communities.

Material and methods

Seasonal sampling was conducted (April, July and October) on seven stations distributed in all three types of ecosystems along Sfântu Gheorghe branch (Fig.1) between 2008-2010. The water samples were collected from within the water column, with a Patalas-Schindler device - on a transversal transect (the middle of the river and near the bank), and pooled together in an average sample.

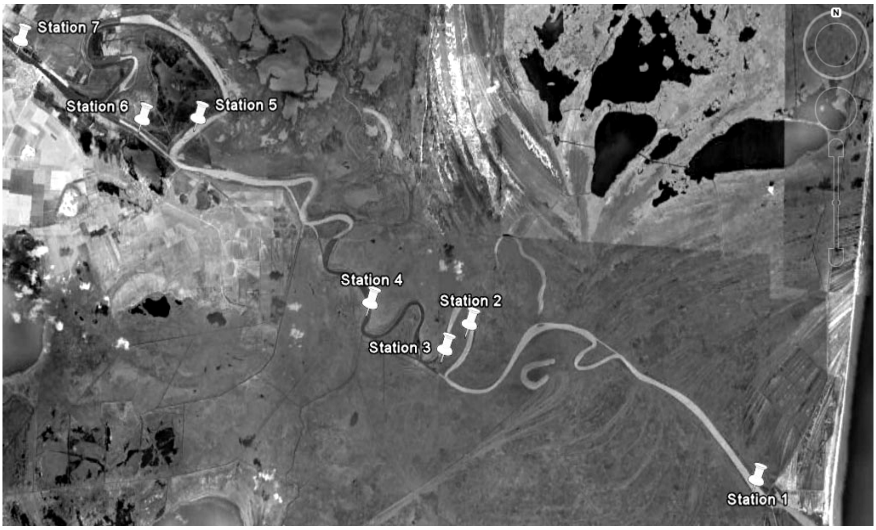


Figure 1. Location of the investigated sections: free flowing sectors: (stations 1 + 4 + 7); disconnected meanders (2 + 5); newly built channels (3 + 6). (map: www.earth.google.com)

Transparency was determined using a Secchi disk; the depth was measured with a sonar Humminbird Piranha Max 220, Technosoni Industries (USA); the temperature, pH, conductivity, salinity, dissolved oxygen content were measured in the field with a multiparameter WTW 340 i (Germany). Samples for chemical analyses were frozen for further analyses in the laboratory. Nutrients were determined spectrophotometrically: NH_4^+ - as yellow compound with Nessler reagent, NO_2^- - as red compound with sulphanilic acid and α-napthylamine, NO_3^- - as yellow compound with sodium salicylate (Tartari & Mosello, 1997), total reactive phosphorus (TRP) - as blue phosphomolybdate, reduced by ascorbic acid, and the total phosphorus (TP) – by oxidation with potassium peroxodisulphate (Tartari & Mosello 1997). The organic matter content was estimated from the chemical oxygen demand determined by oxidation with $K_2Cr_2O_7$ (COD-Cr), while the content of organic matter in the sediment was determined by loss on ignition (Golterman, 1969). Chlorophyll-*a* was extracted on-site with hot ethanol and measured according ISO 10260-1992 on a portable spectrophotometer HACH DR 2400.

Results and discussion

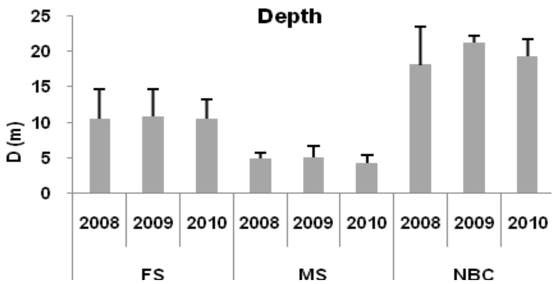
The depth variation in the investigated stretches (Fig. 2) shows a clear deepening of the river bed in the newly built channels in comparison with the free flowing sectors: the multiannual average value was almost double in the first case (19.5 m, and respectively 10.6 m). On the contrary, in the meander section, the average depth recorded between 2008 and 2010 was 4.7 m, - indicating a fast colmation.

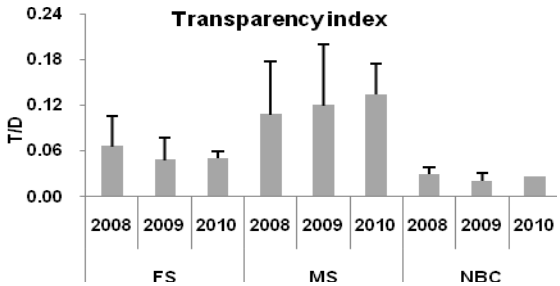
The transparency index, defined as the report between the transparency (Secchi depth) and the depth of the water column, indicates opposite dynamics: while in the free flowing section the average value was 0.5, in the newly built channel,- the average value was 0.2; the highest value was recorded in the meander section (Fig.2).

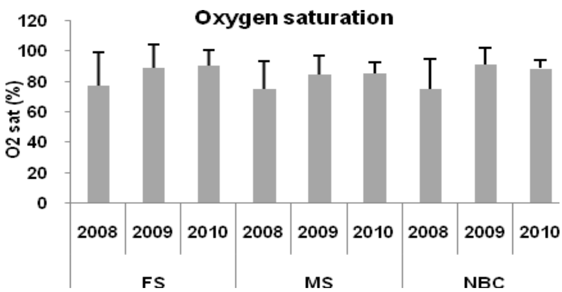
While pH, oxygen saturation and conductivity did not show large variability between the three sections, the chemical oxygen demand and chlorophyll-a recorded the lowest values in the newly built channels, indicating a low amount of organic matter and a weak presence of phytoplankton community. The highest values were recorded in the meanders section: 28 mgO/L^{-1} and respectively, 13 µg $chl\text{-}a/L^{-1}$.

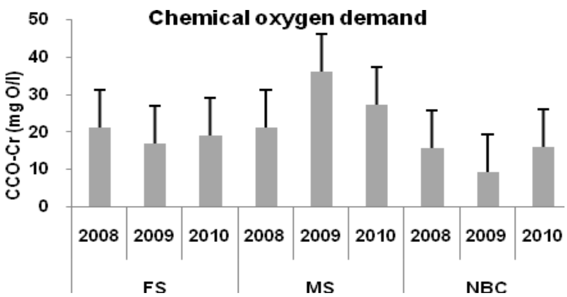
The nutrient dynamics recorded an opposite trend. Due to reduced up-take from the environment, the maximum concentrations were recorded in the newly built channels (Fig. 2). The dominant form of nitrogen was nitrate, reaching up to 81% of dissolved inorganic nitrogen (DIN), followed by ammonium (up to 19% of the DIN).

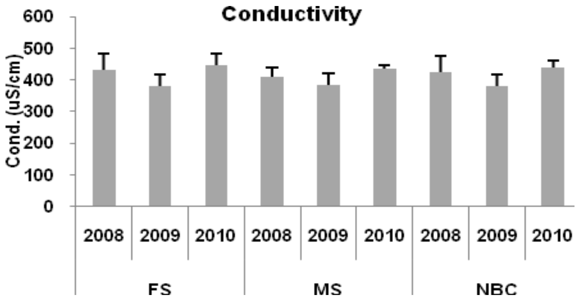
The correlations between chlorophyll-a and the abiotic parameters revealed positive linear relationships with transparency (Fig. 3a, r^2 = 0.624) and temperature (Fig. 3b., r^2 = 0.204), emphasizing the importance of both factors regarding the phytoplankton community.

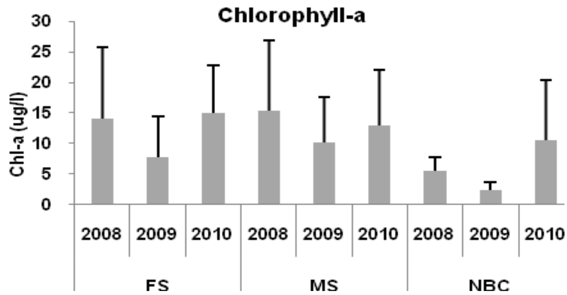

Depth
D (m)
25
20
15
10
5
0
2008 2009 2010 2008 2009 2010 2008 2009 2010
FS MS NBC

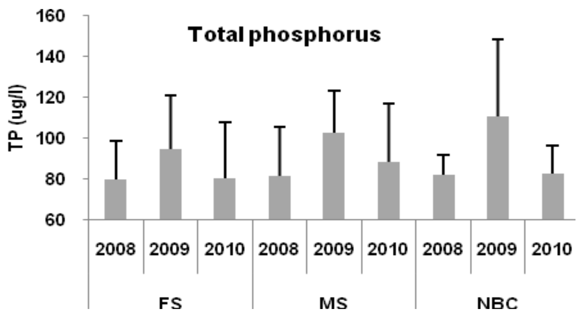

Transparency index
T/D
0.24
0.18
0.12
0.06
0.00
2008 2009 2010 2008 2009 2010 2008 2009 2010
FS MS NBC

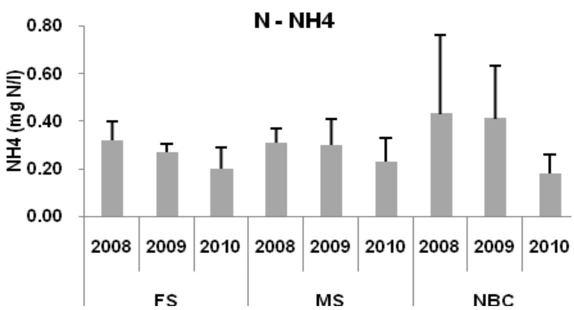

Oxygen saturation
O2 sat (%)
120
100
80
60
40
20
0
2008 2009 2010 2008 2009 2010 2008 2009 2010
FS MS NBC


Chemical oxygen demand
CCO-Cr (mg O/l)
50
40
30
20
10
0
2008 2009 2010 2008 2009 2010 2008 2009 2010
FS MS NBC


Conductivity
Cond. (uS/cm)
600
500
400
300
200
100
0
2008
2009
2010
2008
2009
2010
2008
2009
2010
FS
MS
NBC


Chlorophyll-a
Chl-a (ug/l)
30
25
20
15
10
5
0
2008
2009
2010
2008
2009
2010
2008
2009
2010
FS
MS
NBC


Total phosphorus
TP (ug/l)
160
140
120
100
80
60
2008
2009
2010
2008
2009
2010
2008
2009
2010
FS
MS
NBC


N - NH4
NH4 (mg N/l)
0.80
0.60
0.40
0.20
0.00
2008
2009
2010
2008
2009
2010
2008
2009
2010
FS
MS
NBC

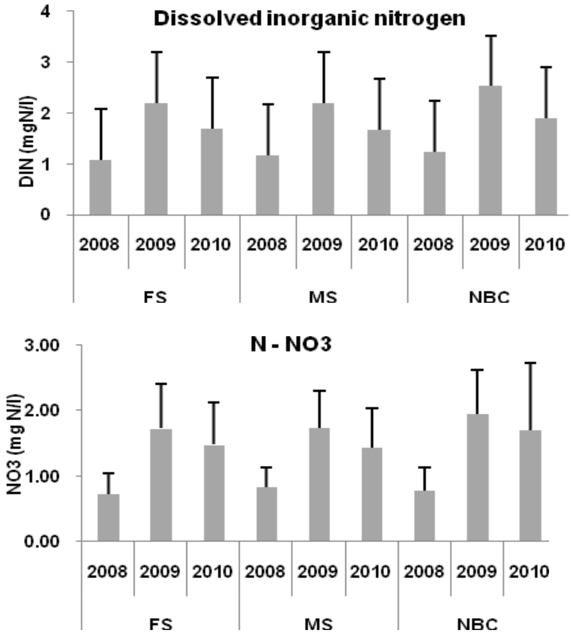


Figure 2. Physico-chemical characterization of water samples from Sfântu Gheorghe branch (FS – free flowing sector, MS – meander section, NBC – newly built channels)

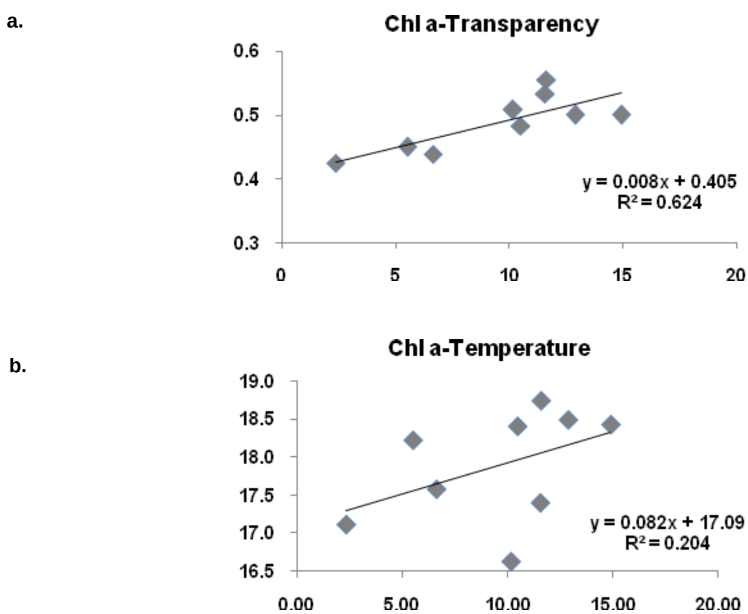


Figure 3. Correlations between chlorophyll-a and transparency (a) and chlorophyll-a and temperature (b) in the investigated ecosystems along Sfântu Gheorghe branch

Outlook and conclusions

The hydrotechnical constructions undertaken along the Sfântu Gheorghe arm induced an increased erosion of the river bed in the newly created channels in comparison with the free flowing sectors, while in the meanders a fast colmation occurs. As a consequence of the modified flow velocity and sediment discharge, transparency of the water column decreased in the new channels. In the disconnected meanders, where the particle could settle, the transparency increased, allowing improved light penetration and development of phytoplankton community. This fact is confirmed by the dynamics of chemical oxygen demand and chlorophyll-a in the meanders, providing an increased amount of organic matter and a higher biomass of the phytoplankton community. The nutrient dynamics emphasize the poor development of biological communities in the new channels; the highest values were recorded on these stretches due to the reduced up-take by the biota. The channelization induced also a loss of diversity of the phytoplankton community; the highest values for Shannon index were recorded in the free flowing sectors (Moldoveanu & Florescu 2010).

The melioration of navigation planned upstream along 800 km of the Lower Danube River and the predicted impact of climate change on the Southern part of Romania will affect biodiversity of Sfântu Gheorghe branch even more: (1) the loss of Danube River meanders and side channels will increase the flow velocity in the main branch, increasing river bed erosion, lowering the water table and reducing the nutrient cycling capacity of the adjacent floodplains; (2) the increased turbidity will decrease the ability of phytoplankton communities to synthesize the organic matter for the whole trophic network even more, inducing cascade changes along the food web; (3) increasing temperature will lower the self-purification capacity of the water and may induce a shift within the phytoplankton community towards more thermophilic cyanobacteria (Wetzel, 2001), especially in the disconnected meanders, where the reduced water flow favour their development. All these changes are expected to affect in the end the ichthyofauna and the waterfowls, with negative consequences on the biodiversity and the social-economic conditions of the area.

Acknowledgements

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****** ISO 10260:1992 Water quality – Spectrometric determination of the chlorophyll-a concentration.***

Bioassessment of a heavily modified lowland river (Tamiš, Serbia) based on phytoplankton and benthic macroinvertebrate assemblages

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Keywords: phytoplankton, benthic macroinvertebrates, altered hydromorphology

Introduction

The EU Water Framework Directive (WFD) considers a heavily modified water body as a water body which has suffered substantial changes of morphological attributes and/or alterations of hydrological regime. The heavily modified water bodies are altered by human activities, the purpose of their alteration is caused by the need to provide certain sociological and economical services. In addition, according to the WFD, the water bodies have to achieve "good ecological status", while the heavily modified water bodies need to achieve a "good ecological potential". Benthic macroinvertebrates and phytoplankton are among the most commonly used biological quality elements in aquatic bioassessments (Birk et al. 2012). While these groups have been extensively used in the past, in the assessment of pressures caused by organic pollution, their adequacy in assessing the impacts on hydromorphologically altered habitats is studied less extensively (for example: Lorenz et al. 2004). On the other hand, hydromorphological alterations have been identified as the main pressure for aquatic diversity in central European streams and rivers (Feld 2004; European Commission 2007).

Assessing the ecological state of the heavily modified water bodies poses a serious challenge in the freshwater monitoring (Kail & Wolter 2011) due to the potential absence of reference conditions or historical information. In addition, the altered hydrology and morphology is often combined with the nutrient enrichment, as it is in the case of the lowland stretch of Tamiš River (Serbia).

The Tamiš River is one of the left tributaries of the Danube River. The lowland reach Tamiš River flows through the north-eastern part of Serbia, encompassing 118 out of 359 km of the total river length. The river has suffered an extensive morphological alteration through the channelization. In addition, its hydrological regime is completely regulated by three small dams, located nearby the settlements of Tomaševac, Opovo (Site 5) and Pančevo (Site 6). According to the standard water quality parameters, measured in the investigated period (Teodorović et al. 2010), both water and sediment of the Tamiš River mostly belonged to the I-II class according to the TransNational Monitoring Network (TNMN) (ICPDR, 2009) criteria, with the general degradation of the water quality occurred downstream (especially nearby the City of Pančevo). However, according to the concentrations of nitrites and orthophosphates, the water column along the studied stretch of Tamiš River was substantially enriched with nutrients (Teodorović et al. 2010). Moreover, an organic matter load, expressed as biological oxygen consumption (BOD_5), was substantially present and increased along the hydromorphologically altered watercourse (Teodorović et al. 2010).

The aim of this study was to assess the ecological potential of a heavily modified water body using the phytoplankton and benthic macroinvertebrates. This was done by the extensive exploration of the saprobiological quality of the studied stretch of the Tamiš River during three seasons (summer, autumn and spring). Furthermore, we aimed to test whether the assessment based on two different organism groups would be correlated. In addition, this paper addresses the knowledge gap in linking biological assessment with hydromorphological state of a heavily modified water body.

Materials and methods

Phytoplankton and benthic macroinvertebrates were sampled at six sites along 117 km of the lower reach of the Tamiš River with the aim to assess the ecological potential of this heavily modified water body. The sampling was, therefore, conducted approximately at every 20 km of the river stretch, during three seasons: summer and autumn 2009, as well as spring 2010. The first sampling site (Site 1, Fig. 1) was located at the most upstream settlement nearby Tamiš in Serbia, Jaša Tomić, while the last sampling site (Site 6, Fig. 1) was located in the vicinity of the mouth of the Tamiš River, nearby the city of Pančevo.

Phytoplankton was sampled using the plankton net with the mesh size of 25 µm. Species were identified with the standard taxonomic keys and the saprobic index was calculated using the individual species saprobic values according to Gulyas (1998).

Benthic macroinvertebrates were sampled using the Van-Veen type of benthic sampler, with a sampling area of 225 cm^2. Samples were sorted immediately after collection, in the laboratory. Taxa were identified using standard keys to the lowest taxonomic resolution possible, usually species.

The saprobic index was based on individual saprobic values according to the www.freshwaterecology.info database for benthic macroinvertebrates of Europe.

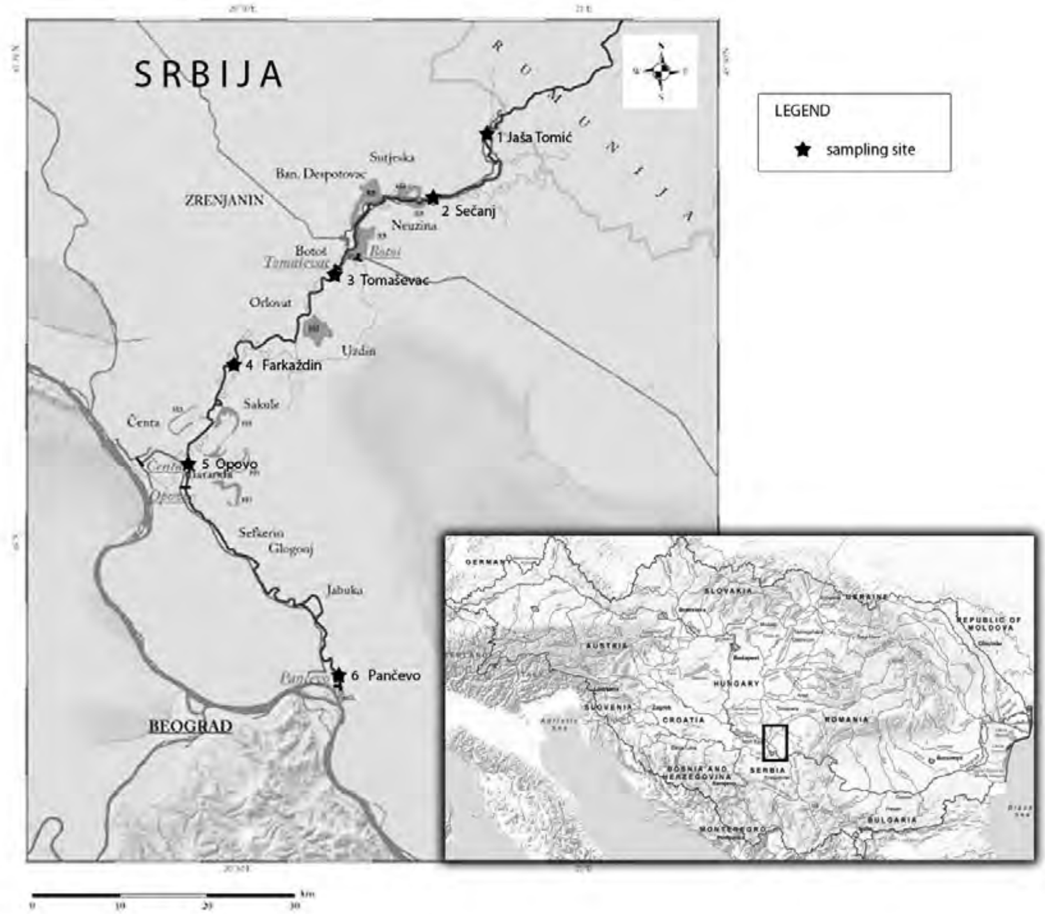

Figure 1. Map of sampling sites along Tamiš River

Results and discussion

The results of the taxonomic analysis of the phytoplankton assemblages in summer 2009 revealed the presence of 56 species belonging to 5 major taxonomic groups (Fig. 2a). The number of identified species was lower in autumn 2009 and spring 2010, respectively with 40 and 36 taxa (Fig. 2b and 2c). The results of the analysis of the taxonomic composition of the benthic macroinvertebrate assemblages indicated the presence of 39 taxa belonging to 11 major taxonomic groups: Gastropoda, Bivalvia, Amphipoda, Isopoda, Oligochaeta, Hirudinea, Turbellaria, Diptera, Odonata, Ephemeroptera and Trichoptera.

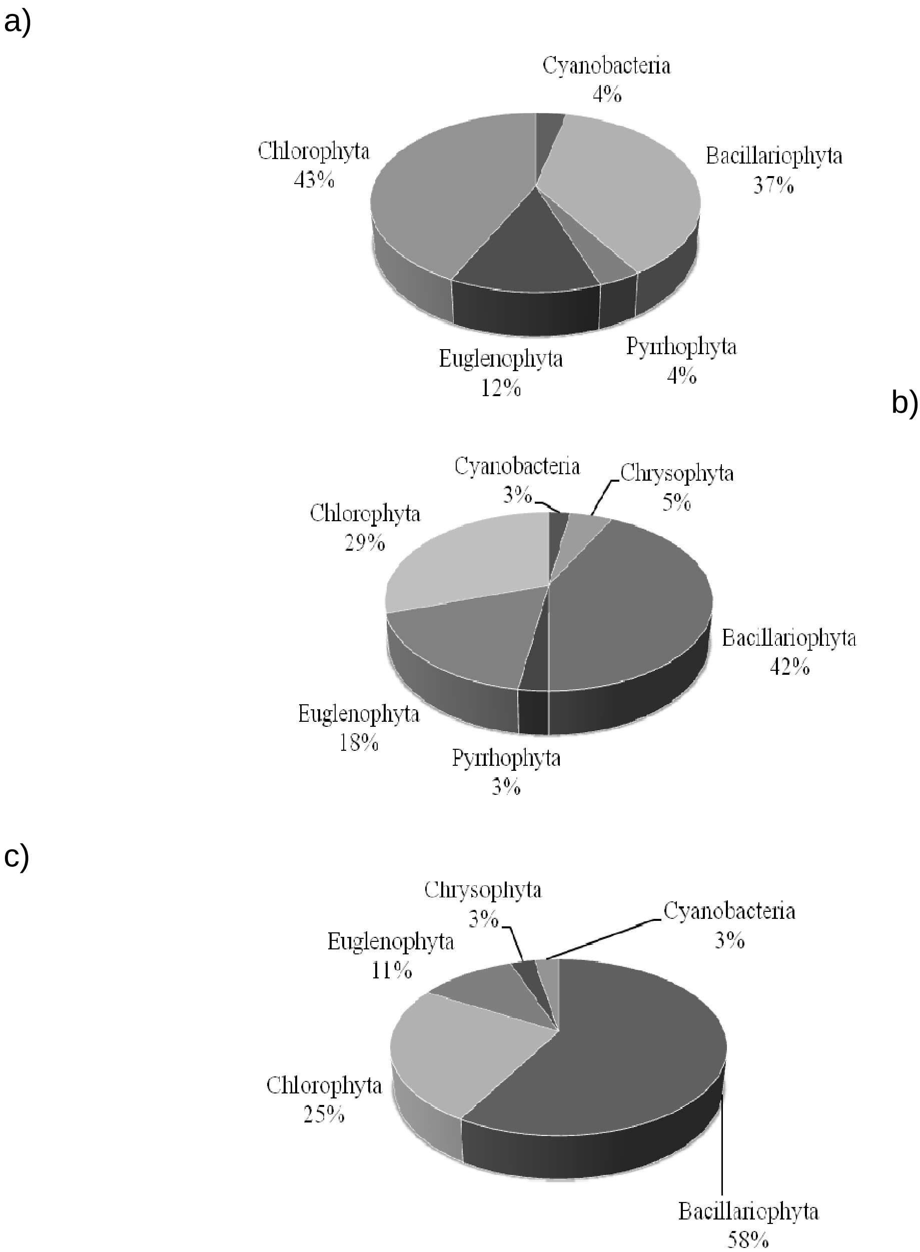

Figure 2. Proportional abundance of the main taxonomic groups of phytoplankton in the Tamiš River from: a) summer 2009, b) autumn 2009 and c) spring 2010

The evaluation based on the phytoplankton community revealed β-mesosaprobic conditions according to the TNMN classification. In addition, there was a significant moderate increase of saprobic values downstream. In contrast, the results based on benthic macroinvertebrates, suggested α-mesosaprobic conditions and a significant but low decrease of saprobic values towards the mouth of the investigated stretch of the river. Moreover, the comparison of the values of the saprobic indices indicated highly significant difference (paired t-test = -13.61, df = 17, $p<0.001$) between these water column and sediment-related assemblages (Fig. 3). Moreover, when averaged values of saprobic indices were related, the results demonstrated negative correlation between the saprobic values of the two assemblages (Pearson r= -0.85, p< 0.05). Similar results were obtained in a study of a small Belgian river when diatom saprobic index was related to the Belgian Biotic Index based on macroinvertebrates (Triest et al. 2001). The discrepancy between the two saprobic indicator assemblages could be caused by the altered hydromorphological features of the river bed and flow regime upstream of weirs (Tomaševac - upstream of the Site 3, Opovo – downstream of the Site 5 and Pančevo – downstream of the Site 6). On the other hand, the question of the adequacy of the phytoplankton for river assessment can be posed, as well as the possible need for the revision of the saprobic indicator values (Walley et al. 2001).

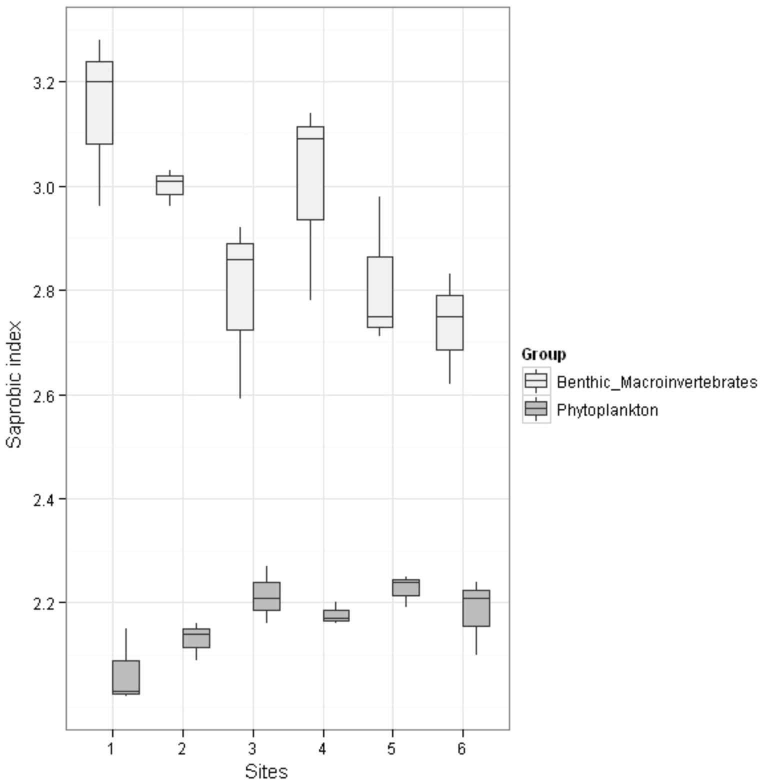

Figure 3. Values of saprobiological indices based on benthic macroinvertebrates and phytoplankton assemblages across the six sampling sites in the Tamiš River averaged for three sampling seasons (August 2009 – May 2010)

Since the ecological assessment according to WFD is based on 'one out – all out' approach, the worst result from any of the biological quality elements would imply the evaluation of the ecological status based on benthic macroinvertebrates, in this case. However, other biological elements should be considered for the assessment of the ecological status or potential, especially the morphological characteristics and the aquatic vegetation. For example, according to the Habitat Quality Assessment of the River Habitat Survey (Raven et al. 1998), the Tamiš River comprised a high diversity of the habitats, with site 1 (near Jaša Tomić) clearly distinguished by its aquatic and semiaquatic vegetation (Radulović et al. 2010). On the other hand, the results of the Habitat Modification Assessment revealed this water body to be from moderately to significantly modified (Radulović et al. 2010). According to Friberg et al. (2009), the hydromorphological degradation serve as a key pressure on river ecosystems worldwide and most river systems are influenced by multiple stressors which operate simultaneously.

