43rd IAD Conference

Rivers and Floodplains in the Anthropocene – Upcoming Challenges in the Danube River Basin

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- Proceedings -

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Preface

Dear Readers,

These conference proceedings have resulted from the 43rd Conference of the International Association of Danube Research (IAD). This conference series has always been a meeting point for research teams from the Eastern and the Western Danube River Basin, facilitating knowledge exchange as well as joint projects and publications in the region. In 2021, the IAD celebrated a special event. For 65 years, it has continuously been present in limnological, river and floodplain research in the Danube River Basin. The Covid-19 pandemic forced the organization of an online event. Nevertheless, there was an awesome engagement of more than 100 participants with many fruitful discussions.

The 43rd IAD Conference was dedicated to the manifold challenges the Anthropocene poses to the rivers and floodplains in the Danube River Basin. The topics of the conference were as diverse and interdisciplinary as river science itself, ranging from hydrobiology to flood protection to policy related issues. The articles in this conference volume reflect this diversity of topics. In addition, they also represent the international character of the Danube River Basin being the most international river basin of the world. Researchers and practitioners from Germany, Austria, Hungary, Croatia, Serbia, Romania and Bulgaria are among the contributing authors.

Bringing together all these experiences from various scientific backgrounds and different countries highlights the relevance of the IAD for cooperation in the Danube River Basin and gives hope for jointly meeting the challenges of the Anthropocene.

The Editorial Team

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Expert debate: Floodplains and Oxbow Lakes in the context of science, politics and law

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1. Introduction

Water protection in the Anthropocene has various aspects and backgrounds: water is the basis of all life, humans included, so quantity, availability and quality matter; aquatic ecosystems investigated by scientists need appropriate care of humans, referred to as nature protection, so as not to be overexploited and destroyed; water management is an important tool for politicians to implement measures of protection ensuring sustainable use of aquatic resources; and last but not least, the states, and the EU in particular, have established environmental laws and regulations to enforce a minimum of aquatic protection in the conflict of interest, i.e. the discrepancy between ecosystem services and human use.

This article exemplifies this situation with regard to controversial approaches in river protection, addressing dynamic floodplains and their oxbow lakes with specific reference to the Danube River Basin. The respective expert debate was provoked by the different goals of the EU Water Framework Directive (WFD) and the EU Nature Directives (Birds and Habitats Directive, BHD) (EC 2010). We provide scientific facts and the basis for any decisions as well as the management perspective and the pragmatic political compromise of how to implement different EU Water Directives for protecting aquatic ecosystems.

2. The scientific basis: ecosystem structure and function – the reference state

A floodplain is an area of land adjacent to a river which stretches from the bank of its channel to the base of the enclosing higher terrain. It experiences flooding during periods of high discharge and, hence, is very dynamic. Floodplains encompass meanders, oxbows, oxbow lakes and bayous, marshes and standing pools (Wetzel 2001). Oxbow lakes are lentic, abandoned meander loops and are fully cut off from the river, although they are still influenced by high flood events and groundwater flow, though often located outside of flood protection dams. In contrast, lotic side arms, featuring fully the discharge dynamics of the river, include aquatic and adjacent terrestrial habitats and biota. The seasonal hydrological dynamics are reflected by considerable differences in macrophyte composition, e.g. in the Tisza oxbows (Janauer et al. 2012). Important to note, intact lateral connectivity is crucial for healthy floodplains (Keruzore et al. 2013; Natho et al. 2020). However, technical impacts by, e.g., navigation, hydropower and flood protection lead to disconnection reducing biodiversity, because biota are adapted to seasonal/temporal water fluctuation (Hein et al. 2016).

If we are keen to prevent or mitigate human impacts on the (aquatic) environment, we need to have sound understanding of ecosystem functions, including abiotic components and biota, and knowledge about different types of ecosystems. Humans are the only creature on earth, which has totally altered whole ecosystems across the globe at any scale, basically through their exponential population growth, their increasing demands and through their development of technology. Hence, rating these impacts needs a natural or near-natural reference, which is referred to as the scientific concept of the reference state. Since the so-called reference is type-specific and to be dated somewhere in the past, i.e. before humans caused significant interference (mainly in the 19th century), the definition of the reference is somehow 'fuzzy'. In practice a reference is still useful, although hydromorphological alterations have caused irreversible modification in many cases, as exemplified e.g. by the floodplain areas lost in the Vienna reach of the Danube (Mohilla & Michlmayr 1996). When focusing on ecosystem function and living conditions of native plants and animals we base on recorded historical data, where available, particularly abiotic parameters including hydromophological features from old maps and, eventually, inventories of biota, and on expert knowledge. In a three step procedure, the reference is first defined as precise as possible; secondly a deficit analysis between reference and actual state is performed, which finally cumulates in a set of measures needed to restore the ecosystem or at least its main functions (Figure 1).

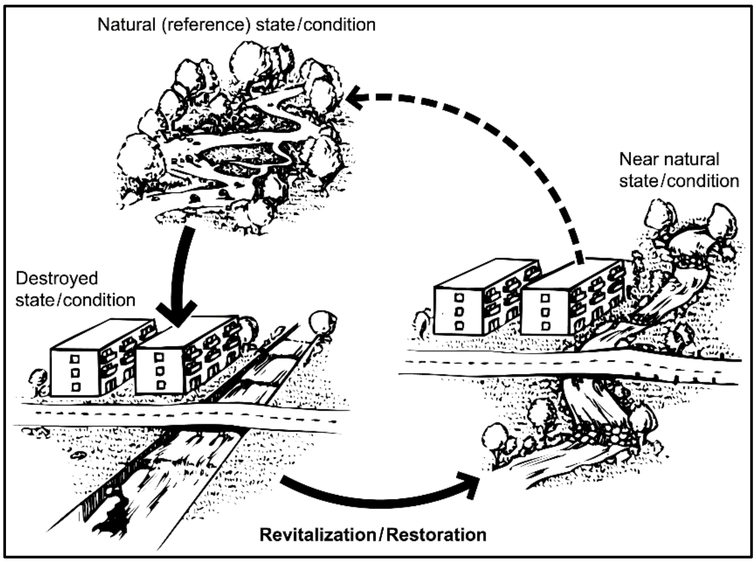

Figure 1: Morphological degradation and restoration of streams and rivers, based on a three step procedure: (1) assessment of the reference state, (2) deficit analysis between reference and actual state, (3) definition of measures to implement restoration that should be as close to the reference as possible, e.g. the Good Ecological Status in the WFD (Bloesch 1997).

Natural river ecosystems and floodplains include both lotic and lentic elements, e.g., dynamic side arms subject to variable water discharge and oxbows as cut off in lowland rivers through meandering. These two different types of riverine habitats host very different plants and animals forming two distinct biocenoses and, hence, their ecological functions are also very different as individual sub-ecosystems or water bodies, according to WFD. But, as a river comprises a continuum from the source to its mouth (though often in 'serial discontinuity' today: Ward & Stanford 1995), both oxbows and other floodplain water bodies are integral parts of the whole river ecosystem.

3. Human impacts and management perspectives

Human impacts as a consequence of over-use encompass (1) the deterioration of water quality by a wide variety of pollutants (Goel 2011), (2) significant change of the hydrological regime, flow dynamics and discharge mainly through large-scale water diversion (water quantity) (Zeiringer et al. 2018), and (3) large morphological alterations through canalization, embankments and disruption of the continuum, triggered by land use, navigation, flood protection and hydropower (Hajdukiewicz et al. 2017). While (1) has been tackled by measures such as waste water treatment plants and nutrient/contaminant reduction and (2) is increasingly influenced by effects of climate change, (3) is seemingly the illness of rivers in the Anthropocene: a tremendous lack of space, needed for river dynamics, heterogeneous habitats and respective biodiversity (Bloesch 2002; Figure 2). Therefore, it is not surprising that hydromorphological alteration is one out of four significant water management issues (SWMI) in the Danube River Basin (DRB; ICPDR 2015). Such river stretches with irreversible alterations are defined as Heavily Modified Water Bodies (HMWB) according to the WFD, where the "Good Ecological Potential" must be achieved.

1726 Current situation

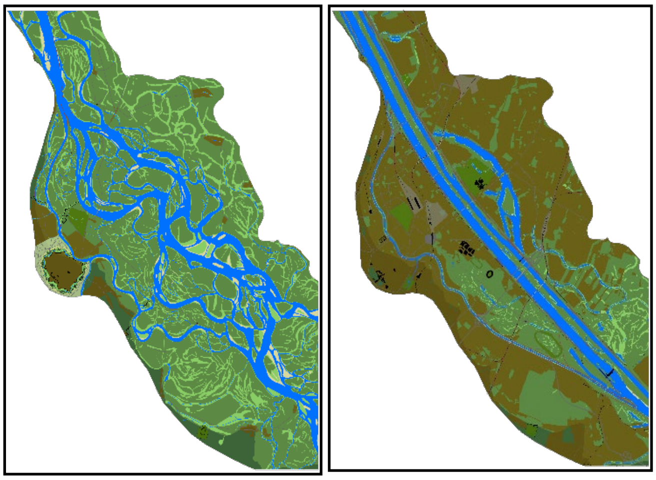

Figure 2: The ‚illness' of rivers in the Anthropocene: Reference state: 18th Century River Danube, Vienna reach: 300 years of intensified regulation eliminated floodplain connections. Maps: adapted to purpose. Originals: Courtesy of Severin Hohensinner © 23.04.2020. University of Natural Resources & Life Sciences Vienna. Department of Water, Atmosphere and Environment. Institute of Hydrobiology & Aquatic Ecosystem Management.