Conclusions

Results of the biological assessment of the hydromorphologically impaired river Tamiš revealed contrasting state of water column- and bottom-dwelling assemblages. While according to the phytoplankton assemblages, saprobiological quality remained in the II class according to the TNMN classification, saprobic values of the benthic macroinvertebrates categorised the bottom of the Tamiš River into the III class (α-mesosaprobic conditions). The results demonstrated the need for integral multi-pressure and multi-indicator approach when assessing the ecological potential of heavily modified freshwaters and the harmonization of methodologies at European scale.

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Bioindication of water quality on macrofauna invertebrates within Kyliya Danube Delta

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Keywords: macrozoobenthos, Danube Delta, bioindication.

Introduction

Upon the approval of the European Water Framework Directive EU 60/2000 (WFD), which defined the priority of the biotic component in water management (WFD, 2000), bioindication of water contamination and ecosystem conditions are gaining more and more significance in European counties. WFD does not propose concrete approaches that are obligatory for implementation in all counties or water basins. Moreover, each country, in addition to assessments based upon the WFD principles, is free to use national-based methodologies. The adequacy of results should be reached by virtue of international trainings, intercalibrations, joint projects and expeditions. In this respect, the most significant for the Danube are the surveys performed under the aegis of ICPDR: JDS (the Joint Danube Survey) and the JDS2, conducted in 2001 and 2007, as well as the JDDS (the Joint Danube Delta Survey) held in 2011. Pursuant to WDF (2000), one of the biological elements of ecological condition classification is the composition and spread of bottom-dwelling invertebrates that are characterized (described) on the basis of a set of indexes. In the reports of the foresaid surveys, to these indexes belong species composition, quantity, biomass and establishing saprobity. The experience of international surveys of the Danube (JDS2, 2008) has demonstrated the differences between sampling and material processing methods, assessment methods that are consistent with WFD principles. The present paper is dedicated to the comparative analysis of the application of some of the well-known European indexes, as well as of the trophic-saprobiologic assessment methodology, which is in effect in Ukraine, to water contamination bioindication of the Ukrainian section of the Danube.

Methods

As materials for analysis, in 2006, 2007, and 2010 season-by-season collections of macroinvertebrates in the water bodies of Kyliya branch avandelta of the Danube (branches, bays and the internal delta Lake Anankin Kut) were used. Materials designated for bioindication were selected from the maximum number of available biotopes in accordance with European standards (Manual… 2002).

Index calculations were performed based on annual invertebrate macrofauna lists. We employed their maximum values received from each separate water body. With this approach, seasonal changes in the invertebrates' complexes composition are smoothed out, as well as the aggregated nature of their distribution, sampling inaccuracy and so on. The retrieved results in our view reflect the condition of a water body the most objectively.

Today, there exists a large number of bioindication approaches and methods (Metcalfe 1989, De Pauw 1993, Mandaville 2002). Special software has been offered that allows to easily calculate hundreds of indexes (Manual… 2002). We opted for the widely known indexes used in bioindication of pollution in large world rivers (De Pauw 1993, Miserendino 2000, Wright et al. 1993), including the Danube river (Arbačiauskas K. et al. 2008; JDS2 2008): Trent Biotic Index (TBI), Belgian Biotic Index (BBI) and Biological Monitoring Working Party Index (BMWP) were used. BBI and BMWP calculations were performed with the help of the ASTERICS 3.1.11 tool (Manual… 2002). The correspondence of TBI to saprobity zones was provided according to F. Woodiwiss (1964), BBI and BMWP correspondence to water quality classes according to standards effective in Belgium and Great Britain (Armitage et al. 1983, Biological… 1984) (Table 1).

Alongside the TBI, saprobity was also established under the Zelinka-Marvan (Z&M) method, keeping in mind that this index was also employed in the JDS and JDS2. Calculations were also conducted with the use of the ASTERICS 3.1.11 software package.

The Trophosaprobiologic Indication (TSI) of water quality was executed in conformity with the Ukrainian standard (Zhukinskyi & Lyashenko 2004) that incorporates 18 indexes, including 6 biological indexes, 10 hydrochemical and 2 hydrophysical ones. Chemical and hydrobiological materials were received in the course of implementation of the Ukrainian-Romanian-Swiss joint project titled "Comparative Assessment of Environmental Factors Influence on the water ecosystems of the Danube delta (Romanian and Ukrainian sections)" (2006-2008), as well as the project under the title of "Hydrobiological monitoring of freshwater ecosystems in the process of Danube-Black Sea fairway renewal and operation" (2005-2010).

Result and Discussion

Macrozoobenthos had a similar initial taxomonic structure in all water bodies: Chironomidae and Oligochaeta were characterized by the largest species diversity (Figure 1). Also many species of Gastropoda and Crustacea were noted in the branches and bays.

A total of 234 species of invertebrates were registered, of which 118 belong to the saprobity indicator species, among which only 12 species are good saprobity indicators (with the weighting factor equaling to 4), 47 species have the weighting factor of 3, and 41 species, that of 2; 18 species can be attributed to very poor indicators, their weighing factor being as low as 1.

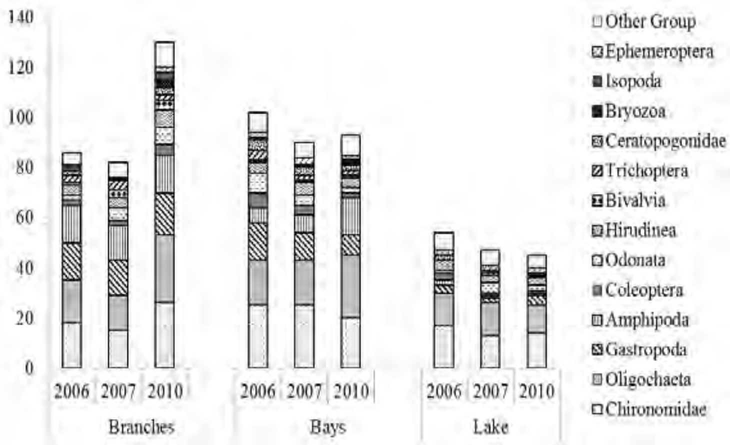

Figure 1. Taxonomic composition of macrozoobenthos of water bodies of Kyliya delta of the Danube.

Oligochaeta are the most diversely represented in the branches and bays where the representatives of all registered families were found: Enchytraeidae, Naididae, Tubificidae, Lumbricidae and Lumbriculidae.

In the lake, the representatives of two families were noted – Naididae and Tubificidae. The majority of species are ineffective saprobity indicators (weighting factor equals to 2 or 1). Effective indicators with the weighting factor of 4 are *Dero digitata*, *D. obtusa* and *Pristina bilobata* (α-mesosaprobes), *Branchiura sowerbyi* and *Psammoryctides albicola* (β-α-mesosaprobes). *Limnodrilus hoffmeisteri* and *Tubifex tubifex* (α-polysaprobes) possess the weighting factor of 3.

Crustacea is represented in the delta branches and bays by 5 orders and 8 families, of which Amphipoda stands out as the most diverse. In the lake, 1 species of Isopoda *(Asellus aquaticus*) and three species of Corophiidae were registered. Seven species of Crustacea are saprobity indicators with the weighting factor of 3. Of them, *A. aquaticus* is an α-mesosaprobe and the remaining ones (*Jaera istri, Corophium curvispinum, Echinogammarus ischnus, Dikerogammarus haemobaphes, D. villosus* and *Limnomysis benedeni*) are β-mesosaprobes.

Insects were represented by 39 families and 7 orders. In all water bodies, Diptera appeared to possess the greatest species diversity. Noted in branches and coves: α-mesosaprobes with the weighting factor of 4 (beetles *Cybister lateralimarginalis* and caddis flies *Ecnomus tenellus*) and with the weighting factor of 3 (beetles *Helophorus aquaticus*, *Enochrus bicolor* and *Peltodytes caesus*); β-mesosaprobes (caddis flies *Agraylea multipunctata,* *Cheumatopsyche lepida, Leptocerus tineiformis, Mystacides longicornis, Neureclipsis bimaculata* and *Orthotrichia costalis*, damselflies *Calopteryx virgo, C. splendens, Coenagrion puella, Erythromma najas, Gomphus flavipes* and *Ischnura elegans,* ephemerans *Caenis horaria,* midge mosquitos *Cladotanytarsus mancus, Procladius choreus, Psectrocladius sordidellus, P. psilopterus* and *Tanypus kraatzi*).

Many saprobity indicator species were found among the most numerous representatives of Chironomidae benthos (36%), however, the majority of them possessed a low weighting factor – 2 or 1.

In branches and bays, taxons were registered that are used in the calculation of pollution indexes as clean water indicators: the caddis flies of the Leptoceridae and Ecnomidae families and the dragonflies of the *Lestes*, *Calopterix*, *Aeschna* orders.

Gastropoda are most diverse in the delta branches – featuring 11 families. Among the mollusks, β-mesosaprobes were prevalent. In the lake, only the representatives of pp. *Lymnaea*, *Anisus* and *Acroloxus* – poor saprobity indicators with a low weighting factor – were detected. Good indicators with the weighting factor of 4 were found in the branches (*Lithoglyphus naticoides)*, bays (*Planorbis carinatus)* and both in branches and bays (*Theodoxus danubialis)*. Also there are widely spread in branches and bays with the weighing factor of 3: *Bithynia leachii, Stagnicola palustris, Physa fontinalis, Planorbis planorbis* and *Viviparus viviparus*.

The majority of indexes were used for TSI calculation were characterized by a wide range of values, which was connected with the seasonal and annual differences of the Danube’s hydrochemical state (Table 1). The variability of concentrations of nitrogenous compounds, oxygen, phosphorus etc. is linked to the hydrocoles’ vital activity and arrival of pollutions from the above-lying land plots and settlements (Hydroecology…, 1993). However, for separate indexes of delta water quality, no clear seasonal dynamics and dependence upon certain factors was established. According to the results of our research, (see Table 1), the overall quality of water did not depart outside the boundaries of classes II-III, β–α-mesosaprobic.

Z&M index values were rather stable and fluctuated within the range from 2.21 to 3.06 – β-α-mesosaprobic water. The water in the branches was characterized with the smallest index values. In the bays and lakes, saprobity was somewhat higher. TBI values also changed within a narrow range from 7 to 9 points, which corresponds to the oligosaprobic water. BBI amounted to 6-9 points in the branches and bays, which corresponds to I-III quality classes, and to 6-8 points in the lake – III-II classes. Minimum BMWP values were noted in the lake (33 points, IV quality class), while the maximum indexes were established in bays (up to 98 points, II quality class).

Assessments were performed by virtue of various methods (see Table 1) demonstrated a certain difference in results. Saprobity changed from oligosaprobic water under TBI to α-mesosaprobic water under TSI and Z&M index and the water quality class varied from I, according to BBI, to IV, according to BMWP. Complete coincidence of assessment results was characteristic of Z&M index and TSI. BBI and BMWP yielded close to assessment results. TBI, in all cases, indicated cleaner oligosaprobic water, which was inconsistent with the results based on other indexes. Undoubtedly, the real indexes, what is more, when retrieved under different methods, at certain moments of time and certain points that may differ from one another and go beyond the limits of the stated classes. In general, the avandelta waters of Kyliya branch of the Danube were β–α-mesosaprobic, predominantly of the II-III quality classes; We believe, that the oligosaprobic zone is overestimated to some extent according to the TBI and I quality class in accord with BBI.

Table 1. The assessment of water quality under trophic-saprobiologic indicators (based on 2006, 2007 and 2010 materials).

Indices	Branches	Bays	Anankin kut Lake
Trophity-saprobiological estimation			
Transparency, m	0.1–0.7	0.1–1.0	0.3–1.3
Suspended substances, g x $m^{-3}m^{3}$	30–134	14–80	12–35
pH	7.8–8.2	7.8–8.9	7.7–8.5
NH_4^{+}-N mg l^{-1}	0.01–0.40	0.01–0.37	0.05–0.34
NO_2^{-}-N mg l^{-1},	0.01–0.20	0.00–0.10	0.01–0.03
NO_3^{-}-N mg l^{-1}l	0.10–0.98	0.13–0.87	0.10–1.10
PO_4^{3+}-P, mg l^{-1},	0.04–0.46	0.03–0.55	0.02–0.50
O_2, mg l^{-1}, dissolved oxygen	4.9–13.9	3.0–13.6	0.1–13.3
O_2, %, saturation	59–131	30–150	1–160
KOI_{Cr}, mg l^{-1}	13–80	8–114	19–74
BOD_5, mg O_2/l	0.2–8.8	2.1	2.0
Phytoplankton biomass, mg dm^{-3}	0.2–5.3	1.1–5.0	1.0–11.6
Number of bacterioplankton, million cells ml^{-1}	5.2–7.1	6.4–10.4	6.1–8.7
Pantle-Buck index	2.1–3.7	2.3–3.8	3.0–3.8
Goodnight-Whitley index	12–100	47–94	41–95
TSI	2.7–5.2	3.2–5.1	3.5–4.9
Saprobity by TSI	β–α-mesosaprobic	β–α-mesosaprobic	β–α-mesosaprobic
Class of water quality	II–III	II–III	II–III
Bioindication of saprobity and water quality			
Values of Z&M index	2.21–2.55	2.56–2.93	2.31–3.06
Saprobity evaluation by Z&M index	β–α-mesosaprobic	β–α-mesosaprobic	β–α-mesosaprobic
Class of water quality by Z&M index	II–III	II–III	II–III
Values of TBI	7–9	8–9	7–9
Saprobity evaluation by TBI	oligosaprobic	oligosaprobic	oligosaprobic
Values of BBI	9–6	9–6	8–6
Class of water quality by BBI	I–III	I–III	II–III
Values of BMWP	95–63	98–47	60–33
Class of water quality by BMWP	II–III	II–III	III–IV

How can the obtained results be evaluated? What assessments can adequately reflect the real state of things? What indexes "work" better? In view of the fact, that a modern mathematical instrument allows to calculate tens and hundreds of various indexes, these questions are rather current. We answered them within the present paper on the basis of certain assumptions, i.e. results should correspond to the general ecological situation and its longstanding changes and should be confirmed by virtue of other research. We also presupposed that coincidence of assessments received through various methods increases the reliability of results.

Water quality assessments, based on the trophic-saprobiological indicators in the Lower Danube, can be traced from as far back as the 1950s, when they were the highest at the time (Kharchenko at al. 1999). In the 1970s, as compared to the 1950s and the 1960s, water quality lowered – according to average indexes, the quality class changed from II to III (Environmental … 1984). In the 1980s and the 1990s, the worst indexes were captured, water quality reached the IV class (Oksijuk et al. 1992). At the beginning of the 21st century, we noted a certain improvement of water quality, now shifted from class IV to class III. Similar results – improvement of water quality and water community conditions in the Lower Danube after 1995 – have been publicized by other researches (Ibram et al. 2001, Zinevici & Parpală 2007).

An adequate assessment of the present-day quality of Danube water can be based on the results of the international Danube Survey JDS2, conducted in the summer and fall of 2007 under the aegis of the International Commission for the Protection of the Danube River (ICPDR), which is nowadays one of the most authoritative bodies of the European community in the sphere of the Danube water quality and water ecosystem conditions control. The results of ICPDR examination (2008) demonstrated that the waters of the Ukrainian section corresponded to the β-mesosaprobic zone (Z&M index of macrozoobenthos changed within the scope of 2.15-2.24), which is somewhat below our survey results (see Table 1). However, this discrepancy is rather acceptable, in view of the fact that in the framework of the JDS-2, research was conducted only at 4 stations in the sections of the delta with the most running water.

Conclusion

The conducted assessments of pollution are based on saprobity indications, biotic indexes and trophic-saprobiological indexes yield grounds to assert that the waters of the avandelta of Kyliya branch are at present predominantly β–α-mesosaprobic possessing the II-III class of quality. A trend has been noted towards a slight quality decrease in water basins in comparison with watercourses. The employed methods yielded similar and correlated assessment results (the exception being TBI), which, in our opinion, illustrated the possibility to apply them in the monitoring of the Danube's ecological condition. The analysis of self-obtained and published research materials testifies a certain improvement of water quality in the Lower Danube in the last 10-15 years. Perhaps, the situation is mainly factored by the economic crisis of the late 20th century that befell Central and Eastern European states after the collapse of the USSR, as well as by the global economic crisis of the latter years. At the same time, one should not underestimate the environmental protection activities of the Danube region countries, the work of international ecology organizations and the efforts of the scientific community.

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Topic 2
Longitudinal, vertical and lateral connectivity in riverine landscapes

(in main channel, side arms and active river-floodplain systems, effects of water regime)

Distribution of structural and functional characteristics of the macroinvertebrates' communities along the longitudinal profile of the of the Upper Tisa basin's rivers

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Keywords: mountain rivers, altitude zonation , macroinvertebrates.

Introduction

Diversity of natural conditions in the upper Tisa basin stipulates a high variety of rivers. They differ by their catchment areas, direction of flow, quantity and quality of the sediments, bottom surface profile, riverbed and river valley morphology, temperature and oxygen characteristics. All these parameters are subordered to the altitudinal zonation and condition occurrence of the different-type of aquatic organism communities. At present there is no single opinion on structural organization of the riverine biocenoses. The most widely accepted is the Vannote's conception of the river continuum (Vannote 1980) and the Townsend's conception of the patches dynamics (Townsend 1989), which are based on distinct ideas on structure of the natural complexes of the riverine biota and mechanisms of its maintenance.

Structural and functional parameters of the macroinvertebrates' communities have been studied since 2000. Habitats were analyzed by general survey of riverside zone and river bottom. Available heterogeneities of the habitats were distinguished according to the AQEM monitoring scheme with some modifications, meaning that samples were not averaged, but were taken from each habitat and processed individually. Samples were taken, conserved and processed according to Ukrainian hydrobiological standards. Furthermore macroinvertebrates' samples were taken with the "kick and sweep" method (EU standard). Those samples which were taken directly over floods, high water, after high water, samples from the non-specific and experimental substrata, drift samples and samples taken directly downstream the rivers' confluence were discarded. The obtained material was statistically processed and functional characteristics of the benthic communities were calculated using the specially developed original software AquaBioBase (Afanasyev, Usov, Pilevich, 2010), which corresponds to the European ASTERICS and Soviet software WACO.

In rivers and other water bodies of the Ukrainian section of the River Tisa basin 267 macroinvertebrates taxa of 20 taxonomic groups were registered. Among them Chironomidae larvae – 57 species, Ephemeroptera nymphs – 55, Trichoptera larvae – 33, Plecoptera nymphs – 29, Oligochaeta – 22, Gastropoda and Bivalvia – 18, Hirudinea – 11, Odonata nymphs – 8, Amphipoda – 5 and other Crustaceans – 6 species, and 23 species of other taxonomic groups (1–3 species of each).

On the basis of similarity analysis of the species composition and quantitative parameters of the benthic fauna at different monitoring points of the Tisa River basin, it was stated that composition of species inhabiting certain sections differs depending on localization of these sections. Species composition in all rivers is formed according to the similar scenarios and of the single biological resource, peculiar for the mountain rivers of the Transcarpathian region. However rivers flowing westwards (western hydrological sub-region) show differences in composition and quantitative relations of the aquatic organisms as compared with those directed south (eastern hydrological sub-region). Thus, in sub-basins of the Latoritsa and Uzh Rivers, directed mainly to west, only 10 species of Ephemeroptera were found, among them *Ecdyonurus affinis*, *E. venosus, Cloeon simile, Ephemerella mesoleuca*, *Caenis horaria* practically did not occur in the Tisa River itself and its south-directed tributaries. In the latter this group was quite diverse, about 40 species. Analysis of other groups of Insecta (Chironomidae, Plecoptera and Trichoptera) also demonstrated their notably lower diversity in the Latoritsa and Uzh basins as compared with rivers Rika, Teresva, Tereblia, Borzhava, White and Black Tisa. Besides, these rivers are similar in terms of the macroinvertebrates species composition; values of Sørensen coefficient were between 0.50–0.65. At the same time they differ from the rivers Latoritsa and Uzh, whereas the latter in turn are similar: Sorensen coefficient was between 0.5–0.7.

It was supposed (Afanasyev 2006) that the mentioned differences in the benthic invertebrates composition were conditioned by streams' different diurnal warming regimes, flowing along the differently-directed valleys (canyons). However, similarity analysis on the invertebrates' composition of the Romanian (left-bank, mainly northern-directed; Vişeu, Iza, Sepintsa) and Ukrainian (the right-bank, mainly southern-directed) tributaries of the Tisa River revealed that bottom fauna of all these rivers was similar. In the Latoritsa and Uzh river basins, sources are located at lower altitudes, therefore taking this fact into account it is supposed that the absence of the "highland" type of the water bodies leads to somewhat impoverishment of the species composition as compared with rivers with sources at high altitudes. Besides, this can be conditioned by other reasons of historical nature, particularly by belonging of these rivers to the basin of the Upper-Tisa Lake, which existed from Pliocene to the middle Pleistocene (Afanasyev, in print).

In the upper sections of rivers of the western hydrological sub-region (low-water season, without pollutions, invertebrates were distributed as follows: Plecoptera nymphs – 9 species; Ephemeroptera nymphs – 15, Trichoptera larvae – 12, Odonata nymphs – 5 species. In the most typical natural river sections occurred *Ancylus fluviatilis, Gammarus balcanicus, Perla abdominalis, Leuctra nigra, Isoperla* sp., *Chloroperla apicalis, Acrynopterix* sp., *Ecdyonurus venosus, Ecdyonurus affinis, Rhyacophila* sp., *Sericostoma* sp., *Onychogomphus forcipatus.*

In the lower river section, transitional to the plain, relation of groups was somewhat other: Plecoptera nymphs – 6 species; Ephemeroptera nymphs –10, Trichoptera larvae – 10, Odonata nymphs – 5, bivalve mollusks – 3 species were observed. In the relatively not-disturbed sections occurred *Hirudo medicinalis, Lymnaea truncatula, Crassiana crassa, Cloeon simile, Ecdyonurus venosus, Chloroperla apicalis, Isoperla grammatica, Hydropsyche ornatula, Cordulegaster bidentatus, Calopteryx virgo*.

Characteristics of the bottom fauna distribution in different sections (eastern hydrological sub-region) was as follows: in the highland sections Plecoptera nymphs – 12 species, Ephemeroptera nymphs – 15, Trichoptera larvae – 12, Odonata nymphs – 3 species. Among species, character for the natural sections were noted: *Crenobia alpina, Erpobdella monostriata, Nyphargus stugius, Perla abdominalis, Taeniopteryx auberti, Baetis alpinus-lutheri* grs., *Rhyacophila obliterate, Rhithrogena* sp., *Hydropsyche bulbifera, Mystacides azureus*.

In the middle altitudes occurred Plecoptera nymphs – 10 species, Ephemeroptera nymphs – 15, Trichoptera larvae – 12, Odonata nymphs – 5 species. In absence of pollution and anthropogenic transformation of the river bed and flood land were noted *Ancylus fluviatilis, Trocheta bykowskii*, *Perla abdominalis, Acrynopterix* sp., *Amphinemura* sp., *Taeniopteryx schoenemundi, Caenis beskidensis, Ephemera lineata, Sericostoma* sp., *Rhyacophila obliterate, Hydropsyche bulbifera*

Transitional sections were characterized by these main invertebrates taxa: Plecoptera nymphs – 7 species; Ephemeroptera nymphs – 10, Trichoptera larvae – 10, Odonata nymphs – 5, bivalve mollusks – 3 species. In the most typical, clean sections of the rivers occurred *Crassiana crassa, Gammarus pulex, Caenis beskidensis, Caenis luctuosa-macrura complex, Ephemera lineata*, *Nemoura* sp., *Isoperla grammatica.*

Further analysis of the structure of the mountain rivers' biota demonstrated that independently on distinctions in qualitative composition of the benthic communities; the character of modifications in their structural-functional parameters were found to be similar within the different hydrological sub-regions.

Probably, changes in the structure of benthic communities from the river source to its plain sections are caused by hydrological modifications. In the Carpathian streams these modifications are in quite good agreement with altitudinal zonation, in the sense of the WFD. It can be a marked zone of the stable grounds in the headwater, zone of intensive erosion, zone of mobile and suspended sediments transport and deposition. The closer the river section is to the lower valleys, higher the temperature and less the average size of the bottom substrate particles are. Analysis of the benthic invertebrates abundance in gradient of the substrate particles size demonstrated that these parameters were inversely dependent. The Spearman’s correlation between the substrate particles’ size and numbers amounted to $R = 0.929$ at p-level = 0.003 (Afanasyev et al. 2008). So, taking this dependence into account it is supposed that the bottom invertebrates’ numbers would decrease with the decrease in altitude. At the same time dependence of quantitative parameters and species number on altitude has an S-shaped curve. The highland zone, located at about an altitude of 1000 m a. s. l. is characterized by quite high species number, number and biomass of the bottom invertebrates, average parameters reached up to 30 taxa, 12000 specimens m^{-2} and 300 g m^{-2}. Below 1000 m a. s. l. a sharp decrease in structural characteristics occurred, their trend’s minimum was noted at the altitude of 800 m a. s. l., which is pointed out as a limit between “highland” and “middle altitudes”. Here only 10 species of invertebrates were noted. Their biomass and numbers did not exceed grams and hundreds of specimens per m^2. Downstream all parameters gradually increased. Numbers and species richness of the benthic communities reached their maximum at the altitude of approx. 300 m. Maximal number of taxa in a sample reached up to 70 (average 32). Maximal numbers reached 45000 specimens m^{-2}, average – to 15000 specimens m^{-2}. Downstream regarding these parameters either sharp (in terms of species number) or gradual (in terms of numbers) decrease was observed. Biomass of the benthic invertebrates reached the second maximum at the altitude of 200 m a. s. l. (which is pointed out as limit between “middle altitudes” and “lowland”) and remained at this level up to rivers entering the Transcarpathian lowland. Maximal biomass reached 1000 g m^{-2} (in case of the mollusks occurrence on the river bottom), average – to 380 g m^{-2}. At the same time inverse dependence was noted for oxygen consumption per 1 m^2 per day, which is an important parameter of functional activity regarding the bottom communities. Independently on structural characteristics’ significant variations, oxygen consumption at all altitudes was quite stable (average 10 mg O_2 m^{-2} per day). Deviations from average notably increased at lower sampling site altitudes. Such pattern in functional activity of the bottom communities was conditioned by normal distribution of temperature along the river stream, over the summer low-water period and stable fair weather. Any temperature changes could significantly change the revealed pattern.

Conclusions

On the contrast to the species composition - which is mainly conditioned by hydrological sub-region, changes of the integral structural-functional characteristics of the benthic communities were conditioned by changes of the temperature regime, water level, granulometric composition and mobility of the bottom sediments from the river source to the lowland. In the zone of the stable sediments at the altitude of 1000 m a. s. l. and above communities with high species numbers were formed, which are presented relatively evenly. In zones of intensive sediment erosion, forming of stable communities is practically impossible – species number decrease, their combinations are random, portion of species, adapted to constant erosion increased. Intensive channel processes condition “dip” of the quantitative parameters at the altitude of 600–800 m a. s. l., where intensive retrogressive deposition of the bottom sediments occurs. In the zone of the sediment transport, where erosion is alternated with partial deposition, habitat diversity grows, thus species number increases, and dominance decreases. When bottom sediments change to accumulative type, wider diapason of parameters and growth of the general dominance increases. The average functional activity of the mountain rivers’ bottom sediments is quite stable along all river streams from the source to lowland. At this S-shaped character of trend is “equalized” by the antagonistic effects on the integral parameter of the community functioning, particularly by growth of the average size of a specimen, which leads to a decrease in oxygen consumption; and by gradual growth of temperature, which leads to an increase in oxygen consumption.

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Support investigation of fishpass operation at the Denkpál tributary closing

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Introduction

On the meeting on 25th of March 2011, the Hungarian-Slovakian Water Commission’s Danube Subcommission defined the task to accomplish investigation on migration of aquatic organisms across water installations around Dunakiliti. In this regard we investigated a fishpass was built near the water level control sluice at the Denkpál tributary closing in the Szigetköz floodplain of the Danube.