In the 20th century the deterioration of the aquatic environment became apparent for the first time, regarding water pollution, impaired drinking water supply and recreational use, and first water protection laws were established. Apart from respecting widely accepted principles such as precaution and the 'polluter pays'-rule, the general management perspective should be: conservation first, restoration second (Boon 2004). Such a strategy has both ecological and economic advantage: conservation prevents irreversible ecosystem damage and is cheaper than technological construction and subsequent restoration. The concept of establishing Protected Areas according to the BHD supports ecosystem conservation, but in reality it is often not well implemented, as conflicting human demands are subject to political evaluation processes allowing exemptions due to "overriding public interest", e.g. according to WFD Art. 4.7(d); L327/p.11 ("*…beneficial objectives … cannot for reasons of technical feasibility or disproportionate cost be achieved…*") and HD Art. 6.4; L0043/p.8 *("… in spite of negative assessment … the Member State shall take all compensatory measures necessary to ensure that the overall coherence of Nature 2000 is protected …*").

4. The political agenda to prevent or mitigate human impacts

The political and legal concept of the EU WFD is rated controversially: IGB (2019) concludes that "the WFD provides one of the best regulatory frameworks worldwide", while in contrast, Voulvoulis et al. (2017) quote that "the WFD is the worst piece of EU legislation". But recently, regarding the 'Fitness Check' of the WFD, the EU Environment Commissioner will continue with the WFD as 'fit-for-purpose', including the Floods Directive and Groundwater Directive (EU Environment, 2019a, 2019b), and respecting pleas by the European Parliament (Water News Europe, 2020).

The final objectives of the WFD are obviously different from those of the BHD, which requires, as an indispensable condition, a harmonized procedure of implementation, as both are subject to River Basin Management Plans. Although laws may not be perfect, the most important is their implementation, which is directed by political will. While the WFD's ultimate goal is to achieve "Good Ecological Status" of water bodies or "Good Ecological Potential" for HMWB and artificial water bodies, the EU HD aims to protect habitats and species by achieving "Favourable Conservation Status". In our context, the WFD supports the restoration of rivers by increasing natural flow dynamics and floodplains, while the BHD aims at conserving (dis-)connected side channels, floodplain lakes, and their biota. Both running waters *per se*, and floodplain ecosystems are important elements needing respective care and protection to maintain overall river system function.

5. A proposal to implement EU law in river protection and restoration

Despite a growing expert debate, relict river branches and oxbow lakes have the same importance as specific sub-ecosystems in a large river system. Therefore, both should be conserved and, hence, river basin management should achieve a "both … and" solution rather than an "either … or" solution of competitive character. This should be in full agreement with the overall WFD and BHD requirements. In practice, this means that first a river basin wide inventory of floodplains and their respective water bodies is needed, including a thorough analysis of habitats and biota. Furthermore, experts shall evaluate where dynamics and where less dynamic hydrological conditions are to be preferred. Finally, both measures must be implemented by the responsible authorities, fostering both types of sub-ecosystems to allow for their coexistence in the whole river system.

In a political context, the original content of WFD and BHD shall be retained, but an Amending Directive, e.g. based on an EU-Standard (CEN) for water body restoration and being elaborated at present, could resolve the discrepancy between river dynamics and lentic communities, which may achieve the aim of "Good Ecological Status", and "Favourable Conservation Status", as well.

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Changes in distribution and abundance of macrophytes in the Ižica River in the period 1996 - 2016

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Abstract

Macrophytes are an essential component of the river ecosystems. They enable the survival of many other aquatic organisms. The presence and abundance of macrophytes depends on environmental parameters and thus reflects the quality of the river ecosystem. Surveys of macrophyte assemblages and environmental parameters in the Ižica River were performed in the same sections in different years, namely in 1996, 2000 and 2016. The number of recorded macrophyte taxa varied between the years 1996 (38), 2000 (25) and 2016 (31). *Potamogeton natans* was a very abundant species in all examined years. *M. spicatum,* which is the most abundant macrophyte species in Slovenian watercourses was not present in the river Ižica in the year 2016, but it was detected in previous surveys in 1996 and 2000. On the contrary, *P. nodosus*, which is also a very abundant species in Slovenian watercourses, found suitable conditions for its growth in the river only in the year 2016 but was not detected in the river in previous surveys.

1. Introduction

Watercourses are heterogeneous ecosystems that offer suitable conditions for the growth of numerous vascular plant communities (Zelnik et al. 2021). Macrophytes are crucial for the structure and functioning of riverine ecosystems (Yu et al., 2019) because they are involved in energy transfer, promote sediment deposition, increase water clarity (Bando et al. 2015) and nutrient cycling (Barko et al., 1998). In addition, the diversity of macrophytes can affect associated communities, like invertebrates and fish (Yofukuji et al. 2021). Macrophytes presence and abundance depend environmental factors and internal mechanisms of succession across the transversal, longitudinal and vertical dimensions of the river (Lozanovska et al. 2020). Macrophytes communities respond to reduced light availability, increased sedimentation, nutrient loading and hydromorphological changes of aquatic ecosystem, usually originating from anthropogenic activities in the catchment area (Lacoul and Freedman 2006). They are also essential as bioindicators in the evaluation of the ecological status of the rivers. For efficient ecological assessments, quantifying the effects of anthropogenic impact on biota, the differentiation between human consequences and the natural background variation in ecosystems is crucial (Alahuhta et al. 2012). The presence and abundance of macrophytes are affected by urbanisation and agricultural activities, which may change with time. These changes are reflected in the distribution and vitality of aquatic vegetation, and can be used as a indicator of water quality. The present reserch aimed to compare the composition of the aquatic vegetation in the Ižica River, which flows through the agricultural landscape, between the years 1996, 2000 and 2016.

2. Material and methods

2.1 Study area

The Ižica River originates as a karstic river, collecting the water from calcareous cathment area. Soon after ist emergence in the centre of the settlement of Ig it runns across the Ljubljana Marshes (Fig. 1) and inflows to the Ljubljanica River after 10.5 km. Ljubljana Marshes (Ljubljansko barje) is located in the southern part of the central part of Slovenia. Wetland covers an area of 163 km^2. Ljubljana marshes is a tectonic depression between the Alpine and Dinaric area, built by 200 m thick alluvial and lacustrine sediments (Budja and Mlekuž 2010).

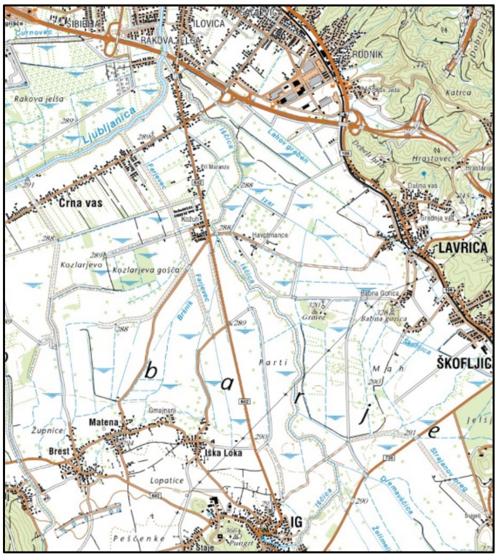

Fig. 1: Map of the Ižica (Iščica) River at Ljubljansko barje (Ljubljana Marshes)

2.1 Macrophyte survey

Macrophyte surveys were performed from the boat, using a rake with hooks. Submerged, floating, and emergent vascular plants, bryophytes, and filamentous algae were recorded. Macrophyte species abundance was estimated as a relative plant biomass using a five-degree scale as 1–very rare, 2–rare, 3–commonly present, 4–frequent, and 5–predominant, as proposed by Kohler and Janauer (2004).

3. Results and discussion

Environmental conditions as flow velocity, type of substratum, and amount of nutrients offer favourable conditions for massive growth of macrophytes in all three examined years (Germ et al., 2003). The number of macrophyte taxa in the Ižica River ranged from 38 in 1996, 25 in 2000, and 31 in 2016. Distribution of macrophytes from years 1996 and 2016 is presented in Figure 2. *Potamogeton natans* was abundant species in all three examined years. Preston (1995) stated, that this pecies with natans leaves is the most tolerant of all pondweeds. It is characteristic for slow flowing waters. The same author reported that *P. natans* survives in different ecological conditions, and it can be found in oligotrophic to eutrophic waters having different types of substrate (Preston 2002). *P. natans* can be often found together with *P. lucens* and *P. nodosus* (Hollingsworth et al. 1995) which were also detected in Ižica. *Potamogeton lucens* and *P. perfoliatus* are also species present in high abundance in all three examined years. *P. lucens* prefers relatively deep, calcareous waters (Preston 1995). *P. perfoliatus* grows in alkaline, brackish, and freshwater lakes and streams. *P. perfoliatus* colonise substrate with low organic matter content forming a firm muddy bottom or sand-based sediment in waters with low current velocity (Bergstrom et al. 2006), in environmental conditions that are also found in the Ižica River.

M. spicatum was absent from the surveys in 2016, while it was present in the 1996 and 2000. The River Ižica is a tributary of Ljubljanica River where we detected similar trend since. *M. spicatum* was abundant in year 2007 and very rare in 2019. *P. nodosus* was found in the upper sections of the river only in year 2016, but not in 1996 and 2000. Zelnik et al. (2021) reported, that *P. nodosus* was the most abundant beside *M. spicatum* and *Phalaris arundinacea* in Slovenian watercourses.

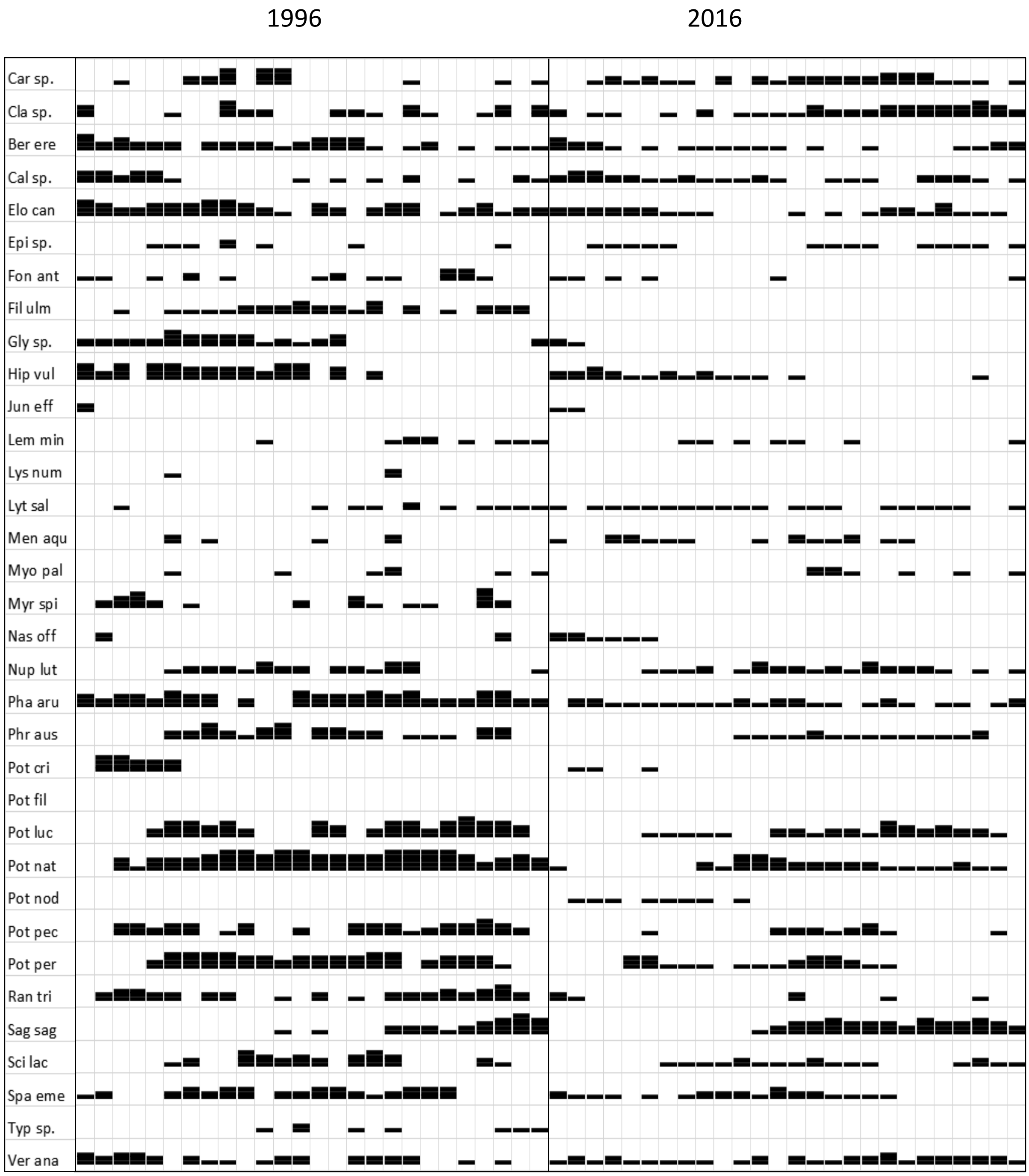

Fig. 2. Distribution of macrophytes in years 1996, and 2016 in all 26 sections of the river. The high of the black column responds to the abundance of the taxa from 1-5.

4. Conclusion

The number of macrophyte taxa in relatively short watercourse Ižica was very high (41), and varied in years 1996 (38), 2000 (25) and 2016 (31). Very common and abundant species in Slovenian rivers *M. spicatum*, was not competitive in this diverse community and disappeared from the river. On the contrary. Natant species *P. nodosus*, another very abundant species in Slovenian watercourses, found suitable conditions for its growth in the river in year 2016.

Acknowledgements

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Zooplankton of different types of water bodies in the Danube delta

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Abstract

The Danube delta is rich in different types of water bodies, such as river branches of different order, bays and lagoons of the sea edge, etc. Along the course of the river, the hydrological and physicochemical parameters of the water change, which is also associated with penetration of the sea waters into the delta. In July 2019, a comparative analysis of zooplankton composition and quantitative parameters in the water bodies of different types and at different distance from the Black Sea was carried out: the main river upstream branching (nearby the Reni town), the Kiliia Branch of the delta (the largest), the Bilhorodskyi branch and the bay of the sea edge of the delta – Solonyi Kut, where the Bilhorodskyi branch falls. During the period of investigations, the water temperature varied from 25,2°C (Solonyi Kut Bay) to 28,7°C (main river). The salinity in the sampling water was close – within 0,24–0,26‰, except the Solonyi Kut Bay, where it reached 5,61‰.

Maximal taxonomic richness of zooplankton was found in the Solonyi Kut Bay – 15 LIT (the lowest identified taxon), 1–10 LIT were registered in the watercourses. The similarity of the taxonomic composition of the water bodies in terms of the Sørensen index did not exceed 0,48. Copepoda prevailed in the bay and branches of the river. On the contrast to the mainly freshwater zooplankton character in the watercourses, in the Solonyi Kut Bay the brackish and euryhaline marine forms occurred, such as *Halicyclops neglectus* Kiefer, *Acartia tonsa* Dana, juveniles of Cirripedia and Polychaeta, and others.

The zooplankton abundance in the water bodies of the Danube delta was low. However, in the Solonyi Kut Bay, it was significantly higher (6730 ind/m^3, 40,23 mg/m^3) than in the watercourses (30–410 ind/m^3, 0,01–7,03 mg/m^3). With the exception of the main river site upstream the branching, where only Rotifers were found, juveniles of Copepoda quantitatively prevailed in the branches and the bay.

Thus, the mixed composition of zooplankton, consisting of freshwater, brackish-water and marine taxa, as well as an increase of its taxonomic richness and abundance in the bay of sea edge of the Danube delta, indicates the existence of the river/sea-type ecotone zone.

1. Introduction

In the very low reaches, the Danube River forms a large delta with numerous branches of different orders, lakes, wetlands, bays and lagoons at the sea edge. Various water bodies of the delta serve as a habitat for the unique aquatic communities, adapted to fluctuations of environmental factors (salinity, hydrological regime etc.), which is typical for the river-sea contact zone (Liashenko at al. 2018). On the contrast to the estuarine-type river mouths with powerful tidal phenomena, where there is a gradient of physicochemical parameters between the ecosystems of the river and the sea, the Kiliia Danube delta is a typical extension delta with an open fore-delta nearshore, where a fairly rapid transition of the hydrological regime of the branches to the hydrodynamic regime of the sea takes place (Lyashenko, Zorina-Sakharova 2015). Water in the branches of the Danube delta is predominantly fresh, while some bays of the front edge of the sea are prone to salinization. The contact zone of river and sea water is not stable, which is associated with the conditions of the sea water penetration into the delta (water levels, surges etc.). It has been established that the hydrochemical parameters, namely the salinity degree, has the greatest influence on the zooplankton of the bays of the sea edge, protected from waves. Previous studies have shown the effects of salinity on the zooplankton communities in the fore-delta of the Kiliia Branch of the Danube River (Zorina-Sakharova at al., 2014). The aim of this study is to compare the zooplankton composition and quantitative parameters in the water bodies of different types of the Kiliia Danube delta at different distance from the Black Sea.

2. Material and methods

Studies were carried out in July 2019 in the Danube delta water bodies of different types and at different distance from the Black Sea: the main river upstream branching (160 rkm, Reni), the Kiliia Branch of the delta (20th rkm, Vylkove) with its branch – the Bilhorodskyi (8th rkm from its mouth) and the bay of the sea edge of the delta – Solonyi Kut, where the Bilhorodskyi branch falls.

The zooplankton samples were collected in the surface water layer using the Apstein plankton net for filtration and preserved by formaldehyde. The samples were processed according to the standard hydrobiological methods (Romanenko, 2006).