It was put into operation in 1998 and it was the first fish pass with bypass channel in Hungary. It bridges a 4 m height difference between the main arm of the Danube and the floodplain side arm system. The first study on operational efficiency of the fish ladder was implemented between 1998 and 2011 (Guti 2002, 2003, Guti & Pannonhalmi 2006, Pannonhalmi & Guti 2002), and since then no comprehensive survey has been carried out. In the last decade, the fish pass was damaged by several floods and the structure was reconstructed. A new study was accomplished in September 2011 and it was purposed to compare the current results with the former ones and provide information about fish pass operation.

The fish pass

Before the construction of the Gabcikovo hydropower dam the right side (Szigetköz) and left side (Csallóköz) floodplain branchsystems were connected through the main riverbed. This connection was lost because of water level decrease in the main riverbed due to diversion of river discharge into bypass canal of the hydropower dam. The water level in the branchsystems was increased by artificial water replenishment and tributaries of the branches were closed by dams.

Closure of the sidearm outlets by dams has blocked the migration route for fish between the main riverbed and the side arms. Lateral connectivity at the Denkpál tributary was rehabilitated by the 250 meter long fish pass. It is divided to 4 cascades, 20 small pools and 3 resting pools.

Previous studies

The earlier studies on operational efficiency of the fish pass was accomplished by Guti (2002, 2003). The first survey was in 1998 just 2 months after the starting operation of fish pass. Next sampling was in 1999 and three suveys were carried out in 2001. Sampling devices were a back pack electro fishing unit and two cage-like fish traps. Investigations detected 32 fish species in the fish pass. The lower part of the fish pass (downstream from the lower resting pond) was not sampled, because it was not wadeable and the upstream concrete section of the fish pass channel was investigated by fish traps.

Methods

In our inspection in October 2011, we used battery powered electro-fishing equipment for the full length of the bypass channel (including the four cascades). The upstream and downstream water space were sampled by a large (8 kW) electro fishing machine powered by aggregator. Before the fishing we stopped the upstream inflow of the fish pass. After 10 minutes the water levels decreased and pools became suitable to wade. Catches were recorded pool-by-pool.

Downstream from the fish pass we investigated both sides of the branch and its internal area was scanned diagonally. We closed the water level control sluice because of its disturbing effect. Upstream from the control sluice, we sampled two 300 m long cross-sections (one of both was at the edge of the Alsó-Jakab island).In the upper concrete section of the fish pass we used the same fish trap, which was used by Guti (2002, 2003). The trap was set up twice after the electrofishing. The first sampling period was 12 hour overnight and the second sampling phase was 36 hours.

Results of the survey

We collected 347 specimens of 22 fishspecies. The biggest one was a 42 cm long burbot (*Lota lota*). The most common fish in the fish pass was the chub (*Squalius cephalus*) with 70 individuals, which was 20,1 % of the whole catch. The population and the number of species were the highest in the resting pools or in the neighbouring pools. In the upper first cascade and at the mouth we observed higher diversity as well (figure 1 and 2). The biggest fish specimen in the samples was a 42 cm long burbot (*Lota lota*).

In all the pools we were able to find fish except the number VI. and XX. pools, that were as upfilled by the floods as their bottom was almost dry after the unloading.

Outside and inside in the fish pass we collected 27 fish species. In the downstream area in the diagonal sampling route we did not catch any fish, because the depth was 7 meter.

There was not remarkable difference in the two samples of the fish trap (12-hours and 36- its 25% entrapping probability (Guti, 2003). In the same time the species number increased from 10 to 15 in the 36-hours sampling comparing to the 12 h investigation. In the upper compartment of the trap (collecting fish from upstream direction) 6 and 8, and in the lower compartment 4 and 7 species were collected. Shraetzer (*Gymnocephalus schraetzer*) and threespine stickleback (*Gasterosteus aculeatus*) appeared only in the fish trap but they were not detected in samples collected by electrofishing.

After the 36-hours sampling, the fish trap was left in the site for 2 days and a 30 cm long dead specimen of pike was found in the lower compartment of the trap. This data indicates the upstream migration of the pike. Gradient of the fish pass resembles to a mountain river, it is quite unique that freshwater sponge (*Spongilla lacustris*) was observed in one of the pools.

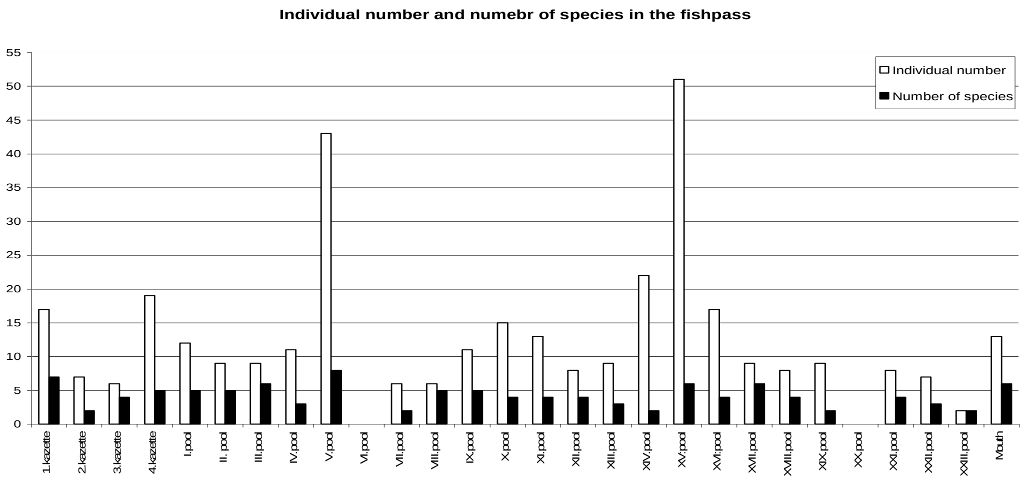

Figure 1. Abundance and species number of collected fish in sampling units of the fish pass.

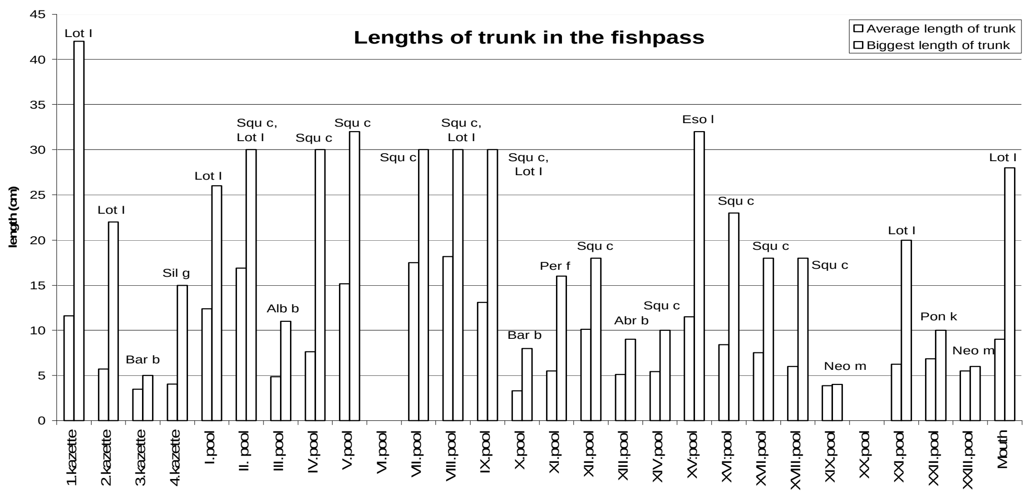

Figure 2. Length distribution of collected fish in sampling units of the fish pass, with indication of biggest specimens and species.

Hydro-eco-morphology map

In the same time of the fish sampling we created a hydro-eco-morphology map with geodetic measurement (Figure 3). In the hydro-eco-morphology map we plotted the hydrologic circumstances, the riverbed morphology, the characteristic bed materials and the ecological information. In the small pool-maps we indicated the main streams and their power, the zero-flow spots, the counter streams and the soil types. We defined the deepest points with depth and area, the shading factor, the type of the bank, the root typology, the characteristic size and quality of rocks, the obstructions and we collected any other relevant information. All the pools were photo-documented with and without water.

These maps are snapshots of the existing abiotic circumstances and they help to detect the long-term changes of the micro-biotopes in the fish pass in the future. For the maps we assigned ecological attributes (e.g. species, number of species and fish) – the guilds, considering the morphological and hydrological parameters. These would support with information the design and operation work.

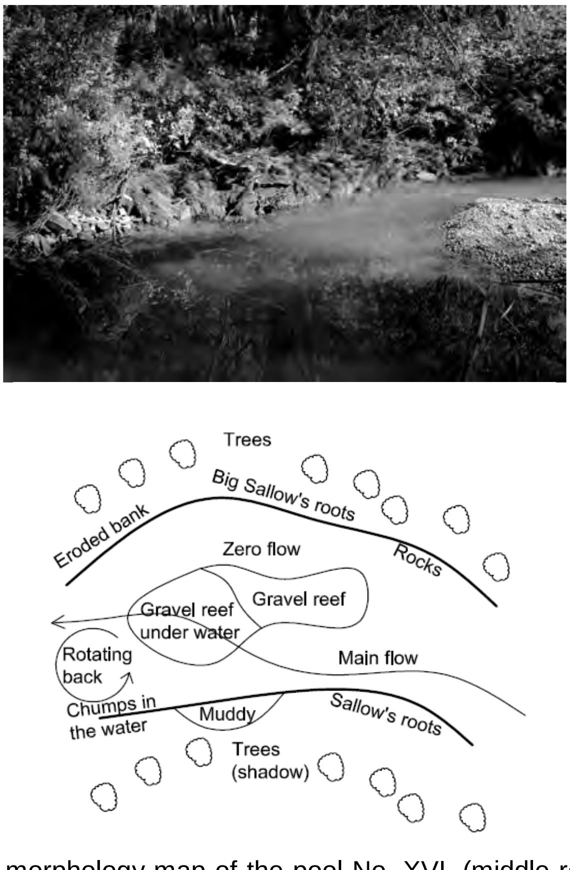

Figure 3. Hydro-eco-morphology map of the pool No. XVI. (middle resting pool) without geodetic data at low water (without water supply) conditions

Suggestions for proper operation

In the future we have to try to place more nature-like stone cover. So instead of riprap huge spherical Danube pebbles could be used or at least partly filling the gap between the rocks with gravel.

The results at Denkpál show that the deeper pools possess with higher diversity. Thus it is recommended to investigate the possibilities to merge pools or expand their dimensions and surface. It would be favourable to reshape the numerous long and rectangular formations to oval or rounded bigger pools (less cascades). Of course the changes must be preceded hydrological calculation.

The daily removal of the driftwood and other obstacles would be preferable because they remarkably influence the flow pattern.

At the upstream inlet a driftwood collector or debris trap should be installed to reduce probability of formation of adverse narrowing.

The flood-transported material has to be removed from those pools which are completely filled. Less disturbed cascades should be left without interventions because the sediment has positive impact on riverbed-forming processes.

When operation of fish trap is scheduled, its installation should be focused to shorter, less than 12-hours sampling time. The fish trap has to be redesigned for higher retention of fish and better catch-efficiency.

In the future all the fish passes should be rebuilt for placement of standard size fish traps and access should be ensured to the fish pass for easy and safe transport of fish trap.

Beside the static photos it is practical to catch the stream conditions by a digital video recorder.

Monitoring of the fish pass operation is advised annually and its costs should be incorporated to the budget of the water supply system of the Szigetköz area. Contribution of fishery companies should be investigated.

Summary

During the monitoring activity we used battery powered electrofishing equipment and a fish trap. The last one allowed us to investigate the directions of fish migration. We detected 347 specimens of 22 fish species.

Furthermore the other purpose of the investigation was to support running and maintenance with field information and distribute the experiences for the profit at other structures. The fish pass is mostly in good condition. Some pools need interventions (sediment clean up, merging and deepening)

Our investigations demonstrated functioning of fish pass. It means species with different swimming ability migrate to upstream. Our results indicated higher fish abundance and diversity in larger (1-2 m deep) pools. Based on the processed data and the field observations we set up the current hydro-eco-morphology map of the fish pass.

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Mid-term changes of planktonic rotifer communities in the Szigetköz floodplain of the Danube, Hungary (2003-2011)

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Keywords: rotifer, floodplain, connectivity, flow pulse

Introduction

Spatial and temporal variability of the river-floodplain systems induces high productivity and biodiversity (Shiel et al. 1998, Armitage et al. 2003). Due to the growing human interference, with mostly adverse effects (e.g. regulation, water use, pollution) the understanding and protection of ecological functions on the natural river-floodplain systems is a pressing need and also a tool to protect the diverse biota of these areas (Berczik & Buzetzky 2006). The planning and processing of floodplain revitalization projects require also particular (and long term) data about the hydrobiological changes of the area under discussion.

Szigetköz floodplain is located in North-West Hungary on the right side of the Danube. Its borders are clearly marked by a 59 km section of the main river and the 129 km Mosoni Danube, a meandering arm (Guti 1996) (Fig. 1.). Before the operation of the Gabčikovo River Barrage, the side arms of the active floodplains were connected with the main arm of the Danube. The dynamically changing lateral connection between the river and the adjacent side arms played a prominent role in the ecological functions of the floodplain. The temporal changes of connection were defined by the overall discharge of the main arm, which varies over time (Lair 2005).

After the operation of the Gabčikovo River Barrage System the lateral connectivity between the active floodplain and the Öreg-Duna (the Old-Danube) ceased due to the significant decrease of water level in the main arm. Due to the revitalization efforts, now a limited water level fluctuation still occurs on the floodplain, which could be sufficient to generate flow pulse effects (Tockner et al. 2000).

The planktonic rotifer populations of river-floodplain systems are affected by abiotic (water age, physical and chemical parameters) and biotic characteristics (food availability, exploitative and interference competition, predation) of each side channel (Dumont 1977, Dijk & Zanten 1995, May & Bass 1998, Lair 2006).

Hydrological and water chemical fluctuations of lotic waters are well reflected in the quantitative and qualitative changes of the local planktonic rotifer communities (Schöll 2010, Schöll et al. 2012).

Since 1991, the Hydrobiological Monitoring Project of Szigetköz was started by the Danube Research Institute for tracking the hydrobiological consequences of the above mentioned interferences. The project included planktonic rotifer investigations since 2003. The aim of our present study was to detect the flow pulse effects on the active floodplain compared to the main arm and the water bodies on the protected side. Our hypothesis was that a flow-pulse effect should be reflected in the rotifer communities, i.e. the highest diversity is expected in the active floodplain, while peak values of density should occur in the protected side.

Methods

Sampling

Sampling was carried out yearly between 2003 and 2011. Ten sampling sites were selected (Fig. 1, Table 1). Our study area included **A**: the main arm of the Danube: DKI, DRE, MED; **B**: the active floodplain affected by water level fluctuations: SCH, CSA, ASV; and **C**: the protected side outside the dike system, with constant water level: LIP2, LIP4, ZAT2 and ZAT4.

Figure 1. Sampling sites on the Szigetköz floodplain. See text for further explanation

Samples were collected from the surface by using a plankton net (mesh size: 40 m) filtering 20 L of water. After the collection live specimens were taken to the laboratory, but others were instantly preserved in a 4 % formaldehyde solution. Live specimens were collected to make accurate identifications of illoricate species which were identified within 4-5 hours. For the identification of rotifers the key of Koste (1978) and the nomenclature of Segers (2007) were used. Specimens in the preserved samples were counted in a Sedgewick-Rafter chamber. Biomass values of rotifers were calculated according to Ruttner-Kolisko (1977).

Data analysis

To characterize abundance-dominance relationships using diversity statistics, we chose the Shannon-Weaver diversity index ($H = -\sum P_i * \ln P_i$, where P_i represents the relative abundance of each species). The standardized guild ratio GR' was also calculated: GR = Σ (biomass raptorial-biomass microphagous/Σ (total rotifer biomass) (Obertegger et al. 2011). *H'* values were compared by using Hutcheson's T-test (Hutcheson 1970) and, owing to the non-normal data distribution, the changes in species richness, density and GR' were analysed by the non-parametric Mann-Whitney U-test using the PAST software (Hammer et al. 2001).

Table 1. Sampling chronology between 2003 and 2011. A – main arm; B – active floodplain, C – protected side

	Sites	2003	2004	2005	2006	2007	2008	2009	2010	2011
A	DKI	X	X	X	X	X	X	X	X	X
	DRE		X	X	X	X	X	X	X	X
	MED		X		X	X	X	X	X	X
B	SCH	X	X	X	X	X	X	X	X	X
	CSA	X	X	X	X	X	X	X	X	X
	ASV	X	X	X	X	X				
C	ZAT2			X	X	X	X	X	X	X
	ZAT4	X	X	X	X	X	X	X	X	X
	LIP2			X	X	X	X	X	X	X
	LIP4	X	X	X	X	X	X	X	X	X

Results and Discussion

During the survey altogether 49 rotifer taxa were determined for the whole area (Tab. 2). Most taxa (39) occurred in the protected side, the fewest (22) in the main arm. The most diverse taxa were the Brachionidae and Trichocercidae. 31% of the species occurred in all water bodies (main arm, active floodplain and protected side), the proportion of singletons was relatively high, 45%. These faunistical characteristics suggest that the faunistical versatility and therefore the hydrological connectivity between the different type water bodies are relatively low.

Species richness and diversity patterns

The values of species richness changed notably during the investigated years, but the patterns were similar: the taxon numbers of the main arm were generally lower than in the active floodplain and on the protected side ($Z=-2.61$, mean rank: 3.083, $P<0.01$; $Z=2.299$, mean rank: 3.278, $P<0.05$ respectively) (Tab. 3). There was no difference between the active floodplain and the protected side ($P=0.28$). In case of Shannon-Wiener diversity values the pattern was similar. The values of the main arm were lower than the active floodplain and the protected side ($Z=-2.01$, mean rank: 3.087, $P<0.01$; $Z=-2.388$, mean rank: 3.128, $P<0.05$ respectively). Similarly to the case of species richness, there was no difference between the active floodplain and the protected side ($P=0.70$). These uniformities suggest the lack of flow pulse effects on the rotifer community of the active floodplain (Schöll et al. 2012). The scarce and controlled flooding seems to be not sufficient to maintain a higher diversity in the water bodies of the active floodplain.

Density patterns

The density values were relatively stable (with exception of some extreme values in 2003) during the investigated years (Tab. 3). The density in the main arm was generally lower than in the active floodplain ($Z=-2.21$, mean rank: 3.056, $P<0.01$). There was no significant difference between the main arm and the protected side and between active floodplain and the protected side ($P=0.07$; $P=0.08$ respectively). The density patterns are also more homogenous than expected. It seems that the meteorological and local effects prevailed while the temporal changes of flow and hydrological conditions are of no relevance.

Guild ratio

The proportion of microphagous species (more negative values of GR) was the highest in the main arm; during the 6 years of our survey not a single raptorial species occurred in the main arm. Positive values (dominance of raptorial species) occurred only in the active floodplain in the years 2009 and 2010 (Tab. 3). The GR values were lower in the sites of the main arm and the protected side than on the active floodplain ($Z=-2.88$, mean rank: 2.944, $P<0.005$; $Z=-2.031$, mean rank: 3.083, $P<0.01$ respectively). The guild ratio of the main arm and the protected side did not differ significantly ($P=0.09$).

The higher proportion of raptorial species on the active floodplain alludes to higher habitat diversity. The higher flowing velocity of the main arm allows just the presence of smaller, fugitive species. On the protected side the proportion of stagnant areas are higher and the biotic interactions (e.g. size selective predation by local fish populations) are dominant. This phenomenon could diminish the larger, raptorial rotifer species.

Conclusions

In our hypothesis we expected effects of flow pulse, caused by the present water level fluctuation on the active floodplain. For this reason we compared the ecological characteristics of the rotifer communities of the different water bodies. The guild ratio reflects the different ratio of flowing and stagnant water bodies on the active floodplain and on the protected side. The diversity on the active floodplain is not higher than on the protected side, so it seems that the expected flow-pulse effect is still missing in contempt of the revitalization efforts. The present frequency and duration of flood events on the active floodplain are not sufficient to maintain a higher diversity which should be typical for an intact floodplain.

Table 2. Rotifer species from the different water bodies (2003-2011)

Taxa altogether: 49	**Main arm**	**Floodplain**	**Protected side**
Bdelloidea sp.			X
Anuraeopsis fissa Gosse, 1851	X	X	X
Asplanchna sp.	X		
A. brightwelli Gosse, 1850	X	X	
A. girodi de Guerne, 1888		X	X
Brachionus angularis Gosse, 1851	X	X	X
B. budapestiensis Daday, 1885	X		X
B. calyciflorus Pallas, 1766	X	X	X
B. diversicornis (Daday, 1883)		X	
B. quadridentatus (Hermann, 1783)	X	X	X
Cephalodella catellina (O. F. Müller, 1786)			X
Colurella colurus (Ehrenberg, 1830)			X
C. obtusa (Gosse, 1886)		X	
Euchlanis dilatata Ehrenberg, 1832	X	X	X
Filinia terminalis (Plate, 1886)	X		X
Kellicottia longispina (Kellicott, 1879)		X	X
Keratella cochlearis (Gosse, 1851)	X	X	X
K. tecta (Gosse, 1851)	X	X	X
K. quadrata (O. F. Müller, 1786)	X	X	X
K. valga (Ehrenberg, 1834)	X		
Lecane bulla (Gosse, 1851)			X
L. luna (O. F. Müller, 1776)		X	X
L. lunaris (Ehrenberg, 1832)	X	X	X
Lepadella patella (O. F. Müller, 1786)	X	X	X
Monommata longiseta (O. F. Müller, 1786)			X
Mytilina mucronata (O. F. Müller, 1773)			X
M. ventralis (Ehrenberg, 1830)	X	X	X
Notholca acuminata (Ehrenberg, 1832)			X
Notholca labis Gosse, 1887		X	
Platyias patulus (O. F. Müller, 1786)			X
Polyarthra dolichoptera Idelson, 1925	X	X	X

P. longiremis Carlin, 1943	X	X	X
P. major Bruckhardt, 1900		X	X
P. vulgaris Carlin, 1943	X	X	X
Scaridium longicaudum O. F. Müller, 1786		X	X
Squatinella rostrum (Milne, 1886)			X
Synchaeta oblonga Ehrenberg, 1832	X	X	X
S. pectinata Ehrenberg, 1832		X	
S. tremula (O. F. Müller, 1786)	X	X	
S. longipes Gosse, 1887		X	
Testudinella patina (Hermann, 1783)			X
Trichocerca birostris (Minkiewitz, 1900)		X	
Trichocerca longiseta (Schrank, 1802)		X	X
T. pusilla (Lauterborn, 1898)		X	X
T. rattus (O. F. Müller, 1776)			X
T. stylata Wierzejski, 1893			X
T. weberi (Jennings, 1903)			X
Trichotria pocillum (O. F. Müller, 1766)			X
Taxon number	**21**	**30**	**38**

Table 3. Ecological characteristics (mean values from each year) of the rotifer communities. A – main arm; B – active floodplain; C – protected side

	Species richness			Density			S-W diversity			Guild Ratio		
Year	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
2003	2.71	2.5	2.71	1082	1378	414	0.65	0.42	0.42	-0.75	-0.81	-0.97
2004	1.13	3.5	2.17	50	1267	83	0.32	0.86	0.57	-1.0	-0.07	-0.61
2005	0.20	1.14	2.00	5	57	78	0.00	0.20	0.56	-1.0	-0.60	-0.62
2006	1.29	4.67	1.67	43	1100	56	0.19	1.19	0.57	-1.00	-0.24	-0.50
2007	2.67	4.56	3.08	139	519	271	0.74	1.13	0.84	-0.38	-0.42	-0.52
2008	3.00	4.00	4.17	146	1325	202	0.79	0.96	1.26	-0.52	-0.03	-0.22
2009	1.33	3.00	3.00	33	175	100	0.23	0.87	0.98	-1.00	0.49	-0.78
2010	1.66	3.5	6.50	58	113	294	0.35	1.21	1.68	-1.00	0.23	-1.00
2011	1.33	4.00	2.5	50	212	113	0.42	0.95	0.79	-1.00	-0.63	-0.79

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Topic 3
Changes in biodiversity

(interactions of metapopulations,
invasive species,
the Danube as ecological corridor,
status of nature conservation)

Diversity and structure of zooplankton communities of the water bodies of the Kiliya Danube delta (Ukraine)

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Keywords: zooplankton, diversity, communities, lakes, Kiliya Danube delta

Introduction

The Kiliya delta is known as the youngest natural land in Europe. It has a history reaching back to the mid 18th century and it is still in the process of development, while being consequently the subject of gradual changes in hydrological regime, salinity etc.

The Kiliya arm of the Danube River is diverged into smaller arms which divide the delta in isles, typical of the delta shape. Their coastal lines are depressed from the seaside, often form bays (lakes) up to tens or even hundreds of hectares. They are connected to the Danube River. These bays are shallow – their depth varies between 0.4–2.2m, depending on the water level in the river. As a result of sand pits forming and alluvia sedimentation of the river the bays are gradually separated from sea and transformed into closed intra-delta water bodies.

Zooplankton in the Ukrainian part of the Danube delta, including the water bodies of the Kiliya delta, has been studied since the 1950s (Markovskiy 1955, Pidgayko 1957, Tseeb 1961, Zimbalevskaya 1969, Polischuk 1974, Polischuk & Garasevych 1986, Parchuk 1993, Polischuk & Belokamennyi 2002). This paper deals with the results of the works carried out within the Ukrainian state program of monitoring ecological effects of the Danube–Black Sea deep-water navigational channel reconstruction. The aim of this work was to study the actual state of zooplankton communities in the different water bodies affected by different types of anthropogenic impacts.

Material and methods

Freshwater zooplankton from the Kiliya Danube delta's water bodies is formed mainly under the influence of the Danube water; it is also subjected to the effect of the North-West part of the Black Sea and depends on the connection of the water bodies and the sea. Zooplankton of the model water bodies (lakes Anan'kin Kut, Potapiv Kut and Deliukiv Kut) was studied over the years 2006–2010. Anan'kin and Deliukiv Kut are the freshwater bodies, connected only by

Danube arms. The Potapiv Kut Lake has a periodically drying channel connecting it with the sea. The saline water reaches this channel and results in minor salinization of the lake. The considered water bodies differ by their overgrowth rate: Potapiv Kut – is a moderately overgrown, Anan'kin Kut – significantly overgrown, Deliukiv Kut is overgrown to a maximal extent, with silty bottom sediments. The vegetation of all water bodies was similar (Zorina-Sakharova et al. 2008).

Sampling and sample processing were carried out according to the standard hydrobiological methods (Romanenko 2006). Borutskiy (1960), Manuylova (1964), Kutikova (1970), Monchenko (1974) and the faunistic study of Borutskiy et al. (1991) were used to identify species. Only preserved samples were analyzed. To determine the quantitative characteristic of the species' diversity Shannon Index was used (Pesenko 1982).

Results and Discussion

Zooplankton in the water bodies of the Kiliya Danube delta was characterized by high biodiversity. It was comprised into 148 lower determinable taxa (LDT) of aquatic animals of three main taxonomic groups, which belong to 27 families and 63 genera. Among them Rotatoria – 74 taxa, Copepoda – 25 (adult copepods, copepodites, nauplii) and 48 – Cladocera and Dreissena veligers were registered. Faunistic spectra regarding zooplankton were as follows: 50% – Rotatoria, 17% – Copepoda, 32% – Cladocera. Rotatoria comprised 16 families and 25 genera and most of the species were the representatives of Brachionidae (16), Lecanidae (12), Trichocercidae (7), Synchaetidae (7) and Asplanchnidae (6) families. Cladocera belonged to 7 families and 22 genera, the most rich in species were Chydoridae and Daphniidae. Copepoda belonged to 4 families and 12 genera, maximal species number were of Cyclopidae. At present zooplankton communities of the considered lakes included some species, neverfound earlier. These were characteristic of the water bodies situated alongside the left bank of the Danube River's lower section. For the first time in the Danube lakes rotifers *Ascomorpha agilis* Zacharias, *Gastropus stylifer* Imhof., Cyclopoida *Microcyclops varicans* Sars, *M. bicolor* Sars, Cladocera *Alona quadrangularis* (O.F. Müller), *Rynchotalona falcate* Sars and some other species were found. However all these species are usual for the Danube basin and are characteristic of the water bodies of the Pontic province (Limnofauna… 1967) or southern region, according to Pidgayko's classification (Pidgayko 1984). It is worth noting that at present notable impoverishment of the species composition of the relict Caspian fauna is observed, probably because its representatives appeared to be insufficiently adapted to the modified environmental conditions. For instance, *Heterocope caspia* Sars and *Calanipeda aqua-dulcis* (Kritschagin) of Calanoida, which earlier were reported to be the mass species, in the recent years were found only as single specimens.

Most of the taxa (126) were recorded from the Anan'kin Kut Lake, somewhat less – in the Deliukiv Kut and Potapiv Kut lakes, 100 and 82 species respectively. In zooplankton of the considered water bodies mass development was noted of the rotifers *Asplanchna priodonta* Gosse, *Synchaeta* sp., *Filinia longiseta* (Ehrenberg), *Euchlanis dilatata* Ehrenberg, *Brachionus calyciflorus* Pallas, *Keratella cochlearis* (Gosse), copepods *Thermocyclops crassus* (Fischer), cladocerans *Bosmina longirostris* O.F. Müller, *Alona rectangula* Sars, *A. quadrangularis*, *Chydorus sphaericus* (O.F. Müller), *Simocephalus vetulus* (O.F. Müller). Maximum density of zooplankton was registered within the sections with minimal overgrowth rate or free of vegetation.

Ecological diversity also is an element of biological diversity that is belonging of the organisms to three ecological groups: pelagic (character for the water thickness, or properly planktonic), coastal-phytophilous and bottom-phytophilous. The main portion of zooplankton communities was formed by the pelagic species, though number of the phytophilous and near-bottom forms were also notable. Relation of these groups of zooplankton species was as follows: 57% – 35% – 8%. Presence of many representatives of the phytophilous and near-bottom ecological groups were conditioned by high diversity of habitats in the considered water bodies.

Each considered lake was characterized by special composition of the dominating complex and relation of taxonomic groups. Some species was peculiar for the certain water body. Domination complex of the Anan'kin Kut Lake included rotifers of the fam. Brachionidae: *Brachionus calyciflorus, B. angularis* Gosse, *B. diversicornis* (Daday), *Asplanchna priodonta,* cladocerans *Simocephalus vetulus*; in the Potapiv Kut Lake – copepodites, nauplii and adult copepods *Thermocyclops crassus, Acanthocyclops vernalis* (Fischer); in the Deliukiv Kut Lake – copepodites, nauplii and cladocerans *Bosmina longirostris, Chydorus sphaericus*. On the whole zooplankton of the water bodies of the Kiliya Danube delta by its species composition can be characterized as Copepoda–Rotatoria. Seasonal dynamics of the species richness in the studied water bodies was different. In some cases the maximal species number was registered in spring (Anan'kin Kut and Deliukiv Kut 2007), while in other in autumn (Anan'kin Kut 2006 and 2008, Potapiv Kut 2006). Other quantitative indices also varied over a wide range. The lowest index of abundance was registered in spring 2010 in the Potapiv Kut (0.06 thousand specimens m^{-3}), and maximal – in autumn 2006 in the Anan'kin Kut (712 thousand specimens m^{-3}). The lowest biomass value was registered in spring 2009 and summer 2010 in the Deliukiv Kut (>0.01 g m^{-3}), and the maximal – in autumn 2006 in the Anan'kin Kut (4.12 g m^{-3}).

The maximal Shannon diversity index (SDI) values regarding zooplankton were up to 3.40 and were registered in the Potapiv Kut Lake, which has the least overgrown surface while the lowest SDI values were registered in the Deliukiv Kut Lake (0.92). During the whole research the SDI values varied between narrow limits (2.21–3.06). In this case the structure type of the zooplankton communities regarding water bodies was oligo- or polydominant. This indicates an equal level of stability and balance.

However, in spite of qualitative and quantitative parameters' heterogeneity, in terms of both seasonal and long-term dynamics, somewhat simplification of zooplankton communities' structural characteristics is observed. It is connected with the decrease of the dominating species and a considerable decrease in abundance of the planktonic invertebrates.

Summary

The results of this study enabled scientist to characterize the quantitative and qualitative parameters of the planktonic fauna in the Kiliya Danube delta's water bodies. Zooplankton showed high species-, taxonomic- and ecological diversity. It was conditioned by the high diversity of habitats and abiotic conditions of the water bodies. During the sampling period 148 species were collected (including LDT) from the three main taxonomic groups. Maximal species (taxa) number belonged to Rotifers. Each lake was characterized with a special composition of the dominating complex and relation of taxonomic groups. Zooplankton development is subjected to seasonal and inter-annual fluctuations in the environmental factors. Regarding all water bodies of the Kiliya Danube delta in question of zooplankton species composition it can be characterized as Copepoda–Rotatoria, and by structure – as oligo- or polydominant.

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Zooplankton monitoring in the Szigetköz floodplain of the Danube (Hungary) (1999-2011): long-term results and consequences

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Introduction

The Szigetköz floodplain is situated in the north-western part of Hungary, on the right side of the Danube, between 1850-1793 rkm. Its borders are clearly marked by a 59 km section of the main river and the 129 km Mosoni-Danube, a meandering arm (Guti 1996). Prior to the main hydrological reconstructions in the nineties, the hydrological regime of the water bodies was governed by the Danube, and the separate side-branch systems were directly connected to the main channel. The oxbow lakes on the active floodplain and on the protected side generally received their water supply from ground water and these only had any connection to the main channel when a high flood occurred. The flood protection dikes divided the original floodplain into three ecologically distinct areas: the old floodplain is protected from floods by dikes; the active floodplain is situated between the dikes and the main channel of the Danube. In the early nineties after the diversion of the Danube and after the operation of the Gabčikovo River Barrage System began, significant hydrological and morphological changes occurred in the Szigetköz and the natural dynamics of the river-floodplain system entirely disappeared. Due to the decrease in water discharge most of the side branches lost their direct connection to the main channel and both the water level and the area of the oxbow lakes (supplied by ground water) decreased largely. Since 1993, several technical changes have been implemented in order to reduce the scarcity of water. The formerly independent side branch systems and oxbow lakes were interconnected by new artificial canals and shortcuts, or by dredged old natural branches to form a water supply system. In this artificial system, the dynamically changing lateral connection between the river and the adjacent side arms was damaged.

In 1991 a Hydrobiological Monitoring Project was started, coordinated by the Danube Research Institute (formerly Hungarian Danube Research Station). The main aim was to investigate the possible hydrobiological and ecological consequences of the above-mentioned artificial impacts. Since 1999, Ostracoda were included in the zooplankton monitoring. In spite of the artificial interventions, the Szigetköz is characterized by great diversity of floodplain habitats and since 1991, 114 (75 Cladocera, 26 Copepoda, 13 Ostracoda) crustacea taxa were collected (Bothár 1994, Kiss 2004, 2009). In this paper, the main results of the long-term microcrustacean monitoring are described for the years 1999-2011 (13 years).

Materials and Methods

Samples were collected 1-4 times a year between 1999 and 2011. Twelve sampling sites were selected (Fig 1.).

In the main arm of the Danube: **1.** Dunakiliti (DKI) 1843 rkm, 1999-2011, 34 samples, **2.** Dunaremete (DRE) 1825 rkm, 2003-2011, 19 samples, **3.** Ásványráró (ARA) 1816 rkm, 17 samples, **4.** Szap (SZAP) 1811 rkm, 1999-2004, 15 samples, **5.** Medve (MED) 1805 rkm, 11 samples. In the active floodplain affected by water level fluctuations: **6.** Schisler-oxbow (SCH) 1999-2011, 35 samples, **7.** Csákányi-Danube (CSA) 1999-2011, 34 samples, **8.** Ásványi-Danube (ASV) 1999-2007, 26 samples. In the protected side outside the dike system, with constant water level: **9.** Zátonyi-Danube (ZAT2) 2005-2011, 13 samples, **10.** Zátonyi-Danube (ZAT4) 1999-2011, 35 samples, **11.** Lipót-march (LIP2) 1999-2011, 32 samples, **12.** Lipót-march (LIP4) 1999-2011, 35 samples.

Figure 1. Sampling area and sampling sites in Szigetköz

Crustaceans were collected using plankton nets (mesh size 70µm) and by filtering 100 or 50 litres of water. The samples were then preserved in 4% formalin. Microcrustaceans were enumerated and identified to species level using an inverted microscope. Very dense samples were subsampled. Gulyás & Forró (1999, 2001), Meisch (2000) and the nomenclature of Dussart (1967, 1969) were used for species identification.

Pearson product moment correlation analyses of the data were performed using PAST statistical program package (Hammer et al. 2001).

Results and Discussion

Between 1999 and 2011 91 microcrustacean taxa (58 Cladocera, 19 Copepoda, 14 Ostracoda) were recorded. Most taxa were recorded on the protected side (main arm: 49, active floodplain: 63, protected side: 80) and more than 50 % (41) of the taxa occurred from all type of water bodies. Several microcrustacean species are quite rare, both in Szigetköz and Hungary (Cladocera: *Alona rustica* Scott, 1895, *Anchistropus emarginatus* Sars, 1862, *Camptocercus lilljeborgi* Schoedler, 1862, *Camptocercus rectirostris* Schoedler, 1862, *Daphnia ambigua* Scourfield, 1964, *Lathonura rectirostris* (O. F. M., 1785), *Monospilus dispar* Sars, 1862, *Oxyurella tenuicaudis* (Sars, 1862), *Simocephalus serrulatus* (Koch, 1841), *Wlassicsia pannonica* Daday, 1904; Copepoda: *Eucyclops macrurus* (Sars, 1863), *Macrocyclops distinctus* (Richard, 1887); Ostracoda: *Bradleystrandesia obliqua* (Brady, 1868), *Dolerocypris fasciata* (O. F. M., 1776), *Prionocypris zenkeri* (Chyzer et Toth, 1858). *Pleuroxus denticulatus*, a new invader in the Danube Basin (Hudec & Illyová, 1998), appeared in 2003 and spread to Szigetköz. There were remarkable differences in the examined parameters of the assemblages between the three hydrologically distinct parts of the Szigetköz.

Main Arm

49 taxa (32 Cladocera, 11 Copepoda, 6 Ostracoda) were recorded between 1999-2011. The number of species per year varied between 4 and 27, and 27.3–58.82% of the species occurred once a year (Fig.2). The total and annual species number in the DKI site (DKI: 44, DRE: 29, ARA: 16, SZAP: 23, MED: 17), as well as was the S-W diversity was higher than at the other main arm sites, presumably due to the impact of the Dunakiliti reservoir (Table 1). The relative abundance of *Bosmina longirostris* (DKI: 48.15%, DRE: 31.88%, ARA: 52.52%, SZAP: 45.15%, Med: 23.07%) was significantly higher than other taxa at the sampling sites. The density of *Bosmina* was relatively high between 1999-2003 (maximum: 391 ind 100 l^{-1}), since 2003 it decreased significantly. The annual mean density of the total community (except for two years) was low, below 40 ind. 100 l^{-1} (Fig. 3). The occurrence and density of euplanktonic copepods (*Cyclops vicinus*, *Acanthocyclops robustus, Thermocyclops*

oithonoides, T. crassus) were low in the main arm sites as it was observed by Vranovsky (1997), a possible reason might be an increase in eutrophication.

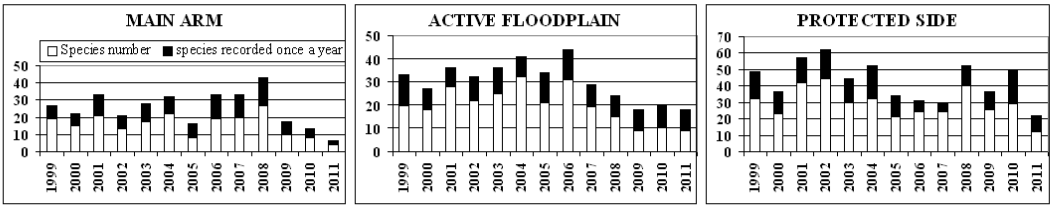

Figure 2. The changes of the species number, the species, which recorded once a year between 1999-2011 in the three hydrologically distinct parts of the Szigetköz

Table 1. The average, minimum and maximum values of microcrustacean assemblages in the sampling sites between 1999-2011 (1: main arm, 2: active floodplain, 3: protected side)

	Species number			**Density** (ind 100 l^{-1})			**S-W diversity**			**Dominance**		
	Aver	**Min**	**Max**	**Aver**	**Min**	**Max**	**Aver**	**Min**	**Max**	**Aver**	**Min**	**Max**
1.												
DKI	4.88	0.00	16.00	51.79	0.00	421.00	1.02	0.00	2.52	0.41	0.00	0.86
DRE	3.73	0.00	17.00	21.79	0.00	86.00	0.71	0.00	2.41	0.55	0.00	1.00
ARA	2.59	0.00	8.00	11.64	0.00	67.00	0.56	0.00	1.63	0.50	0.00	0.75
SZAP	3.60	0.00	6.00	48.13	0.00	240.00	0.89	0.00	1.47	0.44	0.00	1.00
MED	2.27	0.00	5.00	5.90	0.00	15.00	0.66	0.00	1.56	0.51	0.00	1.00
2.												
SCH	8.34	2.00	19.00	1212.5	3.00	5458.0	1.16	0.16	2.17	0.42	0.14	0.87
CSA	3.88	0.00	11.00	38.03	0.00	320.00	0.79	0.00	2.18	0.53	0.00	1.00
ASV	3.73	0.00	10.00	14.73	0.00	67.00	0.88	0.00	1.72	0.42	0.00	1.00
3.												
ZAT2	6.00	1.00	13.00	83.30	1.00	594.00	1.18	0.00	2.26	0.43	0.12	1.00
ZAT4	6.34	1.00	15.00	135.50	1.00	1680.0	1.24	0.00	2.19	0.40	0.14	1.00
LIP2	6.56	0.00	18.00	71.00	0.00	614.00	1.24	0.00	2.28	0.39	0.12	1.00
LIP4	11.45	2.00	26.00	342.90	4.00	3402.0	1.58	0.43	2.44	0.32	0.12	0.77

Active floodplain

63 taxa (43 Cladocera, 13 Copepoda, 7 Ostracoda) occurred between 1999-2011 and most of the species were recorded from the Schisler-oxbow (53). The number of species per year ranged between 9 and 32, since 2007 the number of taxa decreased (Fig. 2). The average number of taxa and the diversity were notably higher in the oxbow, than at the other floodplain sites. The average and maximum density of the assemblages was the highest in the whole sampling area (Table 1). The most frequent species in the active floodplain were *Bosmina longirostris* (12.22%) and *Chydorus sphaericus* (12.87%) and the relative abundance of developmental stages of Copepoda (Schisler: 32.81%, Ásványi-Danube: 11.22%, Csákányi-Danube: 30.03%) was significantly higher than the main arm and the protected side.

In the early twenties the composition of the microcrustacean fauna changed in the Schisler-oxbow, several species (*Daphnia cucullata*, *Moina brachiata*, *Bosmina longirostris*, *Eudiaptomus gracilis*) occurred and proliferated, while the density of other species decreased. The reason behind a significant part of the variation is the artificial channel implemented in 1998, which conjugated the oxbow with the Csákányi-Danube. Between 1999 and 2011 the total density was fluctuating and lower annual mean densities became evident every third year. The density of copepods was remarkably higher than the one of the cladocerans, *Mesocyclops leuckarti* (18.43%), *Eucyclops serrulatus* (9.35%), *Eudiaptomus gracilis* (4.38%) and *Thermocyclops crassus* (3.09%) were the most frequent species.

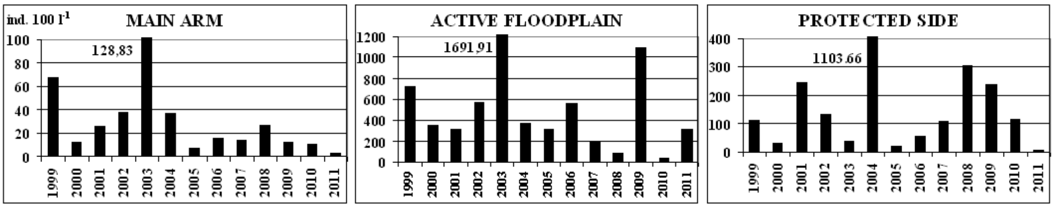

Figure 3. The mean total density of the community (1999-2011) in the three hydrologically distinct parts of the Szigetköz

Protected side

80 taxa (43 Cladocera, 13 Copepoda, 7 Ostracoda) occurred between 1999-2011 and 20 taxa were recorded just from the protected side. The number of species per year fluctuated between 12 and 44 and in contrast to the main arm and active floodplain there was no significant decrease in the number of taxa within the last few years (Fig.2). The average and maximum S-W diversities were the highest in the protected side (Table 1). The ratio of tychoplanktonic and phytophilous microcrustacean species was significantly higher than in the main arm and the active floodplain sites.

The average and maximum number of species and the S-W diversity values were the highest in the LIP4 site of the Lipót-march. The diverse habitats with various submerged macrophytes of the march were characterized by a phytophilous microcrustacean fauna, dominated by Cladocera species (*Pleuroxus truncatus* (20.13%), *Chydorus sphaericus* (11.41%), *Sida crystallina* (10.93%), *Acroperus harpae* (5.57%). In running water systems the physical habitat structure (water regime, depth, current velocity, substratum) is frequently considered as the main factor responsible for lotic fauna distribution (Lair 2006), however the pattern of macrophyte distribution affects the distribution of microcrustacean species too (Grenouillet et al. 2001). The annual mean total density fluctuated during the sampling period possibly reflecting the yearly differences in macrovegetation (presence and coverage) and several human impacts (especially fishing).

Conclusion

Between 1999 and 2011 306 samples were collected from twelve sampling sites of the Szigetköz. A linear relationship between the number of the sampling dates per year and the yearly number of taxa was revealed. Only one sampling per year resulted in a significant lower number of taxa especially in the main arm and the active floodplain sites. An increase in sampling efforts (more sites) had no influence on the number of taxa. On the basis of your results a minimum of three sampling occasions per year and more than one sample per date and locality are required for the examination of the microcrustacean distribution.

The long-term study of the microcrustacean fauna revealed changes in the composition, density and diversity of the communities caused primarily by human impacts in the Szigetköz. Few years after the greater interventions in the nineties, the fauna more or less regenerated, but several unique water bodies disappeared forever. Community structure, diversity patterns and density differed between the three hydrologically distinct sections reflecting the different hydrological connectivity with the main arm.

Acknowledgement

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Comparative description of the Lower Danube macrozoobenthos

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Keywords: macrozoobenthos, Danube Delta, bioindication

Introduction

Under the term of macrozoobenthos, or benthic invertebrate fauna, the WFD (European Water Framework Directive, WFD) (WFD, 2000) implies hydrocolesliving at least for part of their lifecycles on or in the benthic substrates of rivers, lakes, transitional waters or coastal waters. This biotic group is one of the biological components which is monitored during the evaluation of a river's ecologic state. Under the aegis of ICPDR, a number of international surveys of the Danube were undertaken (the Joint DanubeSurvey (JDS), the JDS 2 and the Joint Danube Delta Survey (JDDS)). Danube surveys allowed to test research methods accepted in different countries, outline integrated algorithms of river ecology assessment works, and, furthermore, allowed to point out the existence of considerable blank spots regarding material collecting and processing. Present research paper intends to describe the macrozoobenthos of the Danube mouth area based on the results obtained from the JDDS and to compare them with JDS and JDS2 materials. JDDS scale (16 stations) were limited to the mouth area of the Danube; in the JDS framework 3 stations, while in the JDS2 framework 4 stations were inspected in this area; in fact, the point of JDDS consisted in comprehensive examination of the delta, as well as the improvement of transboundary Ukrainian-Romanian-Moldavian collaboration in water management in conformity with WFD principles.

Methods

The paper presents own materials gathered in September-October 2011 in the course of the international Ukrainian-Romanian-Moldavian survey of the mouth area of the Danube river from the mouth of the Prut river (Giurgiulesti) to the Black Sea encompassing three main delta branches and lakes of the Gorgova-Uzlina system (Figure 1). Macrozoobenthos was sampled in the main channel (st. 1 (N $45^0$47",E $28^0$20"), st.2 (N $45^0$46",E $28^0$24"), and st.3 (N $45^0$23",E $28^0$73")), the Kyliya branch (st. 4 (N $45^0$32",E $28^0$87"), st.5 (N $45^0$43",E $29^0$26"), st.6 (N $45^0$40",E $29^0$87")), the Bystroe branch (st. 7) (N $45^0$34",E $29^0$76"), the Tulcea branch (st. 8) (N $45^0$19",E $28^0$81"), the Sulina branch (st. 9 (N 45^{0}23",E 29^{0}25"), 10 (N 45^{0}16",E 29^{0}70")), the Sf. Gheorge branch (st. 11 (N 45^{0}08",E 29^{0}22"), 12 (N 44^{0}88",E 29^{0}61")), Lake Erenciuc (st. 13)(N 44^{0}00",E 29^{0}43"), Lake Uzlina (st. 14)(N 45^{0}09",E 29^{0}26"), Lake Isak (st. 15)(N 45^{0}11",E 29^{0}27") and Lake Cuibul (st. 16) (N 45^{0}13",E 29^{0}34").

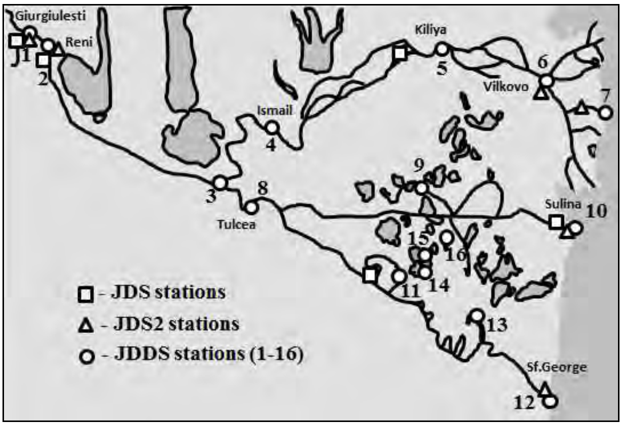

Figure 1. Research area map

Comparative assessment was performed using the report materials provided by the JDS (2001) and the JDS2 (2007), which were collected from the Lower Danube's stations located in the mouth area (Fig. 1).

Sampling in all three surveys, on the one hand, featured certain differences (in terms of station localization, sampling methods), and on the other hand, was based upon common principles and approaches (examining the maximum quantity of biotopes, uniting qualitative and quantitative samples, the use of uniform metrics).

The watercourses of the Danube mouth area are characterized with strong currents and great depths; therefore, the examination of benthos in JDDS was limited to the near-bank areas only, with depths not exceeding 3 meters. At each station the sampling was performed by 2 methods: using adredge (quantitative sample) and a Kick-net (qualitative sample). Similarity analysis regarding macrozoobenthos species' composition was performed on the basis of Serensen'coefficient calculations under the Bray-Curtis method (Complete Linkage cluster method without standardization with Presence/Absence data transformation) with further development of the cluster dendrogram in the BioDiversity ProTool (1997). For the saprobity assessment, the Zelinka-Marvan index was employed in all surveys using the list of the Austrian Fauna Aquatica (Moog 1995); in the JDS2 and JDDS, the ASTERICS 3.1.11» (AQEM, 2002) software package was used. Correspondence of saprobity values to ecological condition classes was stated in accord with the methodology tested in the JDS2 (JDS2 2007, Sommerhauser et. al. 2003).

Results and Discussion

The mouth area of the Danube was characterized with biotopic heterogeneity; the degree of bank area growth increased along the current direction; submersed macrophytes (SM) appeared. In lakes Erenciuk, Uzlina and Culibulculebede, helophyte thickets on the banks were accompanied with SM and plants with floating leaves; in Lake Isakonly helophyte thickets were noted. Silts in the lakes are friable and contain a considerable amount of detritus.

Within the JDDS, a total of 115 species of invertebrates were registered. The most prolific species'diversity is characteristic of Chironomidae and Oligochaeta: 23 and 21 species respectively. 13 species of Gastropoda were registered, 10 of Gammaridae, 9 of Bivalvia, 6 of Odonata, 4 of Hirudinea, Heteroptera and Trichoptera each, 3 of Corophiidae, Ephemeroptera and Coleoptera each, and 2 species of Bryozoa, Cumacea and Mysidacea each. The remaining groups were represented by 1 taxon. In the watercourses (the main channel and delta branches, 89 species of bottom-dwelling invertebrates were registered, and 58 such species were registered in basins (Figure 2); 56 species were found in watercourses, and 22 species in the basins. In the lakes are Oligochaeta, Mollusca and Gammaridae were represented to a higher degree while the quantity of Chironomidae remained the same.

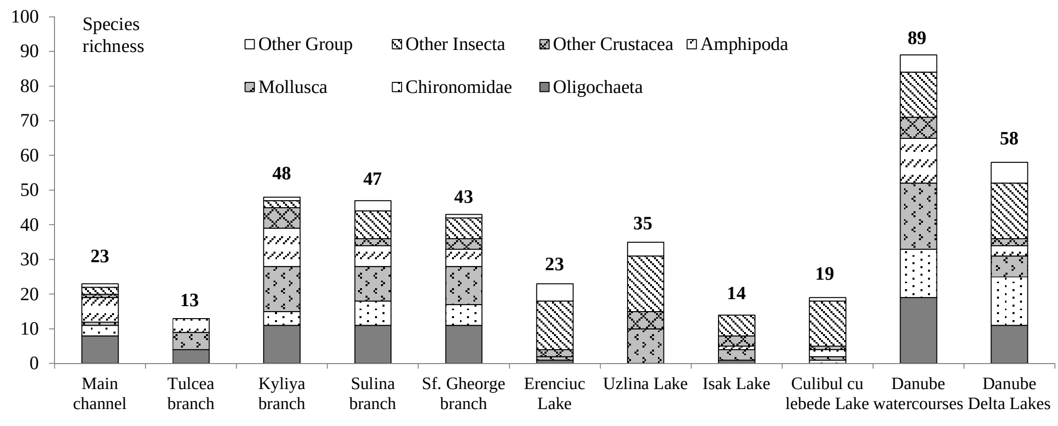

Figure 2. Taxonomic composition of macrozoobenthos of the Danube delta waterbodies

Regarding macrozoobenthos species of branches' and lakes' uniform lists coincidence analysis showed their identity level at 45%. Basins and watercourses formed two large clusters (Figure 3). High congeniality level was captured in respect of the sites featuring similar hydrologic-morphologic characteristics, for instance, the Tulcea branch and the main channel. Kyliya, Sulina and Sf. Gheorge branches form a separate group, with the Kyliya branch featuring a higher level of macrozoobenthos isolation (see Figure 3). Differences in lakes are connected to the nature of basin overgrowth: the difference in the species composition of Lake Isak's macrozoobenthos is likely to be connected to the sole presence of local helophytes.

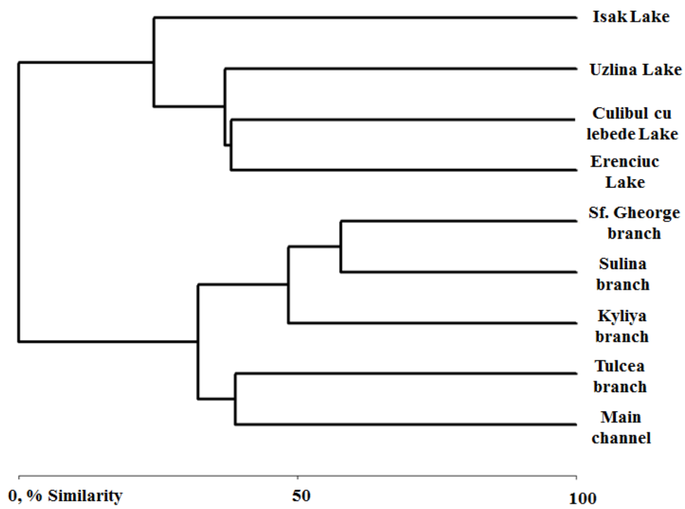

Figure 3. Species composition similarity analysis of macrozoobenthos in waterbodies (based on JDDS materials)

The comparison of macrozoobenthos species' composition based on the results furnished by the three Danube surveys caused certain difficulties. In the JDS and JDS2 reports the provided species lists cover the entire Lower Danube from delta branches to the Dzherdapskiy reservoir, whereas our materials refer only to the river's mouth areaalbeit were collected at more stations. Moreover, the provided results were influenced by the quality of separate invertebrate groups'analysis (the availability of respective experts). Thus, three quarters of the Chironomidae species composition were established in the context of the second research – 61 species (2007), 18 of which were registered at the Danube mouth area stations. In the first expedition Chironomidae were not established in the Lower Danube.Three species were detected (2001), whereas 23 species were noted in the framework of the third expedition.

The characteristics of the macrozoobenthos' taxonomic structure of the Lower Danube can be found in Figure 4. The richest species' diversity was registered in the JDS2 – 168 species, primarily due to the multitude of Chironomidae, and, to a lesser extent, Oligochaeta; the quantities of the remaining prevailing groups presented in all surveys was similar. Attributed to the Other Insecta group are organisms which - though common - are found rather rarely in the sampling mass (Coleoptera, Odonata, Trichoptera, Heteroptera and Diptera subgroup representatives, except the Chironomidae family). Their study calls for special approaches. As a result, the total number of species in this group – 65 – is close to the figure that represents the species registered in each of the expeditions. The Lower Danube macrozoobenthos' overall species quantity adds up to 288, which isa value that considerably exceeds the figures received in the instances of each separate survey.

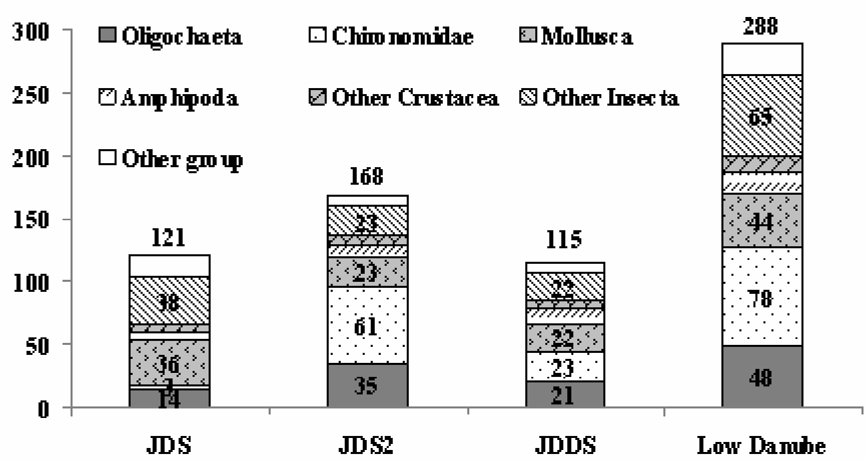

Figure 4. Taxonomic structure of macrozoobenthos of the Lower Danube based on JDS, JDS2 and JDDS results.