The term lowest identified taxon (LIT) was used to describe the taxonomic composition, most of LIT were identified to the rank of the species. The similarity of zooplankton taxonomic composition in different water bodies was determined according to the Sørensen index (Romanenko 2006). Zooplankton taxa were divided into five groups regarding their preferences for water salinity: freshwater (adapted to salinity up to 0,5 ‰), freshwater-oligohaline (up to 5,0 ‰), freshwater-mesohaline (up to 18,0 ‰), mixohaline (within 0,5–30,0 ‰), mixohaline-euhaline (within 0,5–40,0 ‰), though these ranges are not always strict. Nauplii of Copepoda, Cyclopoida juv., Calanoida juv. and Harpacticoida gen. sp. taxa were not taken into account when determining preferences for salinity.

During the period of investigations, the water temperature varied from 25,2°C (Solonyi Kut Bay) to 28,7°C (main river). The salinity in the sampling water from the river and branches varied within 0,24–0,26 ‰ (freshwater). In the Solonyi Kut Bay, the salinity at the sampling site amounted to 5,61 ‰ (mesohaline), corresponding to the average salinity level in the bay, which varied within the range of 3,2–8,8 ‰ (Zorina-Sakharova at al. 2014). According to the Joint Danube Survey 4 scientific report, the general physicochemical parameters measured in the Danube in the same period were typical for July (Hamchevici at al. 2021).

3. Results and discussion

During the period of investigation, in the water bodies of the Danube delta 23 LIT of zooplankton were found. Copepoda was the most rich – 10 LIT, they prevailed in the branches and the bay. Seven LIT belonged to Cladocera, and three – to Rotifera. There were also representatives of meroplankton – free-swimming larvae of barnacles, mollusks and polychaetes.

Maximal taxonomic richness of zooplankton was found in the Solonyi Kut Bay – 15 LIT; 1–10 LIT was registered in watercourses. For comparison, the number of the zooplankton species along the main channel of Danube in the same period varied within 0–21; the number of rotifer taxa was the largest (Kiss, Zsuga, 2021). According to our research, in the Danube delta copepods predominated (Fig. 1).

The similarity of zooplankton taxonomic composition of water bodies by the Sørensen index did not exceed 0,48, indicating the diversity of environmental conditions in the considered water bodies.

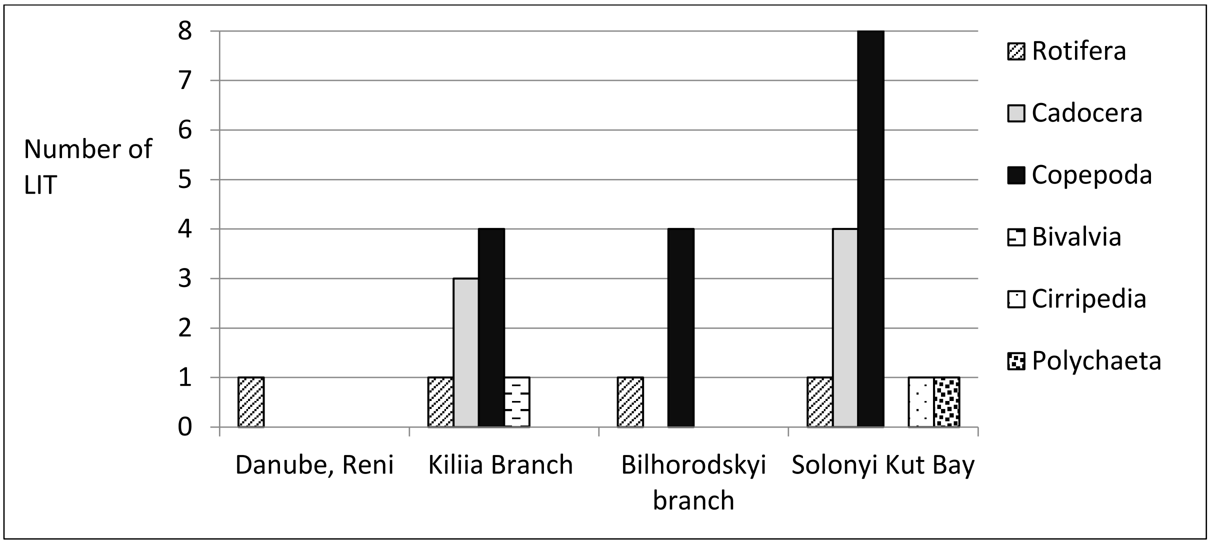

Fig. 1: Taxonomic richness of zooplankton in the water bodies of the Danube delta in July 2019

Zooplankton of the surveyed areas of the Danube delta was represented by freshwater, freshwater-oligohaline, freshwater-mesogaline, mixohaline and mixohaline-euhaline forms. Among the purely freshwater inhabitants there were cladocerans *Coronatella rectangula* (Sars), *Diaphanosoma dubium* Manujlova, cyclopoid copepod *Thermocyclops oithonoides* (Sars) etc. Inhabitants of fresh and oligohaline waters were represented by rotifers *Brachionus angularis* Gosse, *B. calyciflorus* Pallas, cladoceras *Bosmina longirostris* (O.F. Müller), *Moina micrura* s. str. etc. Freshwater-mesohaline cladocera *Diaphanosoma orghidany* Negrea and calanoid copepods *Heterocope caspia* Sars, *Eurytemora velox* (Lilljeborg) were characterized by the highest euryhalinity. It should be noted that the latter species, which is widespread in brackish coastal waters, is able to withstand the extremely wide range of salinity, which allows it to expand the area, occupying new ecological niches in fresh, brackish and salt water (Samchyshyna at al., 2020). *Eurytemora velox* is common in the Danube basin and shows an increase of the occurrence frequency compared to previous results (Kiss, Zsuga, 2021; Samchyshyna at al., 2020). The typical estuarine cyclopoid copepod *Halicyclops neglectus* Kiefer, which occurs in mixohaline waters, has been discovered. The group of mixohaline-euhaline taxa in the Danube delta was represented by the calanoid copepod *Acartia tonsa* Dana, larvae of Cirripedia and Polychaeta.

Zooplankton of watercourses is represented by the freshwater, freshwater-oligohaline and freshwater-mesohaline forms, common for inland water bodies of the region. In the bay there were also mixohaline and mixohaline-euhaline forms (Fig. 2). According to our observations and published data (Tseeb 1961; Polishchuk 1974), the ratio of the freshwater to mixohaline water complex of zooplankton in the sea edge bays can vary depending on the influence degree of river runoff and sea waters. The representatives of mixohaline and mixohaline-euhaline taxa are periodically recorded in the delta branches, which is the result of surges and water levels dynamics. In some periods in the bays of the sea edge and the mouths of the branches, zooplankton is represented exclusively by freshwater, freshwater-oligohaline and freshwater-mesohaline forms (Zorina-Sakharova at al. 2015).

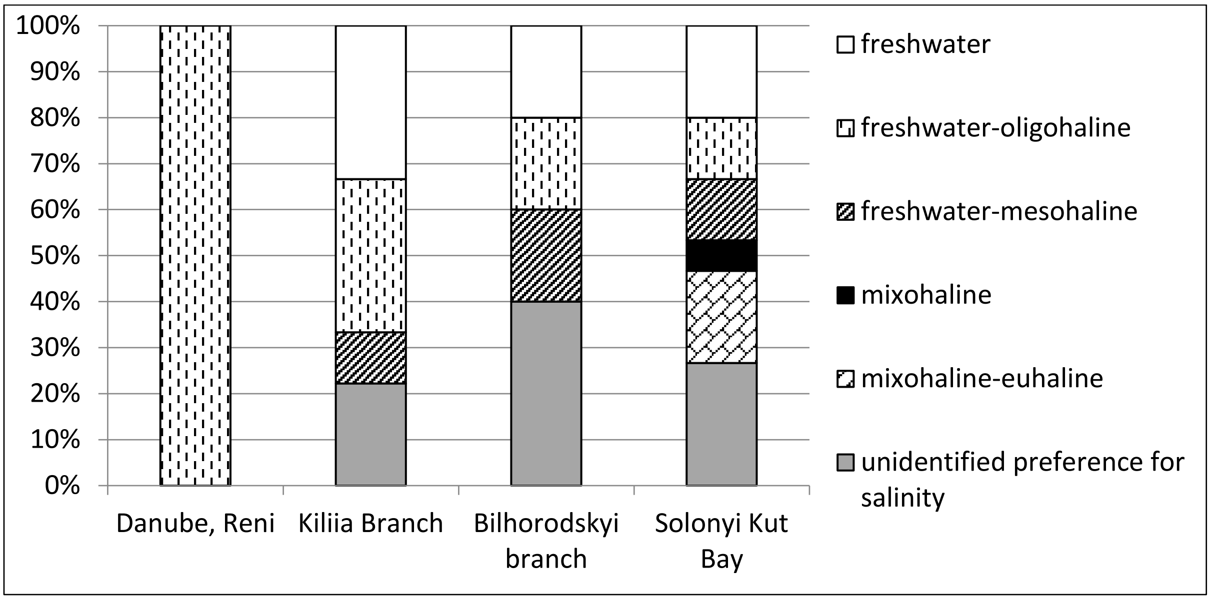

Fig. 2: Portions of zooplankton taxa in the waters bodies of the Danube delta in relation to water salinity in July 2019

The quantitative parameters of zooplankton in watercourses was very low, varying within the range of 30–410 ind/m^3 and 0,01–7,03 mg/m^3, which was probably caused by variable hydrological conditions and high content of suspended solids, which is typical for the Danube (Mykhailov 2004). In the Solonyi Kut Bay, the abundance of zooplankton reached 6730 ind/m^3 and 40,23 mg/m^3. It should be noted, that low zooplankton abundance in the same time was recorded throughout the Danube channel, the maximum values were observed in the Upper Danube (Kiss, Zsuga 2021). Copepods, mainly juveniles, predominated in the branches and the bay, in the main river site only rotifers were found (Fig. 3). In the Kiliia Branch, the most numerous were freshwater and freshwater-oligohaline forms, in the Bilhorodskyi branch – freshwater-mesohaline and freshwater-oligohaline, in the bay – mixohaline-euhaline.