Table 1. Macrozoobenthos species composition coincidence indexes

	Total species		Mollusca		Crustacea		Oligochaeta		Other Insecta		Chironomidae	
	JDS	JDS2	JDS	JDS2	JDS	JDS2	JDS	JDS2	JDS	JDS2	JDS	JDS2
JDS2	41		68		62		41		43		9	
JDDS	33	37	52	62	50	52	34	43	20	22	0	19

The table presents the coincidence results of the overall macrozoobenthos species composition between the main groups of invertebrates. The congeniality level of general species lists is 33%-41%; the highest values are registered among the mollusks – a group that is comparatively innumerous in terms of species but easy in terms of determining the species' belonging. On one hand the decrease in identity index for Crustacea and Oligochaeta may be connected with the increasing difficulty of determining their systemic location. In case of otherInsecta - as is pointed out above- decrease in identity index may have been the result of the catching methods' drawbacks.Chironomidae were not determined at all during the first expedition. On the other hand, low species coincidence levels may be considered as a sign for the region's faunaspecificity. From this point of view minimal species coincidence in all groups - as registered in the JDDS context - points to the diversity of the delta (Figure 5).

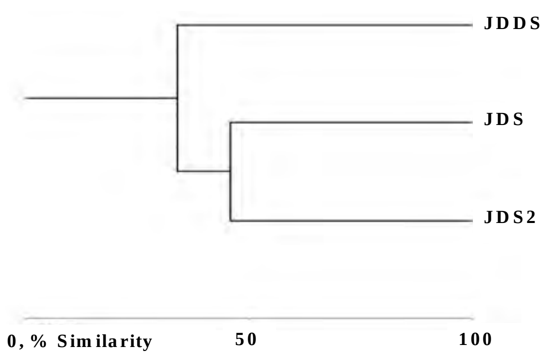

Figure 5. Dendogram of macrozoobenthos species composition coincidence inJDS, JDS2 and JDDS

Figure 6. Ecological conditions classification: white – II-Good, gray – III-Moderate, black – IV–Poor

Quantitative development indexes have not been investigated in the context of the JDS. In the JDS2 and the JDDS, the structure of main taxonomic groups had certain differences in terms of quantity: in the Lower Danube, Amphipoda, Gastropoda, Bivalvia and Oligochaeta were dominant (JDS2 2007); according to JDDS results the sequence of dominating groups in the mouth area was different: Oligochaeta, Gastropoda, Amphipoda and Chironomidae. Bivalvia, though prolific in the JDS2 samples were rather rare in 2011: *Corbicula fluminea* was registered at two stations only and did not form mass colonies; with regard to Dreissena only isolated specimens were detected.

Mollusks (Gastropoda and Bivalvia) accounted for the largest share in biomass. In comparison to the JDS2 results, Bivalvia accounted for over 80% of the total biomass, Gastropoda, for 15%; in the JDDS, the percentage ratio of Gastropoda: Bivalvia constituted 60:37. In both surveys, the share of Crustacea added up to 2% of the biomass, and a slight increase of Oligochaeta biomass was registered in the JDDS (>1% against 1.5%).

In order to determine the ecological condition the Zelinka-Marvan index was employed with the reference value of 2.0 for the Lower Danube (Sommerhäuseretal. 2003). The assessment results (Figure 6) were fluctuating within the boundaries of the II-IV classes of the “Good-Poor” scale. A trend of degradation was noted in the areas of urban influence (Giurgiulesti (st. 1), Kyliya (st. 5), Vilkovo (st. 6)); and the worst condition among the lakes was established for Lake Isak (st.15) – the largest, least running lake without submersed plants overgrowth. The JDS materials provided no figures for saprobity (JDS, 2001) which complicated the comparative assessment, however, the material of all of the surveys yielded the same results.

Conclusions

The conducted research has proved the heterogeneity of macrozoobenthos distribution in the Lower Danube which is caused by complex hydrologic and hydro-morphologic conditions that create rich biotopic diversity and in the long run secure biological diversity. Based on the materials of three research expeditions the quantity of Macrozoobenthos species in the Lower Danube adds up to 288 species. According to longstanding observations by Ukrainian specialists this figure is at least twice as big as the onefor the mouth area of the Danube alone even without taking the macrozoobenthos of near-Danube lakes into account (Markovskyi 2005, Polischuk 1974, Biodiversity… 1999, Liashenko & Zorina-Sakharova 2009). According to data furnished by the Romanian specialists not less than 290 species of bottom-dwelling invertebrates and 353 phytophyles indwell the delta (Danube Delta… 2006). It is clear that the separate expeditions’ results are not quite correlated with the systematic surveillance; moreover, fauna research was not amongst the major objectives of the expeditions. As a matter of fact the understanding of the material’s insufficiency regarding the delta’s comprehensive characteristic of ecological condition urged and led to organizing the JDDS in the framework of the project titled “Joint environmental monitoring, assessment and exchange of information for integrated management of the Danube delta region”. Obtained results supplemented the materials of the previous surveys and replenished the datasets regarding the macrozoobenthos of the Danube mouth area on the whole. Saprobity and bioindication assessments of the ecological conditions based on the materials of the three expeditions yielded the same results; apparently a limited number of stations suffice for the performance of these works. Hot locations situated in the areas under urban influence were detected their present contamination possesses do not character nor encompass the entire delta. Water quality in the delta is characterized predominantly as one belonging to category II: Good water quality and the similar saprobity values are quite logical: in view of a comparatively small expanse of the space from the mouth of the Prut to the sea (about 160-170 km) and high current speeds (average of 1 m s^{-1}) water passes the distance in 24-25 days. The change of quality indices in the lakes is due to the in-basin production and organic substance mineralization processes.

Acknowledgments

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Do researchers have anything to do with “Danubian killer machines”? *Eriocheir sinensis* in Hungary

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Keywords: Invasive species, Danube, Chinese mitten crab, Hungary, academic responsibility

Introduction

The Chinese mitten crab (*Eriocheir sinensis* H. Milne Edwards, 1854) is a commercially important catadromous species native to Eastern Asia. It declined over large areas in its original range due to overfishing, water pollution and dam construction, disrupting migration routes in China since 1982 (Jin et al. 2001). However, due to unintentional human introductions, as a successful invasive species it extended its distribution range to Europe (Linnaniemi 1933, Panning 1938, Herborg et al. 2003), North America (Rudnick et al 2003, de Lafontaine 2005, Hanson & Sytsma 2008), Iran (Robbins et al. 2006), and Iraq (Clark et al. 2006) in the last 100 years. Its European range stretches from Portugal and the U.K. to Finland and Russia (Haahtela 1963, Ingle 1986, Clark et al. 1998, Cabral & Costa, 1999). During the peak period of two invasions in Europe during the 20th century, this species expanded its range by 562 and 380 km per year (Herborg et al. 2003).

Fast growing populations of *E. sinensis* cause serious environmental problems in many ecosystems. Where the Chinese mitten crab became invasive in Europe or North America, the species greatly affected biodiversity, commercial fishing, angling, river bank erosion, especially in banks with steep gradient along sections with fluctuations in water level, e.g. below dams used for peak electricity production (Ingle 1986, Clark et al. 1998, Cabral & Costa, 1999, Herborg et al. 2003,). Due to the burrows it makes, this species heavily damages dikes. In its native range, unlike the European individuals, it is also a carrier of parasitic worms causing a human lung disease, from which at the moment 22 million people suffer from world-wide (Haswell-Elkins & Elkins 1998). As a consequence, *E. sinensis* is on the list of top 100 invaders of the world compiled by the International Union for Conservation of Nature and Natural Resources (Gollasch 2011).

The appearance of *E. sinensis* was of high public concern in Hungary due to the spread of improper information. This article discusses the case and academic responsibility related to the problems of invasive species.

Presence of *E. sinensis* in Hungary

Though Danubian fishermen spoke about occasional catches of crab-like animals since the middle of the 1990s in Hungary, the presence of *E. sinensis* along the Hungarian stretch of the Danube was confirmed only in the 21st century. The first live animal was collected in the main arm of the Danube, south of Budapest in November 2003 (Puky et al. 2005). The second and third specimens were caught by a fisherman south to Mohács, near the southern border of the country in February 2005 (Puky & Schád 2006) and November 2007. The fourth known individual was caught in Budapest, several kilometres away from the river in October 2011; it is suspected to have escaped from captivity.

Media coverage of *E. sinensis*

Altogether four *E. sinensis* specimens are known to be caught in Hungary in eight years, three from the River Danube. In spite of this low number several suspected effects of this invasive species circulated in nation-wide as well as local televisions, newspapers and the Internet. The “Danubian killer machine” was blamed for “being most aggressive”, “attacking everything and everyone leaving nothing behind”, “eating everything”, “destroying flood protection dikes till they collapse“, “killing fish” and forecasted as “becoming predominant”. Unfortunately, these opinions were also supported by some - ill-informed - nature conservation officials and thus, became widely known.

Media campaign against improper scientific information related to *E. sinensis*

The finding of the fourth live *E. sinensis* specimen in Hungary gave opportunity for a media campaign to spread proper information in relation to the animal which is considered to be the “Danubian killer machine”. The presence of this species poses several threats on its environment (Table 1). However, these are not valid for the Middle Danube region due its special geographical location and lung-parasite free environment in Hungary.

Due to the academic responsibility taken by scientists, this media campaign including the national media (radio and television programs as well as - even tabloid - newspapers) evaluated the presence of *E. sinensis* in Hungary in a realistic way. Even if it is listed among the top 100 invaders on Earth, at present it seems unlikely that it would cause much damage or threatens human health in this country. The veterinary investigation of the fourth individual, for example, proved that, similarly to other European specimens, it did not carry lung flukes (Majoros & Puky in press). As expected from the distance to the sea, where this species reproduces, mass occurrence did not happened, either.

Table 1. Main problems *E. sinensis* was thought to cause in Hungary, their validity, probability and necessary conditions for their development (Despite very low probability of occurrence (right column) the media published sensational articles.)

Problem	Validity	Conditions needed	Locations	Probability in Hungary
ecosystem change	Yes	high abundance	in and near large estuaries and bays in Europe and the USA (e.g. Thames)	very low due to distance from the sea
becoming predominant	Yes	optimal habitat	in and near large estuaries and bays in Europe and the USA (e.g. Odera/Odra)	very low due to distance from the sea
destroying flood protection dikes	Yes	high abundance	in and near large estuaries and bays in Europe and the USA (e.g. San Francisco Bay)	very low due to distance from the sea
consuming all possible food	No	extremely high abundance	not known	zero
attacking everything	No	might occur under extreme stress	not known	zero
spreading human disease	Yes	presence of lung fluke species and other intermediate host organisms (gastropod)	Asia	very low due to lack of other intermediate hosts; disease has not been found in European *E. sinensis* so far

Conclusions

E. sinensis is known to be present in the Danube catchment and connected waters such as the Black Sea (Zaitsev & Öztürk 2001, Gomui et al. 2002) and has been recorded in several Danube countries such as Austria, Romania and Serbia (Rabitch & Schiemer 2003, Otel 2004, Paunovic et al. 2004) in the 2000s. Globally, this species had serious ecological and economic impacts and can threaten human health, but not in Central-Europe. European *E. sinensis* individuals, for example, are even suggested to be collected and sold as delicacy for Asian restaurants in the UK (Clark et al. 2008). As a general lesson, it can be concluded that it is often difficult to select the right information on invasive species for non-professionals. As a consequence, researchers are responsible for informing the general public about the actual status of such species and their probable local and regional impacts. .

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Diversity of habitats and macroinvertebrate assemblages in the Brook Morgó (Börzsöny Mountain, Hungary)

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Keywords: *Brook Morgó, low stream, macroinvertebrate, spatio-temporal pattern*

Introduction

Faunistical, ecological estate, water quality and ecological investigations of low streams are more and more urgent because of the increasing number of problems regarding pollution and the negative effects of water usage on water quality. To resolve this, we need to register the long term changes from the aspect of the environmental endowments, water chemistry and fauna.

Small brooks and even rivers are bothered by different kinds of usage depending on the region and landscape. These habitats are especially important for conserving rare or specialised taxa of aquatic macroinvertebrates. Nevertheless, small brooks have important functions being part of a catchment area. That's why it is indispensable to know the results of increasing human interventions.

The structure and composition of benthic macroinvertebrate communities in freshwater ecosystems are very often used for biological assessment of water quality and evaluating the impact of chemical and other pollutants (Hellawell, 1986; Rosenberg & Resh, 1993). Benthic macroinvertebrates are known to be sensitive to habitat characteristics, including interrelated variables such as temperature, oxygenation, suspended sediment, turbulence, current, discharge, light, depth, substrate (Evan & Norris, 1997; Southwood, 1977; Statzner et al. 1988; Townsend, 1989; Ward, 1992). They are also known to respond rapidly to changes in water quality (Richards et al. 1997; Rosengerg & Resh, 1993). For these reasons, benthic macroinvertebrates have been used in several countries, as biological indicators, for assessment of water quality in rivers and streams (Barbour et al. 1999; Chester, 1980; Smith et al. 1999; Woodiwiss, 1964; Wright et al. 1984).

Protocols for the rapid assessment of freshwater ecosystems using macroinvertebrates recommend using the same sampling technique in different localities.

The aims of our study were to:

- demonstrate the changes of the fauna, compared to earlier results,
- demonstrate and explain spatio-temporal changes of density and diversity patterns.

Material and methods

Study area

This study was conducted in Börzsöny Mts., (N 47°4 6′ E18°57 ′, Duna-Ipoly National Park, Hungary), which lies in Northern Hungary. Börzsöny consists of effusive rocks (amphibole, piroxenandesite). The Morgó Brook is a small tributary of the Danube (mouth is at 1689 rkm). It runs down in an andesitic tuff valley to the Danube. The whole length of the brook is 16 km with a 625 m slope and the catchment area is about 600 km^2. The studied length is 12 km. The mean annual discharge is 1.14 m^3 s^{-1}, the minimum is 0.069 m^3 s^{-1} and the maximum is 16 m^3 s^{-1} (Juhász 2011).

The investigation began in March 2008; and lasted one year, with monthly sampling. There were similar previous investigations referring to the fauna and hydrobiological conditions of this brook (Csuták 1973, Kriska et al. 2005, Lien 1984). To refine our knowledge about biological communities in brooks, different sampling techniques need to be tested for shallow brooks.

Sampling sites

Altogether 5 sampling sites were investigated:

1. **MOR 1:** A fast flow section. The water-course is shallow, with stones and rocks of different sizes, the water is clear, anthropogenic activity is negligible.
2. **MOR 2:** Királyrét, with the confluence of the Nagyvasfazék Brook and the Szén Brook, it is called Morgó Brook from here. The water-course is shallow, with stones of different sizes. The anthropogenic pollution is noticeable. It originates from the nearby restaurants.
3. **MOR 3:** In the middle section the flow is fast, the river bed is muddy, sporadically spotted with stones. Vegetation in the stream could only be found here. Some parts of the brook are unshielded. Algae are common on the stones as a sign of benthic eutrophication.
4. **MOR 4:** This section is situated under Szokolya. The brook is bordered with weekend houses on one side and a road on the other. The area is highly populated. The water-course is wide, relatively deep and stony, the flow is fast and it is edged by trees. Algae are common on the stones.

5. **MOR 5:** This section is located before the final station of the railway in Kismaros, 500 m from the mouth of the brook at the Danube. The water-course is wide, relatively deep and stony, the flow is fast, fairly shaded and it is bordered by trees.

Sampling methods

The hydrophysical and hydrochemical parameters as well as hydrological conditions of the water were monitored. Water temperature, conductivity (µS cm^{-1}), pH, dissolved oxygen (mg L^{-1}), oxygen saturation (%) were measured in the field (in situ) with a WTW Multiline 340i device.

To refine our knowledge of biological communities in brooks, we need to test different sampling techniques for shallow brooks. Two types of sampling were used to collect macroinvertebrates at each site. Macrozoobenthos was collected with a dip net (D-frame, edge is 30 cm, mesh size Ľ 0.50 mm) and stone washing (20 piece of fist sized stone at each sampling sites) as well. These were used to collect invertebrates from various microhabitats. Macroinvertebrates were preserved in 85% ethanol for later identification in the laboratory. Afterwards samples were hand-sorted and organisms were identified to lowest level according to keys Andrikovics & Murányi 2002, Bass 1998, Belqat & Dakki 2004, Carausu et al. 1955, Csabai 2000, Csabai et al. 2002, Jedlička et al. 2004, Jensen 1984, 1997, Knoz 1980, Kriska 2008, Lechthaler & Car 2005, Rozkošný R. 1980, Seitz 1998).

Data analysis

According to Southwood (1987), diversity rests upon the simultaneous consideration of the number of species and their abundance in any given assemblage. To characterize abundance-dominance relationships using diversity statistics, we chose the Shannon-Weaver diversity index ($H = -\sum P_i * \ln P_i$, where P_i represents the relative abundance of each species) which is widely used in the field, making the comparisons with other works easier (Magurran, 1988). We used Past software-package for calculate the diversity index (Hammer et al. 2001). Through the non-normal distribution of data the abundance and species richness values were compared by the non-parametric Mann-Whitney test.

Results and discussion

Altogether, 6538 individuals of macroinvertebrates were identified from 90 samples. 46 new species were revealed in the brook’s fauna, one of these, the *Atrichops crassipes* (Meigen, 1820) (Diptera, family Athericidae) was new to the Hungarian fauna and the *Oulimnius tuberculatus* (P. J. W. Müller, 1806) (Coleoptera, family Elmidae) was new to the Börzsöny fauna as well (Boncz 1992, Csuták 1973, Kriska et al. 2005, Lien 1984, Murányi et al. 2009, Újhelyi 1969).

The orders of aquatic insects were mainly the following: Coleoptera, Ephemeroptera, Plecoptera, Simuliidae, Trichoptera. Average number of individuals of mayflies (order Ephemeroptera) was 44.6 in March and the maximum value was in May (227.8). During summer (40.6; 26) and autumn (25.2; 11.4) the values decreased and during winter increased again (Fig 1.). The temporal distribution is explained by the seasonal activity and the swarming time of the species. Mayflies were represented with the highest number of individuals by *Baetis rhodani* (Pictet, 1843); *Caenis robusta* Eaton, 1884; *Ephemera danica* Müller, 1764; *Ephemerella ignita* (Poda, 1761). *Epeorus assimilis* (Eaton, 1885); and *Procloeon bifidum* (Bengtsson 1912) existed near only the spring (MOR 1, MOR 2). The highest numbers of Mayflies were at MOR 4 and MOR 2 where the species richness was the highest.

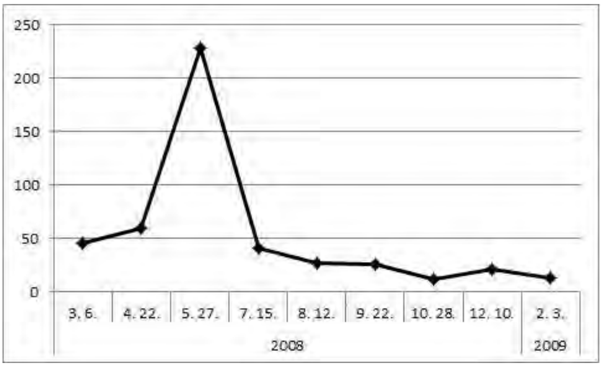

Figure 1. Seasonal value of average number of individuals (Ephemeroptera) - During the swarming period the numbers of larvae can decrease drastically

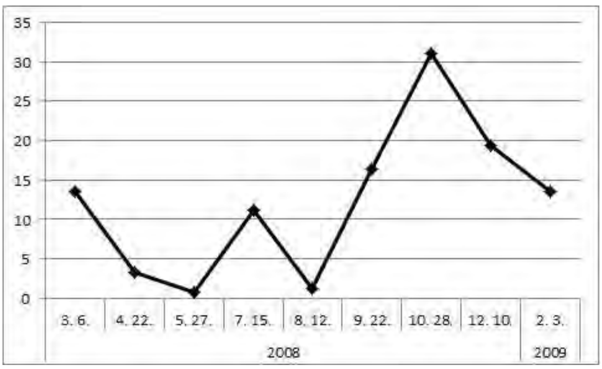

Figure 2. Seasonal value of average number of individuals (Plecoptera) - During the swarming period the numbers of larvae can decrease drastically

Average number of individuals of stoneflies (order Plecoptera) decreased from March to May (13.6-0.8), then it increased to July (11.2). The maximum value occurred in October (31.0), thereafter it decreased during winter time again. (19.4-13.6) (Fig. 2.).

The temporal distribution is explained by the seasonal activity and the swarming time of the species. The most frequent ones were the following: *Capnia bifrons* (Newman, 1839); *Leuctra hippopus* Kempny, 1899; *Nemoura cinerea* (Retzius, 1783). The species of *Brachyptera* genus (*Brachyptera risi* (Morton, 1896); *Brachyptera seticornis* (Klapálek, 1902)) were found beyond Szokolya (MOR1-MOR3) only. The *Protonemoura intricata* (Ris, 1902) and *Protonemoura praecox* (Morton, 1894) species were sporadic along the brook; we found these only at MOR 1and MOR 2 sampling sites. Altogether, the number of individuals and number of taxa were higher at the upper three sampling sites (MOR 1-MOR 3) than under Szokolya. The highest values were obtained from the MOR 2.

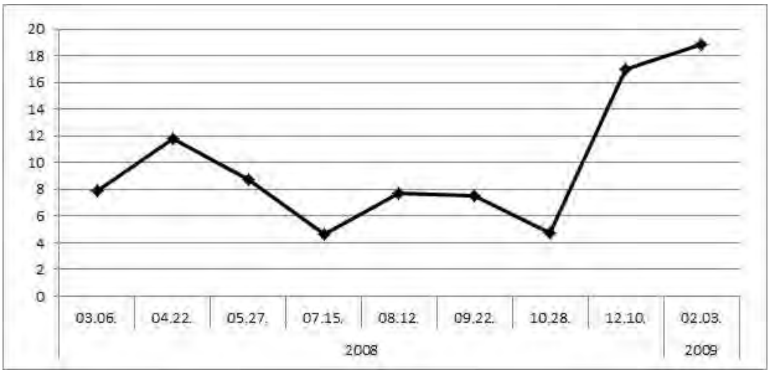

Figure 3. Seasonal value of average number of individuals (Trichoptera) - During the swarming period the numbers of larvae can decrease drastically

Average number of individuals (126.67) of caddisflies (order Trichoptera) decreased from spring to the beginning of summer (11.8-4.6) then it increased from August to February (7.7-18.9) (Fig 3.). The temporal distribution is explained by the seasonal activity and the swarming time of the species. The most frequent ones were the following: *Chaetopreyx fusca* Brauer, 1857; *Ecclisopteryx madida* (McLachlan, 1867); *Lepidostoma hirtum* (Fabricius, 1775); *Polycentropus flavomaculatus* (Pictet, 1834); *Synagapetus mosely* Ulmer, 1938. *Synagapetus mosely* was the most abundant species on the stones and rocks near the spring.

Diversity patterns

We characterized the diversity patterns of Ephemeroptera and Plecoptera by the Shannon-Weaver diversity index (Magurran 1988).

The diversity values of the Ephemeroptera reduced along the stream from the source to the mouth. The number of taxa decreased from MOR 1 (3.39) towards MOR 5 (1.56) as well (Fig 4.). The number of species was the lowest at the MOR ($t(1)= -3.112$, $p<0.01$).). The sampling sites near the mouth have lower density and diversity values because of the increasing nutrient content along the brook (from the spring to the mouth).

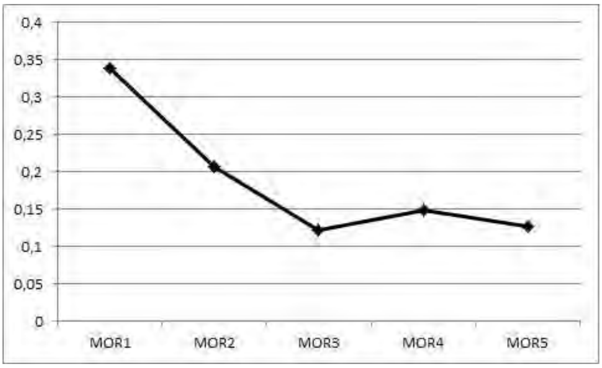

Figure 4. Diversity patterns of sampling sites (Ephemeroptera)

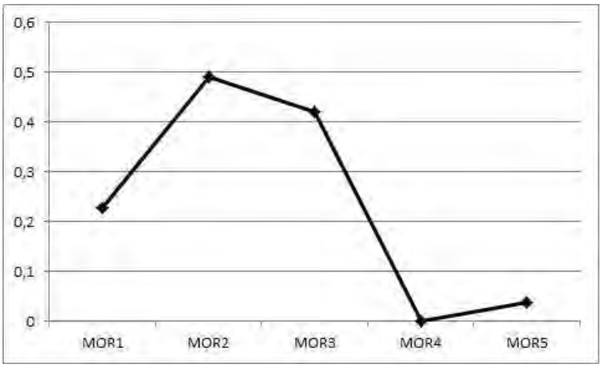

Figure 5. Diversity patterns of sampling sites (Plecoptera)

Regarding Plecoptera the most diverse (0.49) sampling site was the MOR 2. In the lower sections (MOR 4, MOR 5) of the brook the diversity was smaller than in the upper sections (MOR 1-MOR 3) (Fig 5.).We found significant difference in diversity of the sampling site between MOR 5 and the others ($t(1)= -2.11$; $p<0.05$). There were significant differences between the taxon numbers of the sampling sites as well. The highest value was measured at the MOR 2 (2.28). Significant difference occurred in taxon numbers between MOR 4 (0.22), MOR 5 (0.28) and the others (MOR 4: $t(1)= -3.026$, $p<0.01$; MOR 5: $t(1)= -2.932$, $p<0.01$).The sampling sites near the mouth have lower density and diversity values because of the increasing nutrient content along the brook (from the spring to the mouth).

We found growing number of species from four orders out of five (except Plecoptera) (Fig 6.). This is primarily due to know a little about the fauna of Brook Morgó.

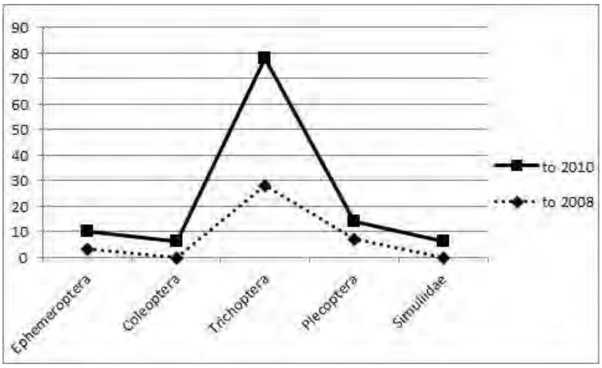

Figure 6. The increase of number of species in the biggest taxa

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Topic 6.
Environment and infrastructure in the European Strategy for the Danube Region (EUSDR): harmonisation of ecological needs and effects of different water usages

(drinking water, irrigation, navigation, hydro-power, dredging, fishing, reed management, recreation)

Irrigation water quality and role in sustainable development of northern Serbia

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Keywords: Danube-Tisza-Danube Hydro System, water quality, irrigation, classification, sustainability

Introduction

Irrigation practice is a major factor that brings advances to the crop production at a global level. However, irrigation activities cause salinization and alkalization, which results an extensive soil and water degradation everywhere where irrigation is practiced. There are well-known cases where changes in the chemistry of irrigation water have caused unacceptable effects in soils and plants. It means that the practices have caused these unwanted effects were not sustainable (Abernethy 1994). Obviously, irrigated agriculture needs to be sustained and rejuvenated (Rhoades 1997). Sustaining irrigation systems is a broad general statement. Various attributes could be considered as objects for sustaining, such as irrigation facilities, production potential, operational performance, but first of all irrigation water quality. The reform of irrigation water quality policies is thus the first and most important step towards creating conditions that encourage the sustainable use of water (Wolff 1999). The use of the existing classifications and the introduction of an additional procedure for water suitability estimate are avenues towards sustainable irrigation.

Vojvodina, the northern province of the Republic of Serbia, has large potentials for intensive development of irrigation. There are 1.67 million ha of arable land (about 75% of the total area of Vojvodina), of which practically all are suitable for irrigation. Introduction of irrigation is an actual necessity because, on average, the agricultural crops require from 100 to 300 mm of water more than provided by natural rainfall during the growing season. Presently, the main source or irrigation water are watercourses (over 90%), and the dominant irrigation method is sprinkling (80-90%). The irrigated acreage predominantly includes agricultural plots and gardens (95%) while the remaining 5% are irrigated orchards (Belic et al. 2001, 2011). Water quality plays an important role in irrigation practice. The irrigation practice brings along some hazards, which are most commonly manifested as secondary salinization and alkalization, typically caused by increased concentrations of salts in irrigation water. It happens frequently that different methods of water quality classification provide contradictory results.

This problem may be solved by introducing an additional, corrective procedure of irrigation water assessment (Lijklema, 1995).

Materials and Methods

The evaluation of water quality for irrigation included several watercourses considered the characteristic of Vojvodina. The evaluation was based on (compiled in the course of) official monitoring programs in the period of 1980 – 2009 and data were presented in hydrological yearbooks for water quality published by Hydro-Meteorological Service of the Republic of Serbia (www.hidmet.gov.rs). During the observed period, water samples were taken 6-24 times per year, depending on the water sampling point in question. The sampling included 30 points, located in the major watercourses in Vojvodina (Figure 1).

The irrigation water quality classifications used in this study were FAO classification, USSL classification, classification according to Nejgebauer and irrigation water classification according to chloride content (Johanson & Zhang 2009, Kirda 1997). An additional procedure of irrigation water assessment was also used, which included the determination of sodium adsorption ratio (SAR), sodium percentage (SSP), residual sodium carbonate (RSC), residual sodium bi-carbonate (RSBC), magnesium content (MAR), permeability index (PI), and Kelly's ratio (KR) (Seilsepour et al. 2009, Van de Graff & Patterson 2001, Prasad et al. 2001, Obiefuna & Sheriff 2010).

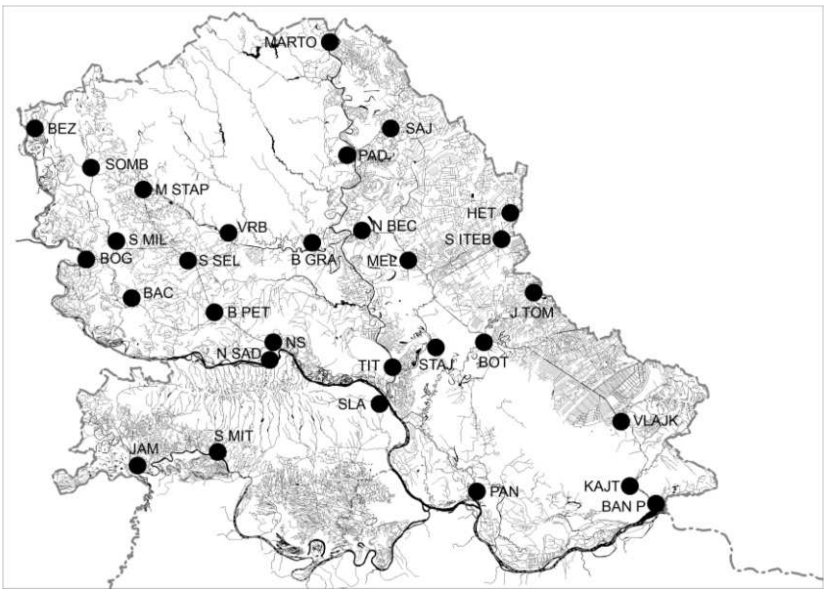

Figure 1. Location of water sampling points

Results and Discussion

According to the classifications of FAO, Nejgebauer and USSL, the waters of all tributaries of the Danube River in Serbia can be considered to be suitable for irrigation (Table 1). The previous statement was contrary to the part of the FAO classification which referred to the restricted use of water prone to salinization. This was also confirmed by the value of SSP, a parameter in the additional assessment of irrigation water quality (Table 2), which was near to the border value that distinguishes the favorable from unfavorable irrigation water. On the other hand, the values of RSC and PI indicated that the analyzed waters could be used for irrigation without restrictions. A general conclusion was drawn that the water of the Danube River can be used for irrigation, provided that the status of water used and treated soils are systematically monitored.

According to Nejgebauer’s classification, more than two thirds of the samples taken from the Tisa River were not suitable for irrigation or this water may be used only for well-drained soils, while ensuring that the status of these soils is monitored systematically and comprehensively. These findings may cause a concern, since irrigation systems are planned to be established on considerable acreages along the Tisa River in both Backa and Banat regions, and these systems will be used for the production of field crops, especially vegetables. The FAO classification considered integrally produced similar results. Potential problems with the water from the Tisa River have also been hinted by the values of SSP, RSC and PI, which were above the allowable limits.

Similarly to the water from the Tisa River, the water from the Sava River was found to be potentially capable of causing problems with soil infiltration and salinization. On the other hand, according to other parameters in the other classifications including the additional one, the suitability of Sava water was not a subject to any restrictions. The USSL classification produced similar results. Most of the samples of water from the Danube, Tisza and Sava Rivers were placed in C2-S1 class, indicating that these waters can be safely used for irrigation. Several samples that fell into C3-S1 class indicated a threat of alkalization of the soils irrigated with such water.

The U.S. Salinity Laboratory Classification (USSL) is a result of many years of team work. It involves a procedure for evaluation of irrigation water quality, including considerations of the hazards of salinization and alkalization of irrigated soils. The classification is based on the values of electrical conductivity as an indicator of salt concentration and SAR values as an indicator of the relative activity of water soluble Na in the adsorption reactions with soil. Nejgebauer’s classification of water had been proposed for the natural conditions of Vojvodina in 1949. This classification placed special emphasis on the ratio (Ca + Mg):Na. The FAO classification (Ayers & Westcot 1985) includes detailed analyses of the effect of salts dissolved in irrigation water on infiltration properties of soil and the toxic effects of certain ions such as Na^+ and Cl^- on plants.

Table 1. Suitability of irrigation water according to the classifications used in the study

Watercourse/ classification		Nejgebauer*	USSL	Cl	FAO			
					Salinity	Infiltration	Na toxicity	Cl toxicity
		Class	Class	Restriction on use	Restriction on use			
Danu -be	Max	II	C3-S1	None	Slight to moderate	Slight to moderate	None	None
	Min	Ia	C1-S1	None	None	None	None	None
Tisa	Max	IIIb	C3-S1	For sensitive plants	Slight to moderate	Severe	Slight to moderate	Slight to moderate
	Min	II	C1-S1	None	None	None	None	None
Sava	Max	Ib	C3-S1	None	Slight to moderate	Severe	None	None
	Min	Ia	C1-S1	None	None	None	None	None
Tami s	Max	II	C3-S1	For sensitive plants	Slight to moderate	Severe	Slight to moderate	None
	Min	Ia	C1-S1	None	None	None	None	None
Bege j	Max	IVb	C4-S2	For semi-tolerant plants	Slight to moderate	Slight to moderate	Slight to moderate	Slight to moderate
	Min	II	C1-S1	None	None	None	None	None
Zlati-ca	Max	IVb	C4-S3	Should not be used	Severe	Slight to moderate	Slight to moderate	Slight to moderate
	Min	II	C2-S1	None	None	None	None	None
DTD HS	Max	IVb	C4-S2	For semi-tolerant plants	Slight to moderate	Severe	Slight to moderate	Slight to moderate
	Min	II	C1-S1	None	None	None	None	None

*According to this classification, irrigation water is divided into four classes, according to the amount of TDS and ratio (Ca+Mg):Na. First class – excellent water quality (Ia - SO<700mg/l, (Ca+Mg):(Na+K)>3; Ib - Ia - SO<700mg/l, (Ca+Mg):Na>3). Second class – good water quality (SO<700mg/l, (Ca+Mg):Na>1). Third class –water quality should be tested (IIIa – SO=700-3000mg/l, (Ca+Mg):Na>3; IIIb - SO=700-3000mg/l, (Ca+Mg):Na>1). Fourth class – unsuitable water quality (IVa – SO<700mg/l, (Ca+Mg):Na<1; IVb – SO=700-3000mg/l, (Ca+Mg):Na<1; IVc SO>3000mg/l, (Ca+Mg):Na>)

Considering the plans to increase the irrigated acreage in Banat, it is definitely important to estimate the status of the water courses in that region. While the waters of the Danube, Sava and Tisa were considered as generally unfavorable, the waters of the Zlatica and partly of the Begej and Tamis rivers were recognized by all classifications, used as unfavorable for irrigation. According to

Nejgebauer, most of the analyzed waters were in classes II or III, with occasional samples in class IVb. According to the USSL classification, the analyzed waters were class C3S1 or worse. The FAO classification indicated that a significant number of the samples posed a hazard of salinization that could be associated with deterioration of infiltration properties of soil and in some instances there was a hazard of toxic ions. Concerning the additional assessment of irrigation water quality, the recorded SSP and SAR values indicated the presence of significant amounts of sodium. Even the values of RSC, RSBC and PI were significantly over the recommended limit values.

The canal network of the Danube-Tisza-Danube Hydro System (DTD HS) should play an important role in the development of irrigation in Vojvodina. Therefore, it is important to establish the current water quality status in the canal network. There was a mild decreasing trend for water quality and there was an increasing mineralization trend in most of the analyzed samples. In the region of Backa, about one third of the waters were classified in C3S1 class. Two thirds of the waters were in class II according to Nejgebauer. These waters can be used for irrigation. Unfavorable SSP ratios, frequently accompanied by unfavorable RSC values, were simultaneously recorded at the same locations. Based on these results, the waters in DTD HS in the region of Backa can be recommended for irrigation of well-drained soils, providing that the status of the irrigated soils is systematically monitored. A similar situation was found in the analyzed DTD HS locations in the region of Banat, noting that the dominant classes were C3S1 according to the USSL and class II according to Nejgebauer. In the Banat locations, SSP values were as a rule significantly higher than the recommended values.

Table 2. Additional procedure for irrigation water assessment

Watercourse/Additional irrigation water assessment		MAR (%)	SSP (%)	RSC (meq x l^{-1})	RSBC (meq x l^{-1})	PI (%)	KR (meq x l^{-1})	SAR (meq x l^{-1})
Danube	Max	86.96	31.87	2.00	2.74	128.96	0.56	1.52
	Min	15.15	5.09	-3.26	-1.72	33.79	0.04	0.11
Tisa	Max	76.92	62.06	4.50	4.69	98.57	1.55	2.31
	Min	8.37	3.66	-3.15	-0.89	33.71	0.03	0.10
Sava	Max	81.37	22.54	1.29	2.87	78.70	0.27	0.80
	Min	7.60	3.34	-3.15	-0.83	31.83	0.03	0.08
Tamis	Max	62.19	68.88	2.32	3.89	93.57	2.17	5.67
	Min	9.20	6.51	-1.92	-1.42	41.29	0.06	0.14
Begej	Max	85.10	69.42	12.93	18.43	95.92	1.99	5.52
	Min	18.51	9.96	-3.56	-0.54	37.32	0.07	0.19
Zlatica	Max	53.67	74.96	3.39	5.55	84.83	2.81	10.58
	Min	26.75	29.78	-3.64	-1.21	56.89	0.39	1.12
DTD HS	Max	82.54	96.96	8.49	9.05	119.63	2.40	7.47
	Min	2.97	3.01	-6.95	-2.65	14.69	0.01	0.04

The results presented in Tables 1 and 2 shows us, how far variable and inconsistent the analyzed assessment procedures were. It can be concluded for the analyzed period and locations that Nejgebauer's classification was the most stringent (Table 1), defining a significant portion of the analyzed samples as unsuitable for irrigation. The waters of the Danube, Tisa, and Begej were found to be acceptable for irrigation, except in some cases when it was recommended to monitor the changes in soil chemistry due to the potential adverse effects of these waters. Considering the results of water suitability for irrigation, obtained by the FAO classification, these results were not always in accord with the other estimates, especially when the hazards of salinization or disturbance of soil infiltration properties were analyzed. Perhaps this can be understood if we take it into account that different irrigation standards had used during this classification procedure.

As the results above showed, when the additional procedure for water suitability estimation (Table 2) is considered integrally that makes the assessment more reliable. In this particular case, the values of SSP were unfavorable for most of the samples. A similar situation was observed for PI. The values of SAR and RSC were unfavorable in a small number of the samples. Thus, most of the analyzed samples showed good agreement between the results of the additional assessment and the USSL classification. The results of the additional assessment were in agreement with the FAO classification only to some extent. Although a significant number of the samples showed good agreement between the values of the additional assessment and Nejgebauer's classification of irrigation water.

Conclusion

The additional procedure for irrigation water assessment may be implemented for evaluation of irrigation water quality in combination with the generally used classifications and it stay within the sustainability framework for irrigation practice. The main purpose of the additional assessment was to confirm or correct the results obtained by the conventional classifications. In this study, there was a good agreement between the results of the additional assessment and those of the USSL and Nejgebauer's classifications. The additional assessment was found to be necessary to amend the results of the FAO classification and the water classification according to chloride content when testing the suitability of surface waters from Vojvodina for irrigation.

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Need for harmonization of contradicting efforts: development of the Danube navigation and protection of river ecosystems

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Keywords: river regulation, waterway improvement, navigability, landscape ecology, stakeholder analysis

Introduction

The Danube has been one of Europe's most important inland waterways for several centuries and it also has formed a transport route between Eastern and Western Europe via the Rhine-Main-Danube Canal since the early 1990's. Nevertheless, the transport volume on the Danube has fallen dramatically behind the other competing road and rail networks. The improvement of mobility in inland waterways, particularly in the Danube, is one of the priority areas of the Danube Region Strategy (DRS), however its assessment requires a multilateral approach. This study reviews some contradicting economic and environmental efforts related to the Danube navigation sector and considers the needs of society, such as improvement of environmental quality and protection or restoration of fluvial ecosystem functions.

The Rhine-Main-Danube transcontinental waterway

The EU’s largest river, the Danube is navigable along almost its entire length, from the Black Sea up to Germany (r.km 2,588). The European inland waterway network increased significantly in 1992, when the Rhine-Main-Danube Canal was completed. The 3,505 km long navigable route between the Rhine estuary (at Rotterdam in Netherlands) and the Danube Delta (or Constanța, through the Danube – Black Sea Canal) in eastern Romania provides an important international waterway (known as the Pan-European Transport Corridor VII). The inland navigation is an indispensable element of the European traffic system, its proportion is more than 10% in t/km, but this activity is mainly concentrated around the ARA (Antwerp-Rotterdam-Amsterdam) seaport area, as well as in their associated waterways (Lányi et al. 2007, MAKK 2007).

The Rhine, where the intensity of boat traffic is 8.5 times higher than in the Danube, is a frequently mentioned example encouraging the better exploitation of navigation potential of the Danube. The main difference between the Rhine and Danube navigation comes from the different industrialization, economic development and density of settlements along these rivers. The Rhine is ideal for navigation: it joins powerful economic centers, connected to the North Sea and the Atlantic Ocean at one of the busiest seaport area of the world, while the average distance between its internationally significant harbors is only 30 km and it is linked to several important waterways as well. By contrast, the Danube joins less powerful economic centers, the average distance between its internationally significant harbors is 90 km (Lányi et al. 2007, MAKK 2007), it is linked to only one important waterway and connected to the Black Sea at the less developed seaport. The Danube river basin is 817,000 km^2, it is the 1/17 part of the continent, which means home to 86 million people and covers only the 1/25 part of the world trade. The Rhine river basin is only the 1/3 part of the Danube basin, but it is home to 140 million people and covers the 1/5 part of the world trade (Soós 2006).

Economic aspects

Often cited arguments encouraging the more intense use of the Danube waterway are, that navigation is the most cost-effective and safest way of freight transport, with the lowest environmental impact. However water transport is in competition with road transport of processed parceled goods. Trucking can provide a door-to-door transport and it can adapt more flexibly to customer requirements and it is more suitable for smaller scale transport needs. Water transport is mainly profitable in large scale carrying of bulk goods, but in this field the rail transport has better network coverage, also it is much faster and its logistic management system is more predictable (PINE 2004, Milewski 2011).

	Inland navigation	Rail transport	Road transport
Transport capacity of the same energy consumption	25	8	1
Investment cost requirements (t/km)	1	6	8
Freight fee income	1	3,5	11,8
Labor demand	1	7	15
CO_2 emission (t/km)	1	1,1	3,7

Table 1. Relative cost and CO_2 emission of inland navigation compared to rail and road transport – modified after Soós (2006).

The main advantage of the inland waterway transport can be its low cost, which seems convincing from economic aspects, but we need to consider that the transshipment expenditure also plays an important role. It is obvious, that ships might serve as the cheapest way of the delivery between two harbors, but entering of goods to the harbors is restricted by several circumstances along the

Danube, such as the obsolete state of harbor infrastructure, narrow transshipment volume, insufficient storage capacity, limited enlargement possibilities due to urban areas and weak connection to the main rail and road lines (PINE 2004).

Different fleet characteristics on the Danube and Rhine waterways demonstrate, that ship-building technologies can adapt to natural conditions and economic circumstances, without massive interventions in the river landscape. A typical self-propelled freight boat in the Rhine has 3,000 t cargo capacity and 2.8 meter immersion. Pushed barges are the most typical in the Danube freight transport, but their proportion is decreasing. A classic self-propelled freight boat in the Danube has 900 t cargo capacity and 2.3-2.8 meter immersion (PINE 2004). The Danubian fleet in Central Europe has become obsolete through uncertain market and regulatory conditions. Currently 1,619 boats are running on the Rhine, which also would be able to travel on the Danube, nevertheless 59 boats are only on the Danube, which are well equipped for navigation on the Rhine waterway (Lányi et al. 2007).

Competition between transport modes forces inland waterway transport to increase its efficiency. Its profitability highly depends on frequency and duration of preferred water depths. Freight transport by larger boats provides higher income due to its lower cost, but its profitable operation period is restricted by the water level fluctuation. Smaller boats can operate at lower profitability, but their cost-effective period is longer and their overall utilization is also better. The larger boat are less competitive on the standard (2.5 meter deep) Danube waterway, therefore their owners are interested in the removal of natural bottlenecks on the navigation route and lobbying for the improvement of the navigability (Tőry 1957, MAKK 2007).

Poor waterway conditions are not the only reason of low-level utilization of fleet capacity on the Danube. Organizational problems and the low quality of water-level forecasts also result in efficiency loss. It is reasonable to assume a 10 to 20% efficiency loss due to waterway conditions (MAKK 2007).

Improving conditions of transcontinental freight transport can theoretically increase the economic competitiveness in the Danube Region, but it is not clear, whether the balance of exports and imports would be positive for the Central and Eastern European economies, in particular the influence of the Far East import pressure. It is a serious issue in agriculture, where the increasing competition would force more intense farming, which can be detrimental for Hungary in consideration of market, society and environment.

Environmental aspects

River engineering for improvement of navigation route (including channel regulation, dredging, dam and harbor constructions, etc.) may adversely affect some other important ways of water uses, in particular the drinking water supply, as well as the agriculture and forestry (due to alteration of groundwater level), furthermore it may cause a decline in self-purification capacity of the river by modification of biological water quality in several section of the Danube, especially in Hungary (Iványi et al. 2012).

Development of navigability has additional significant impacts on the fluvial ecosystem and ecological status of the Danube (Schiemer et al. 2004), as:

- reduced hydrological connectivity both with the groundwater and with the floodplains;
- restricted hydro-morphological processes (formation of bars, islands and new riverbeds) in the floodplain and concentration of the erosive forces on the main river bed.
- lowering water tables both in the stream and in the floodplain due to permanent bed incision.
- loss of natural inshore structures and floodplain water bodies, affecting crucial habitats of river fishes, invertebrates and birds.

Enhancement of inland navigation increases hazards directly impacting on the nurseries of freshwater fish, especially for smaller individuals with limited swimming abilities. Magnitude of ship-induced physical forces (wave and current) limits the availability of littoral habitats for small fishes in low-flowing waterways. Smaller juvenile fishes that are unable to withstand higher currents could become washed out or injured, therefore the recruitment of fish populations declines along the waterways (Wolter et al. 2004, Kucera-Hirzinger et al. 2008).

The damaging impacts of navigation on Danube ecosystems are increasingly recognized by the society and they need to be solved by a multi-level approach. The EU water policy includes strict provisions regarding the options of river engineering, which could lead into conflicts between the inland shipping sector and environmental protection. Harmonization of economic and environmental interest within the frame of sustainability is one of the main issues in the DRS. The maintenance of natural landscape forming processes and functioning fluvial ecosystems of the Danube is the EU's special responsibility, as it is stated in the EU Water Framework Directive (EC 1999) and another European directives and international agreements for nature conservation.

Conclusions

The realized profitability of efficiency enhancement and its relationship to expenses and unwanted consequences is a critical issue for the future of the Danube navigation. In the current situation, the negative impacts are concentrated in the navigation sector, but before the implementation of the enormous and expensive interventions for improvement of navigability, other scenarios for harmonization of interests must be examined from environmental and social point of view (MAKK 2007).

Enhancement of the inland waterway transportation and further enlargement navigation route constitutes a considerable threat for the Danube ecosystems and the remaining natural areas of floodplains, as well as the drinking water supply and groundwater level. Rather than further re-engineering of the river according to certain types of ships, upgrading of transport intelligence, shaping of the fleet to the river, adaptation to water level fluctuations, could be opportunities to create a more competitive and ecologically sustainable waterway transport on the Danube.

In issues of improvement of navigability on the Rhine-Main-Danube transcontinental waterway, reconciliation of sectorial requirements by multidisciplinary approach is a substantial interest for 11 countries with different economic development and natural conditions. Research institutes of scientific academies could effectively contribute to this momentous job, because of their sectorial independence.

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Topic 7
Environment and the implementation of the EU WFD: rehabilitation or sustenance of ecological function, good ecological status accordingg to WFD, good conservation status of NATURA2000 sites, monitoring

Plants, animals and recommendations on rehabilitation of the flood land water body in the upper section of the Tisa River

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Keywords: flood land, lake, plants, animals, recreation, rehabilitation

Introduction

The Teplitsa Lake is a unique water body in the flood-land of the Upper Tisa, located nearby the Bocicu-Mare (Romania) at the altitude 277 m. Its area is about 3 ha, average depth 1.8 m. It was formed at the place of gravel extraction in the 1960ies, when quarries were united, two small isles were formed and the coast line was embanked. In that period the fishes were settled into the lake, plants were planted and adjacent territory was resurfaced. Occurrence of the water body with lentic conditions, properly the unique lake at such altitude, connecting with the Tisa River over the flood period provided a variety of new ecological niches. Their occupation led to forming of the peculiar flora and fauna. Since 1990ies the lake was not paid attention, this led to its almost total overgrowth by the higher aquatic plants. So, the aim of this work was to develop recommendations on the Teplitsa Lake rehabilitation on the basis of investigation of its flora and fauna.

Material and methods

The Teplitsa Lake was investigated in the summer-autumn period of the year 2009. We studied the species composition and distribution of the aquatic and coastal vegetation, bottom and phytophilous invertebrates, phytoplankton, zooplankton and ichthyofauna. Besides, presence of the waterfowl was registered, and local amateur fishermen were interviewed with the purpose to detail species composition of fishes.

Phytoplankton samples were taken at the depth 0.3–0.5 m in the middle part of the lake. Algae were determined and counted using the Nageotte chamber (volume 0.02 ml), using the light microscope Laboval (Germany). Zooplankton and ichthyoplankton samples were taken by filtering 100–300 l of water trough the Epstein plankton net (cell size – 78 μm), and processed by standard methods (Romanenko 2006]. Macroinvertebrates were sampled taking into account visually distinguished habitats along the coastal line, by zoological net 10×10 cm, and by washing organisms off the aquatic plants.

At all sampling sites were carried out biotopes' description determination of the dissolved oxygen concentration (by oximeter Oxi 315i), pH, water temperature (by pH-millivoltmeter pH-150MA and portable pH-meter pHep-2), electric conductivity (by conductometer Dist WP-2), Secchi water transparence. Besides, were carried out distant echo-scanning of the depths and detailed survey of the thermal conditions of all water area of the lake by echo-sounder with temperature detector (Smart Cast RF 35e). Obtained data were calculated and statistically processed using the original software AquaBioBase [Afanasyev et al., 2010], which corresponds with ASTERICS (AQEM assessment system) and Soviet software WACO (Water Community).

The work was supported by the Project "Complex of measures on integrated water and land resources management of the Upper Tisa basin (Ukraine–Romania)" which is realized by the Transcarpathian regional organization of the All-Ukrainian Environmental League with financial support of UNDP-GEF.

Results and discussion

The Teplitsa Lake – the unique big water body in the flood land of the upper Tisa, located nearby the Bocicu-Mare (Romania) (47°56'30.84"N, 23°56'35.49"E), at the altitude 277 m a. s. l. Its length amounts to 440 m, width – 70–75 m, area about 3 ha, average depth about 1.8 m, maximal – 2.7 m. The lake is located at the distance 600 m from the Tisa River stream. The lake sides are sloping, totally embanked. In the central part of the lake probably occurs small source of the thermal waters, which creates zone of elevated by 1–2°C temperatures of 15–25 m diameter.

Around the lake were registered more than 40 species of riparian plants and 7 species of the aquatic plants. Plant cover of the southern side is massive and quite diverse. Among trees and shrubs dominated *Populus nigra* L. and various willow species, mainly *Salix alba* L. f. *Pendula, Salix matsudana* Koidz., also occur *Prunus spinosa* L., *Euonymus europaea* L., *Crataegus* L. and *Rosa canina* L. Grass level is formed by *Artemisia vulgaris* L., *Calystegia sepium* (L.) R. Br., *Centaurea jacea* L., *Chaerophyllum aromaticum* L., *Cichorium intybus* L., *Clinopodium vulgare* L., *Dactylis glomerata* L., *Dianthus* L., *Equisetum pratense* L., *Eupatorium cannabium* L., *Knautia arvensis* (L.) Coult., *Lycopus europaeus* L., *Lycopus* L., *Mentha aquatica* L., *Mentha arvensis* L., *Myosoton aquaticum* (L.), *Peucedanum palustre* (L.) Moench, *Poa palustris* L., *Ranunculus acris* L., *Swida sanguinea* (L.) Opiz, *Tanacetum vulgare* L., *Trifolium* L., *Urtica dioica* L., *Veronica chamaedrys* L., *Vicia* L., *Xanthium albinum* (Widd.) H. Scholz. Plant cover of the northern side was significantly poorer, in the western side it is grazed by the cattle, thus in the waste territory around the lake the plant cover is degraded. In this section dominated *Populus nigra* L. and willows *Salix*.

Two isles in the lake are massively covered by willows, mainly by the shrubby species *Salix fragilis* L. and *Salix rosmarinifolia* L., among them there were small beds of reed *Phragmites australis* (Cav.) Trin. Ex Steud., the mannagrass *Glyceria maxima* (C. Hartm.) Holmb and sedges *Carex* sp.

Aquatic flora comprises all ecological groups; the most widely presented were the emerged plants, 5 species: *Glyceria maxima* (C. Hartm.) Holmb. (14% of the projective cover), *Typha angustifolia* L. (3%), *Phragmites australis* (Cav.) Trin. ex Steud (2%), *Mentha aquatica* L. and *Carex sp*. (1%). Groups of the plants with floating leaves and submerged plants included one species each, accordingly: *Potamogeton natans* L., which dominated in terms of projective cover (55%) and green filamentous algae (about 2%).

Profile of vegetation was as follows: zone of the emerged plants 1 m wide comprised mainly *Mentha aquatica* and *Glyceria maxima*, it occupied the coast line up to 0.4–0.5 m depth. Then were located vegetation of the single species *Potamogeton natans*, due to small depth this plant occupied significant area: about 70–75% of the water area was covered by massive stocks. Green filamentous algae occurred sporadically. The eastern section of the lake should be noted, where vegetation of the higher aquatic plants was significant, processes of bogging were observed, area of massive vegetation of *Glyceria maxima* amounted to 0.25 ha, just in this part of the lake occurred separate beds of *Typha angustifolia*, *Phragmites australis* and *Carex* sp., between them vegetated green filamentous algae and *Potamogeton natans*, so no open water area remained. .

Phytoplankton of the Teplitsa Lake in summer comprised 40 algal species of 8 groups (Table 1). Bacillariophyta were the most diverse – 21 species.

Table 1. Quantitative parameters of phytoplankton of the Teplitsa Lake

Department	N	Number of cells		Biomass	
		thousand cells dm^{-3}	%	mg dm^{-3}	%
Cyanophyta	1	275	7.5	0.004	0.4
Crytophyta	2	10	0.3	0.074	7.5
Dinophyta	2	45	1.2	0.009	0.9
Euglenophyta	2	10	0.3	0.037	3.8
Chlorophyta	6	75	2.0	0.119	12.1
Chrysophyta	5	3070	83.5	0.465	47.4
Xanthophyta	1	5	0.1	0.002	0.2
Bacillariophyta	21	185	5.0	0.271	27.6
Total	**40**	**3675**		**0.980**	

In phytoplankton dominated Chrysophyta. The most abundant was *Dinobryon divergens* (58.5% of numbers and 29.6% of biomass), in terms of numbers sub-dominated *D. divergens v. angulatus* (16.3%) and *Oscillatoria planctonica* (7.5%). In terms of biomass sub-dominated the big-cell Diatom *Gyrosigma acuminatum* (10.7%). Department Chlorophyta comprised equal portions of three orders: Chlamydomonadales, Chlorococcales and Desmidiales (2 species each).

By peculiarities of the considered water body and by conditions, noted in the period of survey (summer) mass vegetation of Cyanophyta or Chlorococcales would be expected. Thus mass development of Chrysophyta is quite interesting phenomenon and requires further investigation. By phytoplankton parameters the lake is characterized as β-meso-saprobic zone (S = 1.86)

Zooplankton of the Teplitsa Lake comprised 23 taxa, among them 13 Rotatoria, 5 Copepoda and 5 Cladocera. The most abundant were species character for the eutrophic and mesosaprobic waters. Among Rotatoria dominated species of limnophilous complex: *Euchlanis dilatata* Ehrenberg, *Brachionus angularis* Gosse, and planktonic-benthic species *Mytilina ventralis* (Ehrenberg) and *Rotaria* sp. Crustaceans were presented less diversely, however they also played notable role in planktofauna. Among Copepoda were found limnophilous species *Eucyclops serrulatus* (Fischer), *Acanthocyclops vernalis* (Fischer), *Mesocyclops leuckarti* (Claus), and typical benthic Harpacticoida sp. The most abundant of Copepoda were nauplia and copepodites of different development stages. Among Cladocera were found *Simocephalus vetulus* (O.F. Müller), *Ceriodaphnia affinis* Lilljeborg, *C. pulchella* Sars, *Chydorus sphaericus* (O.F. Müller) and *Ch. globosus* Baird. All these species formed the main portion of biomass.