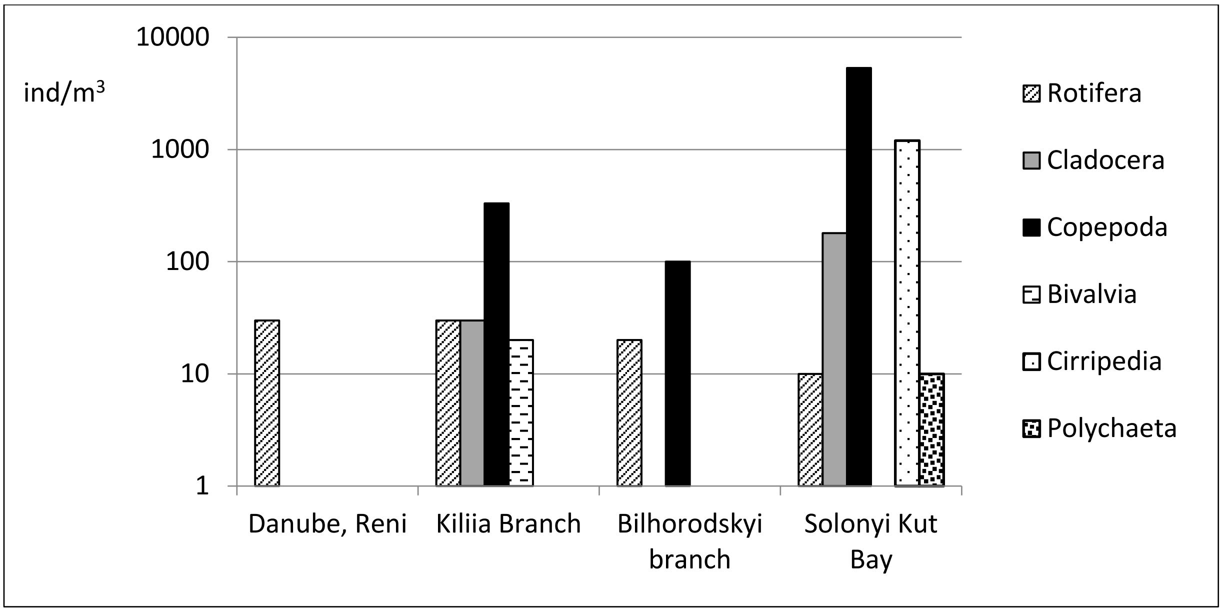

Fig. 3: The abundance of zooplankton taxonomic groups in the lower Danube in July 2019

4. Conclusion

Comparison of zooplankton of different types water bodies in the lower Danube (main channel, delta branches of different order, bay of the sea edge) in July 2019 showed differences in its composition and quantitative parameters. In the considered watercourse sites of the delta, the freshwater, freshwater-oligohaline and freshwater-mesohaline forms typical of inland water bodies of the region were recorded. In the bay of the sea edge Soloniy Kut, where the Bilhorodskyi branch flows, zooplankton was represented by the wide range of taxa from freshwater to mixohaline and mixohaline-euhaline such as *Halicyclops neglectus* Kiefer, *Acartia tonsa* Dana, juveniles of Cirripedia and Polychaeta. Mixohaline-euhaline zooplankton complex numerically predominant in the bay.

Though the taxonomic richness and quantitative development of zooplankton in the bay was higher than in watercourses, in general, these indexes in the lower Danube were low, which was probably caused by the unstable hydrological conditions and high content of suspended solids characteristic of the Danube. With the exception of the main river site, where only Rotifers were found, juveniles of Copepoda quantitatively prevailed in the branches and the bay.

Thus, the mixed composition of zooplankton, consisting of taxa differing in relation to the water salinity, as well as an increase of its taxonomic richness and abundance in the bay of the sea edge of the Danube delta, indicates the existence of the river/sea-type ecotone zone.

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River basin management in transition: The new Bavarian integrated strategy for river development

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Abstract
In a so-called "Fitness Check" for the key European water related Directives, the European Commission recently concluded that both the Water Framework Directive (WFD) and the Floods Directive (FD) are "*fit for purpose, with some scope to improve*". The Commission also assessed whether the Directives are suited to facing future challenges, such as "*climate change, water scarcity and pollutants of emerging concern (e.g. micro-plastics and pharmaceuticals)*" – all hallmarks of the Anthropocene. This was found to be the case, as long as Member States continually adapt and enhance their approaches as the dynamic situation evolves. Actions at different levels – local, regional,national, international – indicate that this message has been understood by many. However, the pressures of the Anthropocene are mounting and the time, resources and knowledge needed to adequately protect and where possible restore our rivers and floodplains will clearly exceed estimates of the past.

In this light, the Federal State of Bavaria is now taking another important step forward: The new Bavarian integrated strategy for river basin development sets out to provide a long-term effective response to a wide range of water-related challenges. The aim is to balance and harmonise ecological, economic and social aspects of river basin management planning in order to focus on the implementation of holistic measures, anchoring the fundamentals of Integrated Water Resources Management and "risk governance" even more firmly in day-to-day water management. The initial focus is on the immediate future until 2030, whilst also preparing the ground for the decades that follow. The new strategy comprises three central "pillars": I) flood protection and prevention – II) ecology and biodiversity – III) social and recreational benefits. The latter is already set to receive increasing attention in the future, as the value of access to green spaces to promote the population's mental and physical health has become widely recognised in the context of the current global pandemic. With a systematic approach that builds on early best practice examples (e.g. Isar-Plan, WertachVital), the three pillars will be combined within integrative planning concepts and projects, e.g. the restoration of natural floodplains, which provides flood retention on the one hand but also improvement regarding ecology, water balance and habitats on the other. In accordance with the principles of "good governance", the programme also includes a commitment to improve target group specific (risk)communication and continually build on a wide and growing knowledge base, integrating input from NGOs, practitioners and administration as well as involving stakeholders in the implementation of measures on the ground. This way, the new strategy will allow the best possible use to be made of existing and potential synergies between the WFD, the FD and the "Nature Directives" with a perspective that goes beyond all three to ensure that the challenges of the Anthropocene impacting our river basins can be met in the long term.

1. Introduction

In a so-called "Fitness Check" for the key European water related Directives, the European Commission recently concluded that both the Water Framework Directive (WFD) and the Floods Directive (FD) are broadly "*fit for purpose, with some scope to improve*" (European Commission 2019 a, page 7). Non-governmental groups such as the WWF welcomed the Commission's subsequent decision not to change either Directive or the so-called "Daughter Directives" (Groundwater Directive and Environmental Quality Standards Directive), pointing out that there had been much pressure from lobby-groups to weaken the WFD, in particular (e.g. WWF 2019). The Commission also assessed whether the Directives are suited to facing future challenges, such as "*climate change, water scarcity and pollutants of emerging concern (e.g. micro-plastics and pharmaceuticals)*" – all hallmarks of the Anthropocene, which according to Paul Crutzen (2002), winner of the Nobel Prize for Chemistry in 1995, names the main challenges of the next 100 years and is the "*present, in many ways human-dominated geological epoch*". Crutzen goes on to explain that a "*daunting task lies ahead for scientists and engineers to guide society towards environmentally sustainable management during the era of the Anthropocene*".

The conclusions of the European Commission suggest that the Water Directives can contribute towards accomplishing this "daunting task": "*The Directives' in-built flexibility and cyclicality leaves sufficient room also for emerging concerns to be adequately addressed, such as the threat from climate change and its impact on water quantity in particular but also on water quality; or from water pollution by new pollutants such as (micro)plastics or pharmaceuticals*" (European Commission 2019 a, page 118). In other words, the Water Directives are, in principle, equipped to cope with the challenges of the Anthropocene, as long as Member States adopt a holistic approach that allows them to continually adapt and enhance their approaches as the dynamic situation evolves.

This is neither an unrealistic nor a completely new prospect. In Bavaria, as is the case for other European neighbours with well-established water and environment administrations, holistic approaches to managing inland waters predate the European Water Directives (France and Spain, especially, have long history of river basin management, see e.g. Giblin 2003, Bukowski 2011). For several decades, Bavarian water administration and local municipalities have been cooperating to elaborate River Development Concepts ("Gewässerentwicklungskonzepte", GEK) or Integrated Flood Protection Concepts ("integrale Hochwasserschutzkonzepte") that combine elements of water ecology, flood protection and nature conservation for adjoining wetlands on an operational level. The advent of the Water Directives, the WFD in 2000 and the FD in 2007, introduced a systematic basin wide approach to water management planning which included features and tools generally associated with "risk governance" (see chapter 2.1).

The hypothesis of this paper is that whilst the challenges facing water management in the context of the Anthropocene and the associated uncertainties are manifold, much can be done to reduce the associated risks based on the secured knowledge and tools we already have. Whilst the wider public may struggle to relate to abstract concepts such as biodiversity or risk, they are familiar with issues surrounding human health and survival. Acceptance of the fact that human health and safety can be endangered as a consequence of nature-destruction, land consumption and the intensification of land use, even if only by indirect causalities, is growing. There are even hopeful signs that climate change debates and other recent developments (drastic measures against air pollution for example or mainstream media coverage of the decline in insect populations, possibly even the Covid pandemic[1])

[1] According to Crutzen (2002), pandemics or, e.g., meteorite impacts are "global catastrophes" but not phenomena of the Anthropocene. However, they produce effects and reactions similar to those associated

are translating these insights into a new collective awareness. Whatever the reasons may be, there is a palpable demand for governments to establish a system of proper holistic environmental management[2].

In the following chapters, we analyse some of the main challenges facing water and environment administration in this context and assess how a new strategy for river basin development, which incorporates and links up existing management tools with specific additional elements and new knowledge and ideas, can contribute towards meeting these demands and be implemented for rivers and floodplains in Bavaria.

2. Material and methods

We begin this chapter with the analysis of existing tools, looking at opportunities for synergies between the European Water and Nature Directives and using the so-called "risk governance approach" as a starting point. We then discuss the challenges facing practitioners in implementing measures in different fields of water management and environmental protection, the types of risk that occur, and the difficulties encountered in harnessing potential synergies, before taking a closer look at the role that societal benefits of access to nature could play in the future. Finally, taking into account the tools and approaches already in place, we explore the contribution a new Bavarian strategy with a specific focus on rivers and floodplains can make in providing solutions to some of the urgent challenges of the Anthropocene.

2.1 Risk governance in European Water and Nature Directives as a basis for synergies

According to Klinke and Renn (2012) "*Risks are not real phenomena but mental constructions resulting from how people perceive uncertain phenomena and how their interpretations and responses are determined by social, political, economic and cultural contexts, and judgments*". In the same vein, the four-field risk matrix proposed by Bonß (as cited in Grambow et al. 2018, figure 1) identifies four elementary risk categories – *normative, technical, suppressed* and *hypothetical* – highlighting the role of perception ("awareness") and interpretation ("understanding") in dealing with uncertainties.

	Known (understanding)	Unknown (lack of understanding)
Known (awareness)	**normative risks**	**technical risks**
Unknown (lack of awareness)	**suppressed risks**	**hypothetical risks**

Fig. 1: Four-field risk matrix (Source Grambow et al. 2018, title "Four-field risk matrix as proposed by Bonß")

In line with these definitions, the principles of risk governance put forward by experts (e.g. Wilderer et al. 2018, cf. Beck 1986, IRGC 2017, ISO 2018) address sector specific issues and challenges, whilst taking

with the Anthropocene and experts have linked the causes of the current pandemic to the destruction of natural habitats (e.g. Tollefson 2020).

[2] e.g. WWF reaction to "Fitness-Check" (2019), Fridays for future (2021), Bavarian referendum on Biodiversity (Volksbegehren Artenvielfalt 2021), French citizens convention on climate change (Democracy International 2020)

uncertainties and factors relating to human perception, subjectivity, societal dimensions and the need for an integrated response to multifaceted complex challenges (highly applicable to rivers and floodplains) into account. The operational details of the response are contingent upon the risk category, i.e. methods and approaches for dealing with hypothetical risks will require more flexibility and adaptive elements than purely normative or, to a certain extent, technical risks (see chapter 2.2).

As summarised in table 1 in a non-exhaustive overview, key elements of adaptive and integrative risk governance as proposed by Klinke and Renn (2012) are enshrined in the FD, the WFD and the Nature Directives (Habitats Directive and Birds Directive). These are: a cyclical or iterative management approach, communication and stakeholder involvement, preliminary assessments ("pre-estimation"/"framing"), specific and targeted detailed assessment ("interdisciplinary estimation"/ "characterization"), planning and implementing measures ("management"), and monitoring and surveillance ("control") to ensure compliance, as well as "evaluation"[3] as a basis for both the initial measures and their optimisation in subsequent cycles (figure 2). As these elements are (more or less) identifiable in all the Directives in question, they constitute analogies, or possibly areas of "common ground", and with that a basis for significant synergies[4].

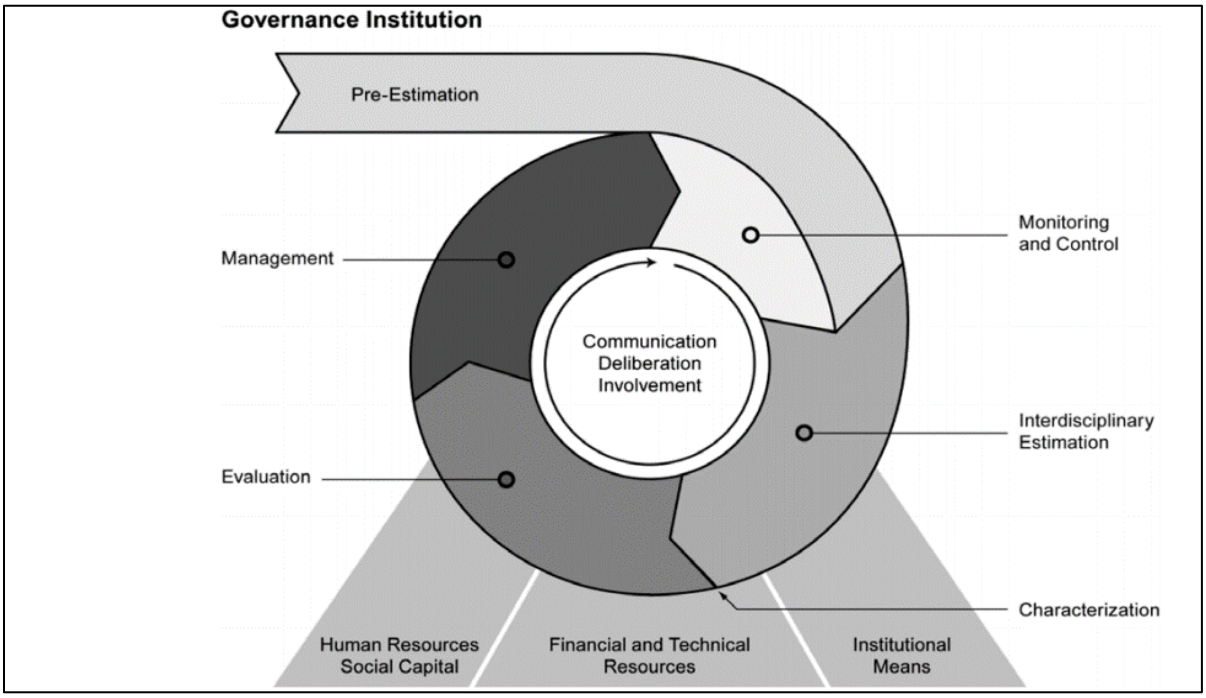

Fig. 2: Elements of "risk governance" (Source Klinke and Renn 2012, title "Adaptive and integrative risk governance model.")

[3] In the Directives in question, "evaluation" is not necessarily clearly distinguishable from "estimation" and "characterization"; though Klinke and Renn (2012) define "evaluation" as primarily referring to the social acceptability of risks.

[4] Beyond the similarities and analogies presented in table 1, the relevant Directives also have other areas of common ground, such as the provisions for the relationships between the targets of the respective Directives and socioeconomic activities: e.g. Habitats Directive Art. 2 (3), specifying that "*Measures taken pursuant to this Directive shall take account of economic, social and cultural requirements and regional and local characteristics.*" In addition, there is the fundamental aspect of managing water on a river basin scale that is common to both the FD and the WFD, and there are specific obligations enshrined in the Water Directives to take the objectives of previously introduced Directives into account: FD Art. 9 obliges Member States to take the objectives of the WFD into account whilst Art. 4 (2) WFD establishes the notion of "*more stringent objectives*" linking the WFD objectives to the objectives of the Nature Directives: "*Where more than one of the objectives under paragraph 1 relates to a given body of water, the most stringent shall apply.*"

Table 1: Non-exhaustive overview of elements of adaptive and integrative risk governance according to Klinke and Renn (2012) in the FD, WFD and Habitats Directive (the Birds Directive generally has equivalent provisions to the Habitats Directive, see for example European Commission 2018, page 8). In the Directives in question, "Evaluation" is not clearly differentiated from "Estimation" and "Characterization".