Total quantitative indexes were low, numbers amounted to 14.03 thousand ind. m^{-3}, biomass – to 0.34 mg m^{-3}. Probably this was conditioned by intensive feeding of the juvenile and plankton-eating fishes on zooplankton.

Table 2. Quantitative parameters of zooplankton of the Teplitsa Lake

	n species	Numbers		Biomass	
		thousand ind m^{-3}	%	mg m^{-3}	%
Rotatoria	13	2.02	14.4	0.01	2.9
Copepoda	5	6.27	44.7	0.28	82.4
Cladocera	5	5.74	40.9	0.05	14.7
Total	**23**	**14.03**		**0.34**	

In the Teplitsa Lake were registered 73 species of invertebrates. Maximal species richness and numbers was character for arthropods, among them prevailed the secondary-aquatic insects: up to 60% of the species number. We found nymphs and larvae of: Chironomidae – 23 species, Heteroptera – 6, Ephemeroptera – 4 Trichoptera – 4, other Diptera – 2, Odonata – 1, Coleoptera

– 2, Megaloptera – 1, and Culicidae – 1 species. By abundance dominated Chironomidae larvae – 36% of total numbers. Among Ephemeroptera the most frequently occurred species of the central and southern-European biogeographic group – *Caenis horaria* (Linne, 1758) and *Cloeon dipterum* (Linne, 1758). Among Trichoptera dominated species of the family Leptoceridae – *Athripsodes aterrimus* (Stephens, 1836). Odonata were presented exclusively by the family Coenagrionidae. Among Diptera the most widely presented were the family Chironomidae, dominated by *Cladotanitarsus gr. mancus* Walker, 1856.

Besides, in macroinvertebrate fauna were noted Crustacea – 12 species, Oligochaeta – 7 Hirudinea – 4, Gastropoda – 3, Arachnida – 2, Bivalvia (Sphaeriidae) – 1, and Nematoda – 1 species. Most species of macrofauna of the Teplitsa Lake are character for the lacustrine ecosystems. Crustaceans were presented by the orders Cyclopoida, Ostracoda, Isopoda, at this in samples prevailed planktonic species. Among benthic forms Isopoda dominated *Jaera istri* Vieuille, and only single specimens of *Asellus aquaticus* (L.) were found. In autumn period Oligochaeta were quite abundant. Among mollusks the most abundant were Sphaeriidae.

Biological indication by invertebrates' parameters demonstrated, that this eutrophic lake belongs to β"-mesosaprobic zone. Water quality deterioration in the lake was observed in summer period. In autumn period organic matters' content in water decreased, at this species richness and amount of invertebrates increased.

Table 3. Quantitative parameters of zooplankton of the Teplitsa Lake (n/d: not determined to species

Group	n species	Numbers	
		specimens m^{-2}	%
Nematoda	n/d	18	0.28
Oligochaeta	7	576	8.87
Hirudinea	4	63	0.97
Gastropoda	3	126	1.94
Sphaeridae	1	351	5.41
Copepoda	6	720	11.09
Cladocera	4	450	6.93
Isopoda	2	252	3.88
Arachnida	2	36	0.55
Heteroptera	6	90	1.39
Odonata	1	54	0.83
Megaloptera	1	36	0.55
Ephemeroptera	4	1044	16.08
Trichoptera	4	279	4.30
Colleoptera	2	18	0.28
Culicidae	1	36	0.55
Chironomidae	23	2313	35.62
Diptera	2	18	0.28
Total	**73**	**6480**	

In the Teplitsa Lake we registered 5 fish species: *Cyprinus carpio* L., *Carassius carassius* L., *Tinca tinca* L., *Esox lucius* L., *Rutilus rutilus* L. According to data (Lengyel 2006; Portal eMaramures.ro 2008) fishes in the lake are quite big.

Among other vertebrates were found the muskrat (*Ondatra zibethicus*) and 4 species of waterfowl: *Gallinula chloropus* L., *Anas platyrhynchus* L., *A. penelope* L., and *A. querqnedula* L.

Comparison of the plants and animals' composition of the Teplitsa Lake with those of the Tisa River within adjacent section (Afanasyev 2010) showed that vegetation in the lake is notably richer in species and more abundant. Also in the lake is formed a unique for the Upper Tisa basin complex of the planktonic algae and animals. Over the floods they considerably enrich biological resources of the river. Among macroinvertebrates the most special species complex is formed of the primary-aquatic animals. Finding of some species of Molluska, Oligochaeta, Hirudinea and Crustacea at the altitude 277 m a. s. l. is a unique for the Tisa basin. Besides, for the first time in the Upper Tisa basin were found invertebrates, earlier not found in the riverine conditions: *Stylaria lacustris* (Linnaeus, 1767), *Acrolocsus lacustris* (Linne); *Sphaerium sp.*; *Jaera istri*; *Notonecta maulata* Fabricius, 1794; *Plea minutissima* Leach, 1817; Sialis sp.; *Athripsodes aterrimus* (Stephens, 1836); *Mystacides longicornis* (Linne, 1758); *Cyrnus flavidus* Mc Lachlan, 1864; *Agabus* sp. The same regarding fishes of the lake. So, in view of stability of the aquatic ecosystems of the Upper Tisa basin and preservation of their high biological diversity, the Teplitsa Lake serves as a refugium, which needs constant protection from pollution and conservation of its good ecological status.

Significant overgrowth of the lake by higher aquatic plants and silts accumulation indicate notable accumulation of the organic matters, so first of all it is needed to mitigate processes of eutrophication, conditioned by recreational and agricultural activity, cattle pasture.

Obtained data on the flora and fauna development and analysis of the eutrophication causes enabled to suggest some measures of the Teplitsa Lake rehabilitation. These measures include limitation of income of the allochthonous organic matters by means of limitation of the cattle pasture in the coastal zone and removal of the nutritive matters from the lake. There are some approaches to solve this problem (Henderson-Sellers 1990, Parchuk 1994, Naumenko 2007). Taking into account ecological status of the lake and economic element, removal of excess aquatic plants can be suggested. Overgrowth of the aquatic plants causes bogging of the water body, and their remains serve as source of the secondary pollution. Besides, for the water bodies intended for economical use cover of the aquatic vegetation should not exceed 10–25% of the total water area (Summary 1986). Removal of the excess amount of plants from water increases dissolved oxygen content and significantly decreases content of the nutritive matters. Removal of plants can be carried out mechanically or biologically. The most environment-friendly and profitable is the method of the lake is fish-amelioration using the grass carp *Ctenopharyngodon idella*.

Issues of the grass carp use as biological ameliorator in the different-type water bodies are substantially reported in the works of the Ukrainian specialists (Vovk 1976, Baltadgi 2009). In the closed water bodies the grass carp does not reproduce (Vovk 1976). This fact is of special importance in view of the Tisa River basin “contamination” by the invasive species. In the given case this species is totally under control and does not pose a threat neither for the gene pool, nor for the ecological niches of the native fishes. We have calculated that for the biological amelioration of the Teplitsa Lake (to decrease overgrowth by higher aquatic plants) it is needed to settle 150 specimens of the grass carp of the average mass 100–500 g per hectare of the water area. The grass carp of such mass practically is not affected by the predatory fishes and actively consume aquatic vegetation. At calculation of the seeding density we have taken into account that excess settling of the grass carp can cause secondary pollution of the water body and algal bloom. In order to mitigate this process it is needed to provide development of the riparian zone of vegetation.

As for mechanical removal of the plants, special attention should be paid to removal of *Potamogeton natans* vegetation, which covers maximal surface of the water body, whereas this plant is a valuable forage object and row material for pharmacy (Heiny 1993). Massive vegetations of *Glyceria maxima* in the eastern part of the lake also should be eliminated.

Conclusion

On the whole it should be noted that as a result of economical developments of the flood land in the upper section of the Tisa River occurs construction of the protective banks and drainage of the flood-land water bodies for the agricultural purposes. At this many organisms, inhabited these water bodies loss their habitats. Floods, which run through the narrow section, complicate conditions of the organisms’ survival in the river beds. The Teplitsa Lake is a unique refugium for the flood land complex of species, just it serves as the “last shelter” for the lentic flora and fauna in the upper section of the Tisa River basin, and creates conditions for enrichment and interchange of the species between the Tisa River stream and its flood land. All this causes special responsibility for the further fate of the Teplitsa Lake and to develop and realize measures on its rehabilitation and conservation in good ecological status.

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Topic 8
Technical aspects and the implementation of the EU WFD: ecological effects of water engineering facilities *(barrages, object of flood protections and bed regulations)*, navigation, hydro-power *(direct and indirect effects, short and long term observations)*

Impact of hydropower constructions and dyking on the Danube riverine ecosystems

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Keywords: biodiversity, floodplains, ecosystem function, hydromorphological alteration

Introduction

The Danube, with a length of 2826 km, is one of the most important European rivers. Its catchment area of 817,000 km^2 covers 8% of Europe's surface. The Danube flows 1075 km through Romania (38% of the total length), of which 800 km are impounded.

According to the geomorphological and hydrological characteristics three sections are distinguished along the Danube: *the Upper Danube* from the springs to Devin Gate, *the Middle Danube* from Devin Gate to the end of the Iron Gate gorge and *the Lower Danube* from the Iron Gate gorge to the mouth of the river.

The Danube receives 120 major tributaries on its entire course, of which 34 are navigable: among them, Isar in the Upper Danube, Tisza, Drava, Sava, Morava in the Middle Danube, Arges, Ialomita, Siret, Prut in the Lower Danube on the left side, and Timoc, Isker and Intra on the right side in Bulgaria (Brezeanu et al. 2011).

Hydropower constructions and dykes, the latter for over 100 years, represent a major impact by dividing and transforming the river course. These hydromorphological alterations have caused radical changes in biocenotic structures and fluvial ecosystem function.

The impact of hydropower dams

62 large impoundments on the Danube have changed the geomorphological, hydrological and physico-chemical properties of the river. The formation of new ecosystems caused obvious changes in the river life (Fig. 1). Moreover, hydropeaking impacts on aquatic and riparian communities.

By damming, the water flow in the Lower Danube decreased from 3-5 m/s to less than 1 m/s, thus influencing considerably the hydrological regime and hydrobiological function of the Danube. Reduced flow caused the acceleration of suspended sediment deposition and, hence, water transparency increased from 30-50cm to 2-3m. This led to deeper solar light and heat penetration into the water column causing variable thermal stratification during summer.

The hydro-chemical character has changed and the amount of oxygen is higher at surface than in depths, especially near the banks where the water current is much reduced (from 0.75 to 0.25 m/s). In these areas, the mineral particles and the organic particulate matter were deposited rapidly at the bottom of the newly formed ecosystem changing the structure of the benthic facies. The rocky bottom was covered with a thick layer of mineral-organic deposits over 10-11m in some areas of the river, respectively at the Iron Gate I Reservoir.

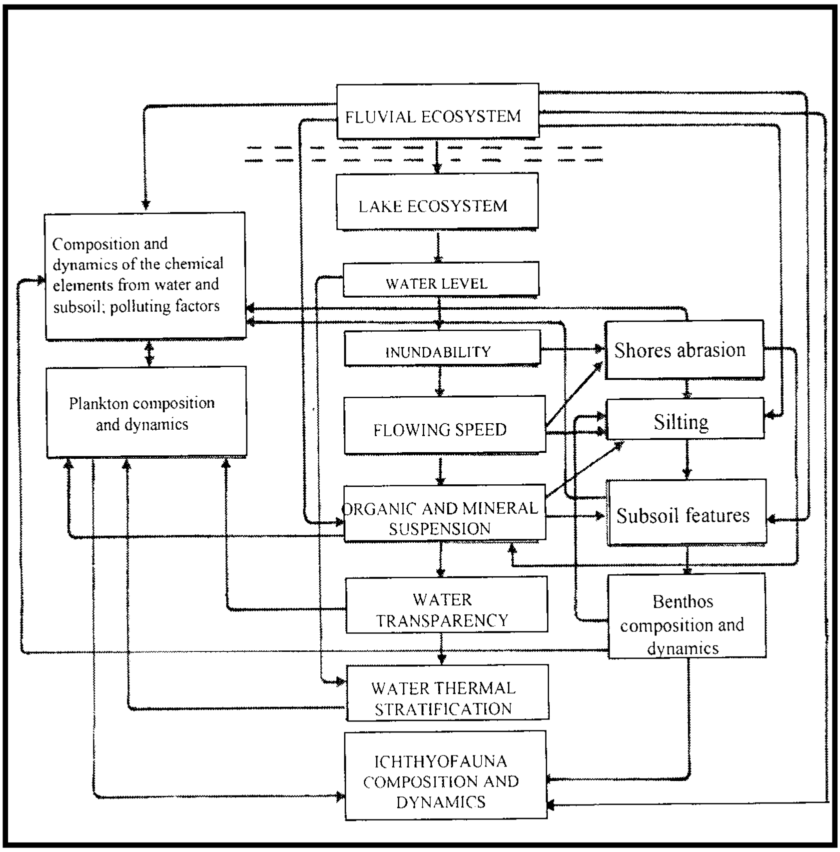

Figure 1. The structural-functional relationships of reservoirs on the Danube

The impact of hydropower constructions caused fundamental changes in the structure of Danube biocenoses. For example, explosions of phytoplankton development have occurred due to increasing eutrophication (Kiss et al. 2000). *Pandorina morum, Chlamydomonas* sp., *Peridinium* sp., *Melosira granulata, Cyclotella meneghiniana, Fragilaria crotonensis, Tabellaria fenestrata, Synedra acus, Diatoma* sp., *Cymatopleura solea*, and *Surirella robusta* became dominant within the fluvial-lacustrine ecosystem (Brezeanu et al. 2011).

Obvious changes occurred in the zooplankton structure in terms of quantity, in this respect four periods are distinguished in its development: During 1971-1972 the density increased from 30000 ex x m^{-3} to 4654500 ex x m^{-3} , followed by a slight decrease in 1972-1973; in the third period (1973-1974) the decrease continued to 450000 ex x m^{-3} (corresponding to 800 mg x m^{-3}); since 1974 to present the numerical and biomass density stabilized at average values, recorded in the Iron Gate I Reservoir in 1974 (Brezeanu & Cioboiu 2006, Schöll et al. 2010).

From 493 invertebrate species identified before damming, 353 species have disappeared during the first 2-3 years after reservoir formation. At present about 90 species can be found, specific to the pelophile biocenoses, with dominant groups such as chironomides, oligochaetes, Corophiidae, molluscs (*Dreissena polymorpha, Sphaerium riviculum*) (Brezeanu & Gruia 2000, Oertel 2000).

The ichthyofauna structure was changed by an increase of *Alburnus alburnus, Pelecus cultratus, Rutilus rutilus, Esox lucius, Perca fluviatilis* and *Schizostedion lucioperca* due to biocenotic changes in correlation with the hydrological regime. The Iron Gate dams in the Lower Danube disrupt the migration of fish, particularly the sturgeons *Huso huso*, *Acipenser gueldenstaedti* and *A. stellatus.*

The impact of Danube dykes

A fine example of large-scale river bank construction impacts is the Danube dyking in the Romanian sector (Antipa 1910, 1921, Ardelean et al. 1964, Cioboiu & Brezeanu, 2008).

During 1962–1965 and especially after 1970, the river became a subject of a vast scheming process through the construction of a 1,157 km long dyke on the territory of Romania. Thus, the river was separated from its floodplain (Fig. 2). As a consequence, the temporary and permanent lakes and pools, with a surface of 300,000 ha, were large parts of the former floodplain were transformed into agricultural fields with poor productivity due to sandy, low-nutrient soils and due to the lack of flooding phenomenon.

As the flora and fauna structure is specific to the floodplain, hundreds of aquatic and terrestrial plant and animal species disappeared (Cioboiu 2004). Local and regional hydro-geomorphologic and topoclimatic systems were also affected. In the context of global climate change, when meteorological and hydrological extremes become more frequent, the disconnection of the floodplain stresses the excessiveness of the continental dry climate in the area.

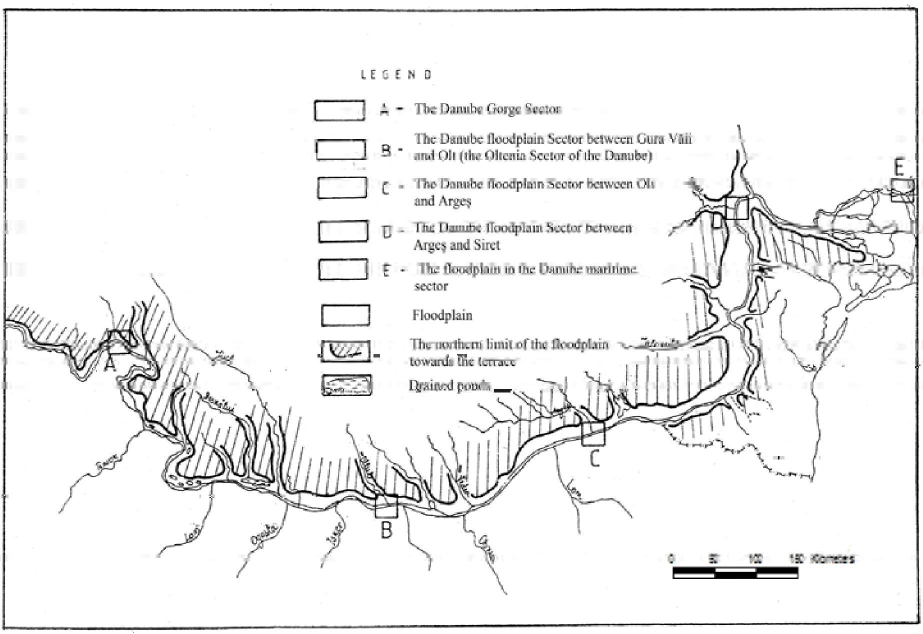

Figure 2. The Lower Danube floodplains (rkm 28 – 900) (after Ardelean et al. 1964)

This experience from Romania proved that the most of the agricultural planning works were inefficient or even prejudicial. Under the present climatic conditions, negative processes affect soil evolution within the floodplain, such as salinization, deterioration of the soil structure by decreasing the amount of organic substances, decrease of nutrient content, extremely low cereal production etc.

The disappearance of floodplains in the present context represents a factor of ecologic unbalance with negative implications from many points of view – decrease of biodiversity, disequilibrium of the local and regional climate, drastic reduction of the natural resources and ecosystem services specific to floodplains (Bloesch 2002).

The Danube dykes at rkm 811-661 demonstrate the formation of new biotopic and biocenotic structures, i.e. new types of terrestrial and aquatic ecosystems and a decrease of biodiversity.

Plant associations have developed, in which woody species as *Salix* sp., *Populus* sp., *Ulmus minor*, *Fraxinus excelsior* and herbaceous species as *Secale sylvestre*, *Festuca vaginata*, *Silene conica*, *Trifolium arvense*, *Dianthus* sp. became dominant. Characteristic animal populations emerged with snails (*Helicella candicans*, *Cepaea vindobonensis*, *Helix pomatia)*, beetles (*Cerambyx cerdo*, *Lucanus cervus)*, toads (*Bombina variegata)*, snakes (*Natrix natrix)*, tortoises (*Testudo hermanni)* and some species of birds and mammals.

Typical aquatic flora elements are the algal groups of *Cyanophyceae, Euglenophyceae, Bacillaryophyceae* and *Chlorophyceae*, species of marsh macrophytes (*Phragmites communis, Typha latifolia, Scirpus lacustris, Mentha aquatica, Iris pseudacorus*) and aquatic macrophytes (*Lemna minor, Nymphaea alba, Polygonum amphibium, Potamogeton crispus, Salvinia natans, Ceratophyllum submersum*).

The faunal structure is characterized by over 200 species of invertebrates, belonging to the groups rotifers, copepods, cladocera, oligochaeta, gastropods, bivalves, amphipods, odonata, chironomidae as well as vertebrate species of fish (*Esox lucius*, *Scardinius erythrophthalmus*, *Aspius aspius*, *Misgurnus fossilis*, *Cobitis taenia*, *Silurus glanis)* (Cioboiu 2008; Tomescu 1998).

Conclusions

The described hydromorphological impacts by dams led to a simplification of population structures, turning fluvial into fluvial-lacustrine ecosystems.

Since dking disrupted the lateral connection to floodplains, their natural flooding was stopped and the entire structure of the ecosystems has significantly changed. Within the floodplain, permanent lakes (40%), temporary lakes/pools (40%) and rarely flooded terrains (20%) were lost.

Acknowledgements

I would like to express my great appreciation to the reviewer who helped me improve the quality of the paper.

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The structure and functions of the rotifer assemblages on Sfântu Gheorghe branch (Danube Delta) impacted by hydrotechnical works

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Keywords: rotifers, natural and anthropogenic factors, biodiversity, Sfântu Gheorghe branch

Introduction

The Danube Delta is the youngest and most changing land in Romania. It is one of the largest wetlands in the world (580700 ha) (Pringle et al. 1993) and also because of its ecological characteristics it is the only delta in the world which was declared to be a Biosphere Reserve since 1990 (Oosterberg et al. 2000).

The anthropogenic impact on Danube Delta's fresh water system increased further with industrial and agricultural development. Responding to the direct anthropogenic activities, the biological integrity of aquatic ecosystems and biodiversity suffered significant changes (Gâştescu 2009). The hydrotechnical works performed on Sfântu Gheorghe branch in the 80s in order to improve navigation on the river affected the structure and functionality of aquatic biocoenosis by altering the physico-chemical factors (Gâştescu & Ştiucă 2006). After hydrotehnical changes a complex of ecosystems with different features: new channels, meanders and natural sectors were born.

In freshwater systems, zooplankton forms an important link in the food web, the main consumers of primary producers and source for the next trophic categories, including fish (Michael 1973).

Rotatoria is a representative group in the zooplankton structure, easy to be found in various aquatic ecosystems. Their species composition, abundance, biomass and productivity can give important information regarding aquatic habitats. One of the reasons why they can be used as indicators for eutrophication processes and water quality changes is their sensitivity to environmental changes (Sakesena 1987).

The aim of our research was to identify the variation of rotifers in different areas (natural and altered due to hydraulic works) on Sfântu Gheorghe branch, in relation to the key physical and chemical drivers.

Materials and methods

Samples were taken and measured for physical, chemical and biological parameters seasonally between 2008-2010, in April, July and October. In order to do so 7 transects were established with coastal and medial prelevation points on the branch (44°53’984”N 29°34’660”E and 45°05’79 5”N 29°04’885”E).

Zooplankton samples from the water column were collected using a Patalas-Schindler plankton trap. 50 L of water were filtered through a 65 µm mesh size net and immediately preserved in 4% formalin solution. The species and abundance were identified using an inverted microscope. For biomass calculations, the dry weight of the organism was used according to Dumont et al (1975) and Odermatt (1970). The results were expressed in µg wet weight L^{-l} according to Winberg (1971). The productivity was expressed in µg wet^{-l} weight L^{-l}/day and determined using IBP methodology (Edmondson & Winberg 1971).

Species diversity (Shannon index), dominance (Simpson’s index) and evenness (E1 index) were calculated in order to provide further information about community composition than simply species’ richness. Furthermore Pearson correlation coefficients (determining the linear connection between two datasets) were calculated between physical-chemical factors and ecological parameters of rotifers. Multiple regression analysis was used to calculate the statistical relationships between biotic variables and abiotic factors and to obtain predictive models.

Results and discussion

Species composition and diversity index

Taxonomic investigations on Sfântu Gheorghe rotifers highlight 62 species in meanders followed by natural sectors with 54 species. Specific richness was the lowest in the channels (45 species) possibly due to unfavorable conditions (high flow velocity, increased turbulence, high amount of suspended solids).

The following persistent species were found: *Asplanchna priodonta* Gosse, *Brachionus angularis* Gosse*, B.calyciflorus dorcas* Gosse, *Keratella cochlearis* Gosse and *Polyarthra remata* Skorikow*.*

Compared to years prior to spring 2010, the values for the Shannon Wiener index were significantly higher in natural areas, channels and meanders. Evenness index value tends to 1, which means a uniform distribution of individuals among the species. The inverse correlation between the Shannon Wiener index and Simpson’s index (describing dominance) means that, if there is a high diversity of species it will be characterized with a low numerical dominance in the certain community (Fig. 1).

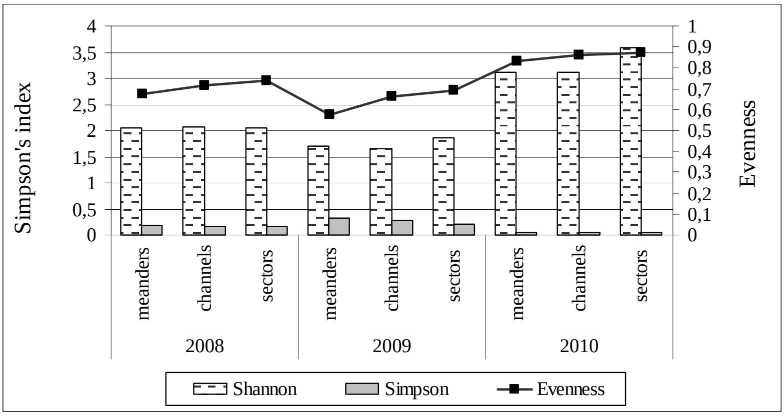

Figure 1. Shannon-Wiener index, evenness and Simpson dominance index in spring

In summer 2010-compared to spring – the Shannon-Wiener indices substantially increased in meanders. Regarding the dominance index in all three years in the meanders its values are quite low and the evenness indicates no major difference among the areas not spatially or temporarily (Fig. 2).

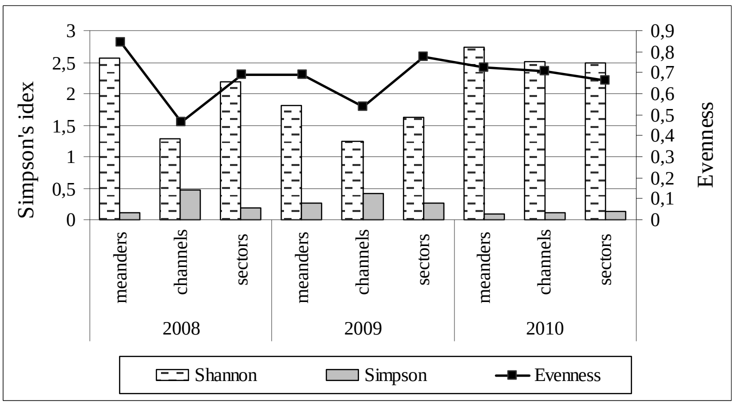

Figure 2. Shannon-Wiener index, evenness and Simpson dominance index in summer season.

The highest values for diversity indices were observed in autumn in the natural sectors (2010) and meanders (2009). The inversely variation of Simpson index with Shannon index unambigously shows that where diversity is low (October 2008) some rotifers species will dominate in terms of abundance and biomass. (Fig. 3).

The values of rotifers abundance on Sfântu Gheorghe branch are generally moderate (tens or hundreds ind L^{-1}), compared to the Danube Delta lakes, where they can reach thousands ind L^{-1} (Zinevici et al. 2006).

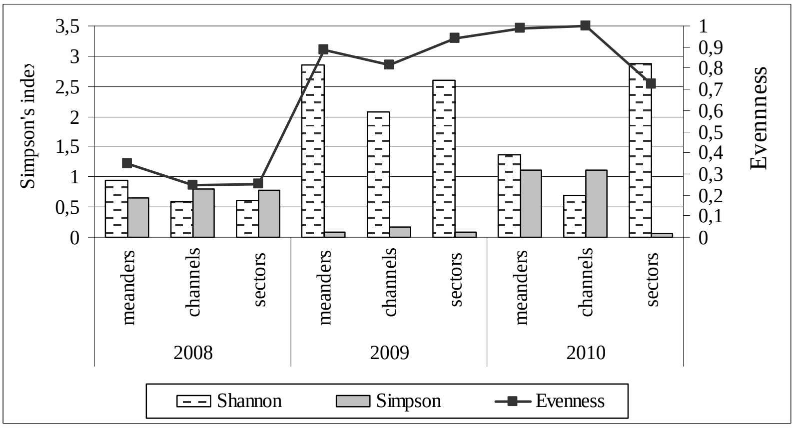

Figure 3. Shannon-Wiener index, evenness and Simpson dominance index in autumn

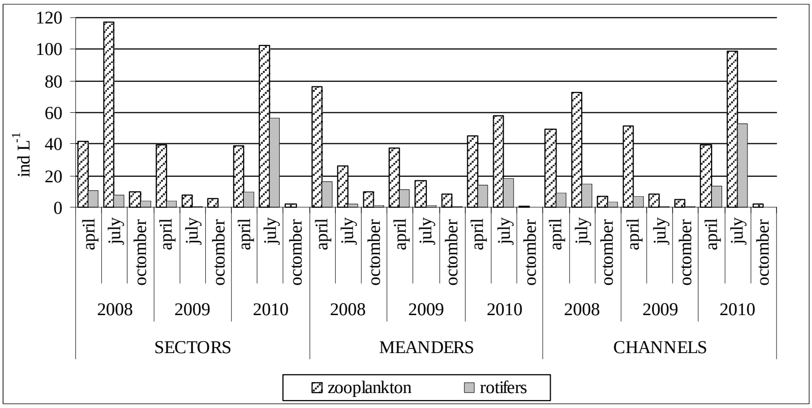

Figure 4. Seasonal variations in the abundance of rotifers

In the entire period the abundance of rotifers fluctuated between the seasons and the three areas. If the abundance of the three seasons are compared it can be said that the greatest values can be found in spring and summer in the natural sectors (56.81 ind L^{-1}), followed by channels (52.81 ind L^{-1}) and meanders (18.32 ind L^{-1}); these values decrease in autumn in meanders (0.035 ind L^{-1}), in channels (0.071 ind L^{-1}) and in sectors (0.198 ind L^{-1}). With regard to the zooplankton community's abundance these show the same trend as the rotifers (Fig. 4).