	Floods Directive	**Water Framework Directive**	**Habitats Directive**
Cyclical approach	Art. 14 Reviews, reports and final provisions	Art. 13 River basin management plans	Art. 17 Reviews and reports
Communication	Art. 9 Public information and consultation	Art. 14 Public information and consultation	Art. 17 Public Information / Art. 22 Supplementary provisions
Pre-Estimation/ Framing	Art. 4 and 5 Preliminary flood risk assessment	Art. 5 and Annex II *("pressures and impacts assessment*") Art. 14(1)(b) ("*significant water management issues")*	Art. 3 ("*maintained (..)or restored a favourable conservation status*") Art. 4 (1) and Annex III (*"identification priority sites*")
Interdisciplinary Estimation (characterization/ evaluation)	Art. 6 Flood hazard maps and flood risk maps	Art. 5 and Annexes II (*"identification of water bodies at risk*")	Art. 6(3) ("*appropriate assessment of risk reduction")*
Management (planning and implementing measures)	Art. 7 and 8 Flood risk management plans	Art. 11 Programme of measures	Art. 6 (1) ("*appropriate management plans*") Art. 6(2) *("steps to avoid deterioration")*
Monitoring and control	Annex *("assessment of the progress made")*	Annex V *("monitoring requirements")*	Art. 11 Surveillance Art. 14 (Evaluation) Art. 18 (Research)

The Water and Nature Directives presented above have another common characteristic, though this is not reflected in the actual legal texts[5]: They share an intrinsic ability to meet the individual and societal demand for access to nature, making them a potentially significant force for progress, cooperation and consensus. For example, experience and best practice examples have demonstrated that by helping to meet the societal demand for health and cultural benefits, additional legitimisation of the overall objectives and an almost unanimous acceptance of measures in the fields of water protection, flood risk management and nature conservation can be achieved (e.g. the LIFE-Nature project "River experience Isar" in Lower Bavaria[6]). Again, this thinking is, of course, not wholly new. For example, the established tool "GEK" mentioned in the introduction has always included provisions for taking cultural

[5] One could argue, however, that it is implicit in the references to socioeconomic issues, e.g. Habitats Directive Art. 2 (3).
[6] EU-LIFE-Projekt „Flusserlebnis Isar" (Regierung von Niederbayern 2017).

heritage and cultural and aesthetic value of urban and semi urban landscapes into account (e.g. Isar-Plan in Munich or WertachVital in Swabia[7]). We will revisit this essential aspect in chapter 2.3.

2.2 Challenges facing practitioners in harnessing synergies

Though there is a demand for – and a willingness to – harness the potential for synergies between the Directives, practitioners frequently face a wide range of challenges. These are primarily "universal" challenges, i.e. problems encountered in the implementation of measures in all fields of environmental management. The main ones are finite resources, knowledge gaps, uncertainties, legal and technical limitations, and difficulties in securing stakeholder-cooperation. It is beyond the scope of this paper to outline the many facets of these challenges in detail, reports and publications such as EEA (2018), SRU (2020), UBA (2021), WWF (2020), to name but a few, paint a less than optimistic picture. This chapter summarises selected aspects of the "universal" challenges and goes into more detail on the issues of uncertainty, as a "risk-category-specific" challenge, and scale as a "synergy-specific" challenge, i.e. a challenge specifically affecting the potential to harness synergies between the Nature and Water Directives.

"Universal" challenges:

The challenge of managing finite resources (financial, human, material, land, etc.) is a constant companion in environmental administration and was already an issue during the drafting of the WFD. The Commission attempted to reassure Member States stating that "*the probable costs of this proposal will be affordable over the timescale involved*" (European Commission 1997, page 18) whilst at the same time admitting that there was no sound data for assessing the likely costs[8]. In an older WFD draft from 1994, the maximum investment for dealing with historical physical alterations (i.e. existing hydromorphological pressures) is estimated at 400-600 million ECU for all Member States[9] (European Commission 1994, page 9). We now know that the overall cost for hydromorphological measures needed to reach the objectives for Germany alone is estimated at approx. 22 billion € (LAWA, in press). The sheer volume of necessary investments coupled with competing priorities have clearly contributed to the current delay in reaching the WFD objectives. Nevertheless, it would be wrong to conclude that measures to improve the ecological status of surface water bodies are not cost-efficient. Firstly, Member States generally have strict requirements on procurement and tendering in the public sector. Also, whilst the FD is clearly more geared towards cost-benefit analysis than the WFD, Annex 3 of the WFD stipulates that Member States should strive for the "*most cost effective combination of measures […] based on estimates of the potential costs of such measures*"[10]. However, one undeniable contributing factor is the rising costs in the construction sector. In Germany, they have risen by about 15 - 20 % in the last 5 years alone[11]. Tendering procedures have also become more complex, with new specifications and requirements resulting from, e.g., environmental impact assessment (EIA) requirements or EU public procurement regulations, increasing the administrative burden and costing

[7] Isar Plan (Wasserwirtschaftsamt München 2018); WertachVital (Wasserwirtschaftsamt Donauwörth 2003)

[8] "*There is a certain-irony in the fact that the Framework Directive is designed to establish many of the information gathering mechanisms that would have enabled the production of a more complete economic analysis of the proposal itself.*" (European Commission 1997, page 18)

[9] There were twelve Member States at the time, as this was before EU expansion of 1995.

[10] There are strong arguments for increasing efforts to develop sound practicable methodology for the widespread application of *eco system services* assessment: Without such tools the long term value of ecological but also social cultural and health benefits cannot be properly gauged and the overall cost-benefit ratios will invariably be biased against ecological measures, e.g. European Commission 2021 (page 5) *"We need to better understand the interdependencies between climate change, ecosystems, and the services they deliver."*

[11] e.g. general construction work ("Rohbauarbeiten") and excavation work ("Erdarbeiten") in 2020 compared with 2015 (Statistisches Bundesamt 2020).

additional time. Also, there is still uncertainty regarding the actual effectiveness of measures (cf. Pottgiesser 2021), which makes investment decisions much more challenging. Then, as mentioned above, practitioners also frequently face an unwillingness amongst stakeholder to engage or cooperate in the relevant processes. Unfortunately, it is also becoming more common for resistance (deriving either from unfounded fear of disadvantages and losses or from genuine conflicts of interest) to lead to active confrontation, and practitioners are observing an increase in legal challenges, especially in regions with limited land supply.

"Risk-category-specific" challenges:
The choice of methods, the framing of analyses (scale, objectives, thematic focus) and the relative weighting or prioritisation of actions and operational measures are highly dependent on the risk category. For example, flood protection deals primarily with *normative* and *technical* risks, i.e. the mechanisms are well understood and the uncertainty derives primarily from limitations in meteorological predictions and the (residual) risk of system failures. Here, the precautionary and proactive approach is undisputedly suited, i.e. protection against flood events with a certain statistical return period can always provide a (more or less) calculable level of risk reduction. However, with the progression of the Anthropocene, the relative impact of *hypothetical* and *suppressed* risks in flood protection is also increasing and more flexible approaches are imperative. In nature conservation, the focus is traditionally on preventing the deterioration of a protected good against an only partially pre-definable range of possible influences. What might constitute a "disturbance" (Habitats Directive Art. 6) in the future (e.g. a motorway bridge, a hydropower plant, or a surge in invasive species) is assessed in legal procedures such as EIA and – especially for Natura 2000 sites – "appropriate assessment" (AA). However, the full impact of such a disturbance, especially in combination with other (cumulative) pressures cannot be comprehensively predicted and – which is worse – the risk of crossing critical thresholds ("tipping points") within environmental systems is often negated or deliberately ignored by those set to gain from the development in question. This highlights the need for a proactive preventative approach in the light of the *suppressed* and *hypothetical* nature of the relevant risks[12]. For water resources management and the implementation of the WFD, the situation is different again: The multi-faceted processes and objectives generally involve tackling *normative, technical, suppressed* and *hypothetical* risks on a comprehensive (mainly river basin wide) scale and in different combinations (ecological status, biodiversity, chemical status, human health, inland and coastal waters, ground water, surface waters, water quality and quantity, rural and urban pressures, point- and non-point pollution sources, "natural" and "heavily modified" water courses, etc.). In this regard, water resources management can offer experience, methodologies and, possibly administrative support to the "neighbouring" Directives.

"Synergy-specific" challenges:
An example of a significant practical challenge to harnessing synergies between the Water and Nature Directives is that of spatial and temporal scale. Certain actions within the scope of individual Directives are linked to specific spatial scales or time frames. Consequently, flexibility to adapt in order to accommodate the requirements of another Directive can be limited. Each Directive foresees a process of defining and delineating units of management, and the respective units reflect the scale at which

[12] However, the wording of the Nature Directives and implementation practices seem to suggest that the *hypothetical* nature of the majority of the relevant risks is not always recognised; the focus often appears to be on the "known" (normative) risks and technical issues, i.e. resistance against local physical interventions, rather than a system-based analysis of cumulative risk constellations.

the objectives of that particular Directive are best addressed[13]. The process of integrating several Directives will therefore invariably require step-by-step optimisation and a cautious approach in order to avoid unintended disruptions[14]. In many cases, the iterative management regime established in the cyclical approach (see above), is already providing good opportunities for harmonisation. However, there are also differences regarding basic aims and temporal requirements. Whilst one central objective of the WFD is to attain a new, better water body status (Good Status) which requires dynamic development towards a set of specific objectives, the Nature Directives are largely geared towards preserving an existing status in a more static way. This difference is emphasised by an inbuilt imbalance in their cyclical approaches: Whilst the Nature (and Floods) Directives strictly follow what could be described as a purely cyclical model, the WFD is heading towards a significant landmark, or bifurcation, in 2027. The original deadline for achieving the objectives of the WFD was the year 2015 and the upcoming river basin management cycle from 2022 to 2027 is the last one for which Art. 4 (4) of the WFD allows the, thus far, widely applied option of extended deadlines for technical or cost reasons. Beyond 2027, 6-year extensions granted under WFD Art. 4 (4) will only be applicable if prevailing natural conditions are responsible for the failure to meet the objectives. Delays in implementing necessary measures could then, in theory, lead to Member States having to set less stringent objectives according to Art. 4 (5) of the WFD for many of the water bodies still failing to meet the objectives in 2027. Water managers have the huge responsibility of ensuring that this unprecedented situation does not undermine current and future efforts to achieve the ambitious environmental objectives.