Biomass and secondary production

Biomass and production showed a similar seasonal variation as abundance. The smaller values of biomass were recorded in 2010. In the meanders: 0.06825 µg wet weight L^{-1} and sectors: 0.186 µg wet weight L^{-1}. However under favorable conditions (for developing rotifers biomass; in spring) these reached the maximum of 86.97107 µg wet weight L^{-1} in the sectors.

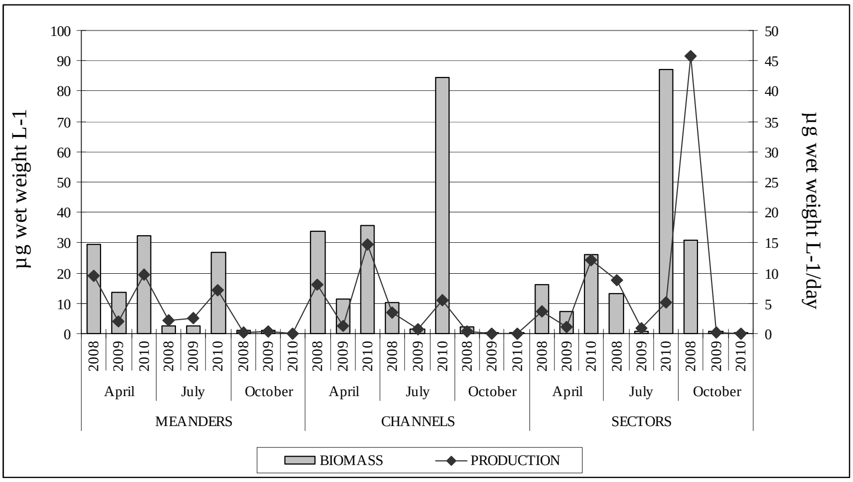

Figure 5. Seasonal variations of biomass and secondary production of rotifers

The highest values of secondary production were recorded in 2008 in the sectors (45.74 µg wet weight L^{-1} /day) and in 2010 in the channels (14.65 µg wet weight L^{-1} /day). In question of the seasons the most balanced production values were recorded in summer in all three types of ecosystems (Fig. 5).

Statistical data analysis

The simple correlations between the rotifers' ecological parameters and physical - chemical parameters pointed out the main factors modulating this community. The results showed that the species richness is primarily determined by NO_2, P org (µg /l), ($p< 0.0001$), and in a smaller extent by NO_3 (mg N/l) and DIN ($p<0.05$). Rotifers' abundance was correlated with NO_3, ($p< 0.0001$), NO_2 ($p< 0.01$), COT ($P<0.001$).

In the literature there are only a few studies dealing with biomass dynamics and production depending on physical-chemical factors (Illyová et al, 2008). Biomass was correlated with following parameters: NO_3 ($p<0.0001$), DIN ($p<0.001$), COT, NO_2, temperature, water depth, transparency. Also there are strong linear relationships between rotifers' production and the concentration of the following physical and chemical factors: DIN ($p<0.001$, NO_2 ($p<0.01$), P org, COT ($p<0.05$).

The multivariate analysis of the rotifers' ecological parameters and the physical - chemical factors allowed us to develop mathematical models describing their relationship. Multiple regression equations were determined which approximate the dynamics of species richness, numerical abundance, biomass and

production. Species richness = -5.09 + 1.17562X pH + 0.12215XCOT -12.6896 X NO_2 + 1.300265X NO_3,
Abundance = -7.14343+0.605586 x Temp. -59.4637 x NO_2 + 10.99045 x NO_3
Biomass =12.8226 + 1.040896 x Temp. - 73.9846 x NO_2 + 13.19086 x NO_3
Production = - 1.90201 + 0.19613 x DIN + 0.171896 x Abundance - 0.0949 x Biomass

The ANOVA test is widely used in ecological data processing to demonstrate the differences between the means any parameter. In order to assess statistically significant differences between the three-years of the study unifactorial ANOVA test was applied. It was used to measure rotifer community's environmental parameters in Sfântu Gheorge arm. Regarding numerical abundance, biomass and production ($p < 0.01$, F> F critical) the test showed significant differences between the three years (Table 1).

Table 1. Results of Anova test for statistical differences between ecological parameters rotifers in different years

Ecological parameter	F	P-value	F crit
Abundance	6.233	0.0026	3.072
Biomass	8.485	0.0003	3.072
Production	6.012	0.0032	3.072

Conclusions and Outlook

The analysis of the rotifer community's structural and functional parameters showed the impact of the hydraulic works. It was reflected in low values witnessed in the meander areas and the newly built channels.

By applying simple correlations between the rotifer's ecological parameters and physical - chemical parameters we have revealed that there are statistically significant factors that modulate the structure and functions of this community.

The four mathematical models are only valid for the branch Sfântu Gheorghe. To use it in other types of aquatic ecosystems validation by empirical observations is required.

The ANOVA test on the rotifers' community indicated statistically significant differences in the three study years. Regarding these parameters: 2007, 2008 and 2010 had different characteristics in the functional regime of the Sfântu Gheorghe branch (hydrology, climate, precipitation) and these influenced the abundance, biomass and production differently as well.

Sfântu Gheorghe branch shows the marks of anthropogenic activity from the years 1985-1990 when the course was regulated by cutting the meanders and constructing the channels. These measures resulted in a complex of ecosystems with a changed structure and function.

Acknowledgements

Our study was part of the Institute of Biology project named: “The impact of hydraulic works on the ecological systems of Sfântu Gheorghe branch, in the context of sustainable development”. We thank the Romanian Academy for the financial support of this study. Thanks to anonymous reviewer for the help and guidance in completing these works.

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BioDiversity Pro, available for download at http://www.sams.ac.uk/research/software

XLSTAT, available for download at http://www.xlstat.com/en/

Structural dynamics of phytoplankton community in Sfântu Gheorghe branch (Danube Delta). Predictive possibilities

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Keywords: phytoplankton dynamics, diversity indices, statistical analyses

Introduction

The Danube Delta, located between Danube River and Black Sea, is worldwide recognized as Biosphere Reserve. The Sfântu Gheorghe branch (44°53'984''-45°05'795''N latitude and 29°04'885''- 29°34'660'' E longitude) that belongs to the lotic type aquatic systems of the Danube Delta, is strongly influenced by the Danube hydrological regime (Gâştescu & Ştiucă 2006).

The hydrotechnical works for navigation improvement were performed on Sfântu Gheorghe river branch in the 1980s, affected the structure and functionality of phytoplankton community as a consequence of alteration of the hydrogeomorphological conditions within the natural and modified river sections. The aim of this study was to highlight the structural dynamics of phytoplankton community in Sfântu Gheorghe branch in the 2008-2010 interval and to try to predict the possible development in the future.

Statistical analysis is an important tool in the study of the microalgae ecology. Oltean et al. (1985) presented one of the first statistical attempts to establish the correlations of plankton variables in the Matița-Merhei Lake (Danube Delta). Also, Cristofor et al. (1992), determined the influencing factors of light availability in shallow lakes of the Danube Delta by using means of statistics. Our similar based studies have already been addressing the phytoplankton of the Sfântu Gheorghe Danubian arm.

Materials and methods

The samples were taken seasonally between 2008 and 2010, covering the natural sectors, meanders and the newly built channels.

The samples have been taken from 7 transects in May, July and October of 2008, 2009 and 2010, each included two sampling areas (both banks and the middle of the river). The water samples (500 ml) were collected from the whole water column with a Patalas-Schindler device and they were preserved with formalin to 4% final concentration. Also, water samples have been taken for the physical-chemical variable determinations. The transparency was determined with a Secchi disk. The temperature, pH and dissolved oxygen content were measured on the field with a multiparameter WTW 340 i (Germany). Samples were frozen for further chemical analyses in the lab. Nutrients were determined spectrophotometrically (CECIL 1100, UK): NH_4^+ – as yellow compound with Nessler reagent. NO_2^- – as red compound with sulphanilic acid and α-naphthylamine. NO_3^- – as yellow compound with sodium salicylate (Tartari & Mosello 1997). Total reactive phosphorus (TRP) – as blue phosphomolybdate, reduced by ascorbic acid. Total phosphorus (TP) – by oxidation with potassium peroxodisulphate (Tartari & Mosello 1997). The organic matter content was estimated from the chemical oxygen demand, determined by oxidation with $K_2Cr_2O_7$ (COD-Cr).

The identification of species and abundance were made by using a Zeiss inverted microscope according to Utermöhl (1958). Phytoplankton biomass was determined by volumetric and gravimetric measurements (Britton & Greeson 1987).

All statistical analyses were performed by using SPSS 15,0 Windows Evaluation Version, which is available for download at http://www.spss.com. BioDiversity Pro available for download http://www.sams.ac.uk/research/software. Simple correlations between the physical-chemical factors and the structural characteristics of phytoplankton were calculated. The Pearson parametric correlations have either positive or negative character. A multiple regression analysis was used to calculate the statistical relationships between biotic variables and abiotic factors and to obtain predictive models. In order to establish the selection strategy for the most adequate multiple regression model, a multicollinearity test between independent variables was made. A common solution for the multicollinearity problem is to eliminate one of the strong correlated independent variables. The temporal distribution of biotic parameters among the Sfântu Gheorghe branch that characterizes the structure of phytoplankton was assessed by analysis of variance (ANOVA).

Results and discussions

Taxonomic composition and diversity indices

Taxonomic investigations on Sfântu Gheorghe phytoplankton highlighted the presence of 3 dominant groups: Bacillariophyceae, Chlorophyceae and Cyanobacteria. The groups of Euglenophyceae, Chrysophyceae and Xanthophyceae had negligible contribution to the phytoplanktonic assemblages. The Bacillariophyceae had the highest species richness, which was observed mainly in spring and automn (81.33%, 74%, respectively). Indeed, the role of diatoms in lotic aquatic ecosystems is widely recognized (Bere & Tundisi 2010).

Compared to previous studies in the 1960-1961 period (Brezeanu & Prunescu 1962, Brezeanu et al. 1966) considerable changes in hidrochemistry and biotic parameters have been found in the present period. The anthropogenic impact was visible mainly on the richness of phytoplankton species (confirmed by Shannon diversity index): a decrease of species number was noticed in the newly created channel - 102 species, compared to 136 species found in the natural sectors (Figure 1). This response was possibly due to unfavourable conditions (such as high current velocity, increased turbulence, high load of suspended solids).

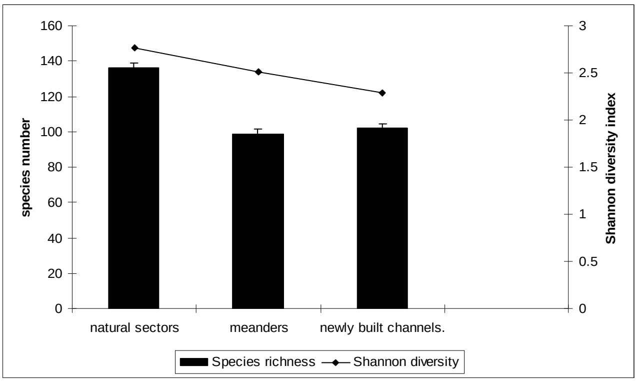

Figure 1. The average values and standard deviations of phytoplankton species number and Shannon diversity index in Sf. Gheorghe branch (2008-2010)

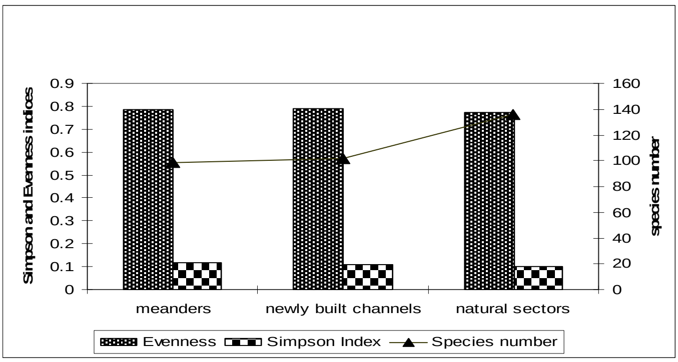

Figure 2. The average values of species number, evenness and Simpson diversity index of phytoplankton community in Sf. Gheorghe branch (2008-2010)

The diversity of phytoplankton community was influenced by the species richness (r=0.93, R^2 = 0.87, P<0.05), while the evenness explained only 31% of the diversity variations (r=0.55, R^2 = 0.31%, P<0.05). The evenness did not show any significant fluctuations, neither by years, nor by seasons, or between studied sections (Figure 2). The Simpson dominance (D) showed an inverse correlation with the Shannon index of phytoplankton (R= -0.95 after Pearson). This confirms that in the period with low diversity only a few species dominated in terms of abundance and biomass (Botnariuc & Vădineanu 1982). The dominance index decreased among species with the uniform distribution of individuals (Wilsey et al. 2005).

The natural sectors of Sfântu Gheorghe arm have offered favourable conditions for phytoplankton development, hence the recorded numerical abundance and biomass of phytoplankton showed the highest values ($216x10^3$ ind l^{-l}, respectively 1.292 mg wet weight l^{-l}), while the impacted zones had the lowest values ($193x10^3$ ind l^{-l}, respectively 0.989 mg wet weight l^{-l}) (Figure 3, 4).

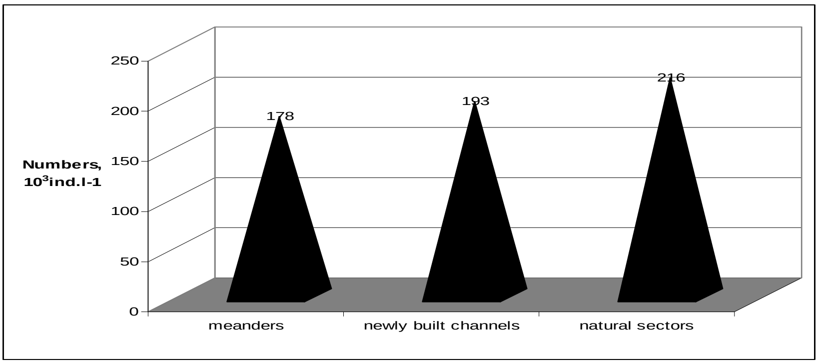

Figure 3. The phytoplankton abundance (10^3 ind l^{-l}) in Sf. Gheorghe branch (2008-2010 average)

The Bray-Curtis similarity index, based on numerical density of phytoplankton, showed the highest similarity between meanders and newly built channels (89.80%), while the natural sectors formed a separate cluster.

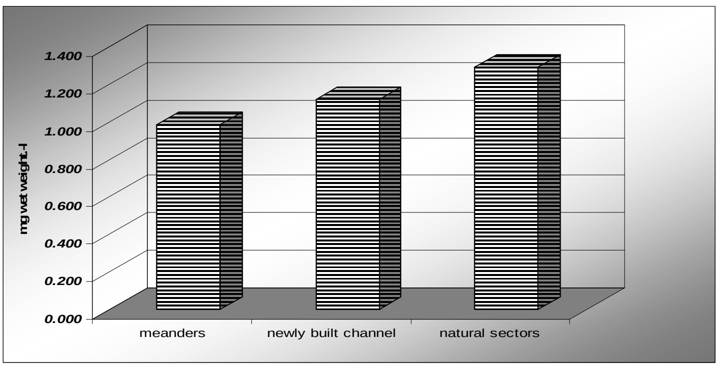

Figure 4. The phytoplankton biomass (mg wet weight l^{-1}) in Sf. Gheorghe branch (average in 2008-2010)

The diatoms have held the highest percentage in biomass (80%-95%) in the 2008-2010 period without showing any differences between the studied channel sections. The biomass values did not exceed the threshold of algal bloom (5 mg wet weigh) (Oltean 1985) in any of analyzed sections.

Probably due to the high water velocity, the newly built channels had a low phytoplankton biomass compared with the natural sectors, where the biomass (1.292 mg wet weigh l^{-l}) was comparable to Danube River values (Gomoiu et al. 2008). Although the meanders did not show a great turbidity, they did not present favorable conditions for development of phytoplankton biomass, due to the maintenance of high water velocity, similarly to the newly built channels.

Statistical data analysis

In order to test the phytoplankton community variables in Sfântu Gheorge arm for statistically significant differences between the three years of study, a one-way ANOVA was applied. The test has shown statistically significant differences between the three years of study, in species richness, abundance and biomass ($p<0.01$).

The simple correlations between ecological parameters of phytoplankton and physical and chemical parameters have indicated the main factors to modulate this community. The abundance depended on organic P ($p<0.001$) and TP ($p<0.01$), while the control factors for biomass were: transparency and dissolved oxygen ($p<0.0001$), temperature, pH ($p<0,001$), organic P, TP, ($p<0.01$), NO_3 and DIN, ($p<0.05$).

Taking into account the complexity of ecological systems and the multiple existing interactions, for the majority of the structural and functional parameters, the fluctuation is not the response to the action of a single factor, but a complex of factors which act synergistically (Botnariuc & Vădineanu 1982). This problem has resolved to establish a mathematical model trying to describe the fluctuations of the dependent variable, depending on fluctuations of several factors as independent variables.

Mathematical modelling is an important tool in the study of the microalgae ecology (Jorgensen & Meyer 1983). Many models have been developed for lakes in order to predict the biomass and production of phytoplanktons (Hakanson & Boulion 2003). Therefore, our results were further used to calculate multiple linear regressions in order to describe the relationships between phytoplankton structure and environmental components of the Sfantu Gheorghe system. To achieve the multiple regressions, a matrix of 1386 was a starting point, that took into account 11 physico-chemical parameters: total depth (m), transparency (m), T/D index, temperature, (℃), pH, dissolved oxygen content (mg O_2/l), organic matter content (TOC) (mgC/l), NH_4^+ (mgN/l), NO_2^- (mgN/l), NO_3^- (mgN/l), DIN (mgN_2/l), TRP (ug/l), organic phosphorous (ug/l), TP (ug/l), also three structural phytoplankton parameters: species number, abundance and biomass.

The main results were achieved in this first attempt to predict the structural dynamics of the phytoplankton community, depending on the biotic and abiotic control factors in the Sfântu Gheorghe ecosystem, with three multiple regression equations. In order to reject the null hypothesis, the general statistics of the regression equations and a global ANOVA test for all coefficients have been carried out. These tests have led to the conclusion that the obtained models are valid.

The first model presents the regression equation of species richness as dependent (y) and algal abundance and pH as independent variables (y = -9.47328 + 0.024563 Abundance + 1.698817 pH). Multiple R=0.76541, R^2=0.585853, F=13.2619, Significance F=9.6E-12

The second model was based on algal abundance as a dependent variable: y=374.4451 + 126.6977 x Biomass – 5.21697 x Depth – 252.57 x T/A – 9.19298 x Temperature. Multiple R=0.727915, R^2= 0.52986, F=9.266658, Significance F=2.85E-09

The third model consists of: Biomass = -3.25477 + 0.003871 x Abundance + 0.02362 x Depth + 1.375331 x Transparency + 0.306799 x pH -1.30332 x NO_3 + 1.22853 x DIN. Multiple R=0.829952, R=0.688821, F=20.75231, Significance F=3.38E-16

Conclusions

A tendency was noticed towards the changes in the hydrogeomorphological features of the meanders and newly built channels structure, caused by the anthropogenic impact of the hydrotechnical works in the Sfântu Gheorghe arm. This effect is reflected also by the structure of the phytoplankton community.

On the other hand, one could assume a transformation of some meander sections towards lentic character systems, in the sense of ecological succession at temporal scale. Most of them probably depend on the Sfântu Gheorghe branch hydrological regime, since these zones would become shallow lakes in the future.

The further development of our preliminary attempt to design prediction models may require validation and integration of other driving factors, that influence phytoplankton community, such as river flow, light conditions, bacterioplankton, zooplankton and icthyofauna.

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Topic 9
Restoration ecology, landscape ecology, land use

(restoration needs and plans;
planned and realised projects along the Danube;
experiences and observations)

Historical review of river engineering in the Hungarian section of the Danube

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Keywords: landscape ecology, landscape history, river regulation, historical habitat change

Introduction

Identification of historical changes in fluvial hydro-morphologic processes and habitat dynamics are essential criteria for rehabilitation and conservation of river ecosystems. Millennia-old river engineering is one of the major human impacts modifying the Danube. The study provides a historical review on river control interventions along the Hungarian section of the Danube, with particular attention to their influence on natural ecosystems. Structural and functional deficiencies of river ecosystem (areal decline of natural aquatic habitats, change of bed load transport, decrease of lateral river-floodplain connectivity, etc.) can be recognized by analysis of historical changes in water- and land-use. Description of pristine state of the river can contribute to delineation of environmental objectives for ecological rehabilitation, however pristine state of natural Danube ecosystem does not exist anywhere and therefore findings of historical analysis of landscape development are indispensable.

Milestones of river engineering

The struggle of mankind for and against the water goes back thousands of years of history. Romans and Celtics had advanced experiences in water engineering. Danube was one of the strategic borders of the Roman Empire controlled by army and minor deforestation works were only implemented in the floodplains. However these interventions did not result in any significant changes regarding the river system (Fejér 2001). Several Roman settlements were urbanized and used piped water. The centre of the Pannonia province, called Aquincum, was a major spa, where a lot of public bathes operated in the 2nd century.

Grazing livestock provided livelihood for the nomadic Hungarians, and fishing was their further substantial activities along the large rivers. The abundant fish stocks and river fisheries had great importance in nutrition of human population. In the 10th and 11th centuries, the eventual settlements were built on the higher terraces near the rivers, where pasturing and fishing were available. From the 12th century numerous artificial floodplain lakes were described by the historical sources. Most of them were used as fishponds, but occasionally utilized as bathing place or drinking trough (Herman 1887).

In the Middle Ages, a special floodplain farming was created along the lower section of the Danube in Hungary. Its essential facility was a semi natural channel network, called “fok”-system, which supplied water from the main river bed to the floodplain water bodies (oxbows, backwaters, abandoned channels) and floodplain meadows. The extensive and diverse fok-system provided favourable conditions for fish production and fisheries. Residents of local villages were able to diminish the devastating effects of the floods by intentional diversion of flooding water (Andrásfalvy 1973).

Medieval shipping started to upswing in the 13th century by construction of ship towing roads. Ships were towed to upstream by horses or men along a 5-6 meter wide tow-pass on the riverbank (Tőry 1952, Ihrig 1973).

In the 13th and 14th centuries medieval towns started to develop and increasing demand for drinking water prompted advanced solutions for water supply. The castles along the Danube, which were built in this period (Pozsony, Komárom, Esztergom, Visegrád, Buda), already had their own water sources. Water supply was mostly provided from the river bed, and facilities were defended by particular bastions located in the Danube (Fejér 2001), however lack of sewerage system and infections caused by overpopulation often resulted in serious epidemics.

In the 16th and 17th century, during the one and a half century long Turkish occupation, military water usage became widespread. Settlements and fortresses along the Danube increased their security by digging of water ditches and creation of artificial swamps, however swampy wetlands spread in an unexpected extent due to more humid weather of the medieval “Little Ice Age” (Mann 2002). The extensive floodplain farming was given up, because most of the villages became abandoned (Ihrig 1973, Fejér 2001).

After the Turkish exodus, in the 17th and 18th century, social and economic conditions started to recover. The cereal production became more important and area of cultivated agricultural lands was increased. Even so the floodplain farming started to develop again till the end of the 18th century at some localities in the Sárköz floodplain, in the lower section of the Danube in Hungary (Andrásfalvy 1973).

The strategic interests in the Danube navigation shifted to waterway developments, therefore the famous military engineer, Marsigli was charged with mapping of the Middle Danube. Despite the fact that mapping had already been completed in the beginning of the 18th century, the renovation of the tow-path was accomplished in the second half of the 18th century due to the grain prosperity. In the Sárköz floodplain, inlets of the fok-system were destroyed by tow-path construction therefore floodplain growers protested at the royal court of Vienna, but their claims were ignored, since the privilege of shipping was superior to any other forms of river utilization (Andrásfalvy 1973).

At the beginning of the 19th century, the need for flood protection was greater than ever before due to increase of agricultural lands and farms. In this period river engineering was conducted locally, with the aim of flood protection, prevention of ice pack formations, maintaining of tow-path, as well as the extension of arable land. By the beginning of the development of steamboating, from 1830, to improvement of navigability became one of the most important tasks for river engineering. Progress of regular boat services, particularly between Budapest and Vienna, necessitated dredging, tightening and straightening of the river bed including cutting off meanders. In this period the inland navigation was more important than the road transport, because most of the unpaved roads were impassable in rainy weather. However a lasting competition started between the inland and land transportation by the beginning of construction of the railway network. This conflict of interests forced further improvements on navigation ways for larger and larger boats (Tőry 1952, Dezsényi & Hernády 1967).

The regulation of the Budapest section of the Danube began in 1871, in order to protect the town from floods and ice aggregation. Riverbed was dredged and tightened, and embankments were built on the river sides. The engineering works on downstream of Budapest vicinity of Paks started in the 1880s in order to avoid formation of ice packs and devastating ice flooding. River section was shortened by cutting of meanders. The regulations were also included construction of flood protection dikes and dredging of riverbed (Guti 2001).

The extensive regulations in the upper stretch of the Hungarian section of the Danube were accomplished from 1886 to 1896. Earlier interventions in the first half of the 19th century were less successful due to intensive aggradation. Engineering included flood protection by dikes, as well as facilitating of rapid ice and sediment run-off and improvement of navigability by creation of a main channel through the delta-like ana-branching river section, characterized by multiple channels, bars and unstable island. Although the run-off conditions were improved, riverbed rising could not be stopped (Göcsei 1979).

In the beginning of the 20th century the growing domestic and industrial water demand in Budapest necessitated the upgrading and extension of the drinking water network, followed by sewerage system works, but sewage and contaminated waters directly flowed into the Danube. Between the first and second world war, only minor maintenance works were implemented along the Hungarian river section.

In the second half of the 20th century, installations of the high water regulation were maintained or reconstructed, navigability was improved and hydropower utilisation started to develop. In 1997 Czechoslovakia and Hungary agreed to the construction of the hydroelectric power station system at Gabčikovo and

Nagymaros. This project was intended to provide peak electricity production of the Gabčikovo power plant and it required a reservoir upstream of Gabčikovo and a compensating storage lake on its downstream, provided by the Nagymaros hydropower dam. In 1989 Hungary unilaterally suspended any further works on its major installations explained by environmental consideration, and this decision provoked a severe conflict between the two countries. Finally Czechoslovakia unilaterally constructed a new diversion dam at Čunovo and in 1992 the Gabčikovo power plant was put into operation. Since then, the Danube has been diverted into a 29 km long bypass canal and only 20 % of its discharge has remained in the former river bed. In the subsequent years minor mitigation measures were implemented for water replenishment in the floodplain branches, and several scenarios were proposed for extensive rehabilitation of the river-floodplain ecosystem, but bilateral negotiations between Hungary and Slovakia have not resulted any significant outcomes (Kern & Zinke 2000).

Since the beginning of the 1990s, when the Rhine-Main-Danube Canal was completed, further improvement of navigability in the Hungarian section of the Danube has been encouraged, but development of navigation way may have numerous negative impacts on the ecological status of the river. The EU water policy includes strict provisions regarding the options of river engineering, which could lead into confrontation between the inland shipping sector and environmental protection (Guti 2012).

Conclusions

The Danube provides considerable and strategic benefits for the society. Human populations have intervened in the natural course of the river since before recorded history, to make transport routes or protect against flooding. From the 19^{th} century, the modern time river regulations formed a straightened and channelized riverbed to avoid formation of ice packs and ensure a more suitable route for navigation. Construction of flood control dikes reduced devastating effects of the floods and extended land became available for agriculture and development of settlements.

River regulations have eventuated several negative impacts on the Danube ecosystems. Modifications of landscape forming hydraulic and geomorphologic processes by river engineering have resulted in serious alterations of habitat patterns and diversity since the 19^{th} century. The pre-regulation habitat composition has been changed in the direction of general loss of aquatic areas. The habitat turnover became restricted, and only few particular mosaic elements of the original fluvial landscape can be found at some locations. Aquatic habitats and wetlands are essential criteria of life for many forms of wildlife. Habitat loss and changes significantly contributed to disappearance of numerous flora and fauna elements and decline of biological productivity of natural river-floodplain ecosystems.

Since the last decades of the 20th century, degradation of river ecosystems has been increasingly recognized by the society, and river engineering has had environmental concerns broader than immediate human benefit and some interventions have been concerned exclusively with the rehabilitation of natural habitats and hydrologic circumstances. This approach is emphasized in the EU Water Framework Directive, with the objective of the "good ecological and chemical status". The trans-European program of the Danube Macro Region Strategy, focuses on the sustainable utilisation of the Danube, but it can lead some conflicts between economic development and environmental protection. Harmonization of these controversial interests will be one of the central issues of the sustainability and river engineering in the near future.

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