2.3 Social and cultural value of rivers and floodplains

Though the importance of access to green spaces for the population's mental and physical health has become widely recognised in the context of the global pandemic, the societal demand for health and cultural benefits of nature in general, and natural water environments in particular, has long been overlooked as a potential driver for progress on key environmental issues. Yet river restoration projects such as the so-called "Isar-Plan" and "WertachVital" have met with almost unanimous acceptance, based largely on the added value of recreational uses and the sense of ownership fostered by involving local communities in the planning and implementation of the measures. Such positive effects can be replicated, whether in the field of water protection, flood risk management or nature conservation. As mentioned above, the established tool "GEK" already contains relevant provisions[15].

Of course, giving more people access to natural beauty spots can also lead to the danger of overuse and conflicts of interest between nature conservation and recreational activities. On the other hand,

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[13] FD Article 3(2b), for example, allows for the definition of different Units of Management and the majority of Member States have chosen "the default option" which is to use the WFD River Basin Districts (RBD) as the Units of Management (European Commission 2014). However, this choice has not been a noticeable driver for integration between the Directives because most WFD-related actions focus on the much smaller "water bodies". Also, the WFD foresees some context-specific shifts to different scales: For example, individual project sites are assessed under WFD of 4 (7) and the Programme of Measures according to Art. 11 of the WFD can address issues of basin wide or supra-regional relevance and can require transboundary coordination. Similarly, the Nature Directives establish management areas but also deal with individual project sites or, for example, individual breeding sites on the one hand whilst tackling issues affected by large-scale issues such as migration routes (potentially thousands of kilometres) on the other.

[14] Though, for obvious reasons, the saying „never touch a running system" cannot apply to the questions at hand, it does contain a warning that an improvement at one level could cause potential disruption at another.

[15] The non-binding character of GEK meant that implementation of actual measures was, in many cases, slower than many would have wished and the advent of the new Water Directives, the WFD in 2000 and the FD in 2007, provided Member States with a legal framework that promised to accelerate the relevant processes. Overall, the verdict „*broadly fit for purpose, with some scope to improve*" used by the EU Commission to describe the Water Directives (European Commission 2019 a) seems also to apply to the Bavarian River Development Concepts (Gewesserentwicklungskonzepte, „GEK").

there is a growing body of knowledge and experience from pilot projects that will allow water managers to roll out measures of this kind successfully at a much broader scale in the future. This will not only apply to restored river stretches. Some forms of technical flood protection and other water management infrastructure, which can be necessary to provide reliable flood protection for some settlements and urban areas, can also deliver health and societal benefits if designed in a multifunctional way. Other options, such as combining safe public access to rivers and streams by allowing maintenance routes to be used as foot or cycle paths, may be less commonly reported but are also becoming common practice.

2.4 The new Bavarian integrated strategy for river development

As we have set out above, the pressures of the Anthropocene are mounting and it will take time, resources and knowledge to adequately protect and where possible restore our rivers and floodplains. Actions at different levels, local, regional, national, international and both strictly within and beyond the scope of the European Water and Nature Directives, indicate that the lessons of the Anthropocene are being taken on board by many: For example, local authorities in Bavaria have implemented a systematic procedure to harmonise measures in the habitat based Natura 2000 management plans and the river-basin wide Programmes of Measures as required under the WFD[16].

To accelerate progress, the Federal State of Bavaria is taking another important step forward: The framework of the new Bavarian integrated strategy for river development sets out to provide a new long-term effective response to a wide range of challenges. The initial focus is on the immediate future until 2030, whilst also preparing the ground for the decades that follow. In keeping with the sustainability concept illustrated in the "sustainability triangle" (Bundesregierung 2008), it seeks to balance and harmonise ecological, economic and social aspects of river basin management planning, applying the fundamentals of Integrated Water Resources Management (IWRM). This means a conscious move away from sectoral approaches and, in the light of additional climate change related challenges, the inclusion of new elements: Further resources will be allocated to managing pluvial flooding and plans to improve connectivity and biodiversity will go beyond the already ambitious requirements of the WFD to incorporate targets and actions in the broader field of nature conservation and climate change adaptation. The programme also includes a commitment to harness new opportunities for cooperation and synergies beyond the formalised process of implementing European Directives wherever possible, by seeking dialogue and cooperation with NGOs and third-party initiatives. This will be supported by another central objective, which is to deliver safe and easy access to rivers and streams for people seeking recreation and relaxation wherever this is feasible.

As presented in figure 3, the strategy comprises three central "pillars" concerning the water issues surrounding I) flood protection and prevention – II) ecology and biodiversity – III) social and recreational benefits, and a comprehensive, adaptive toolbox that serves all three "pillars". Each pillar is underpinned with designated action-areas and individual targeted measures: For Pillar I these are the key measures under the FD such as flood avoidance, natural retention, technical flood protection, prevention, managing floods and regeneration. Pillar II combines actions towards attaining the

[16] Other examples are (non-exhaustive list): At the Federal State level, the Bavarian Ministry for the Environment adopted the "Masterplan Bavarian Danube" in 2017, which is a bottom-up oriented compendium of measures for enhancing biodiversity for the Bavarian Danube and its floodplains. The German national joint LAWA-catalogue of water management measures (LAWA 2020) comprises measures for Flood Risk Management Planning, the WFD and the Marine Strategy Framework Directive, including a systematic attribution of potential for synergies and conflicts. Recent EU initiatives like the EU Green Deal (European Commission 2019 b) have the potential to significantly improve progress whilst action on cross-boundary issues that go beyond the frontiers of the EU, are also gaining momentum, e.g the Danube Sturgeon Task Force, which is supported by the contracting parties to the International Commission for the Protection of the Danube River.

objectives of the WFD and the Birds and Habitats Directives i.e. river and floodplain restoration, measures to improve river continuity and the protection and reinforcement of nature-based maintenance practices. The aim of the measures in Pillar III is to enhance the social and health benefits of natural water-dependent ecosystems and water management infrastructure for the wider population. Measures in Pillar III can be either strategic or structural, with the latter being eligible for public funding if they are integral parts of projects in Pillars I and/or II.

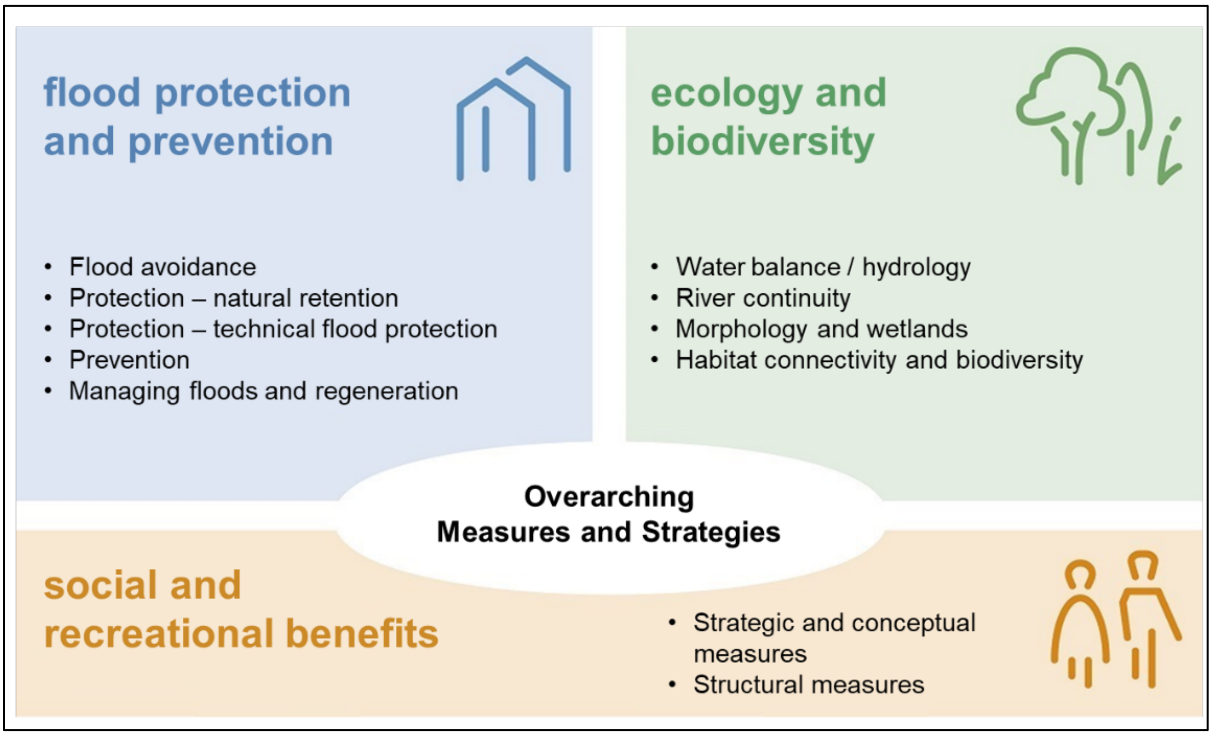

Fig. 3: Schematic representation of the elements of the new Bavarian integrated strategy for river development

With a systematic approach that builds on early best practice examples, the three pillars will be linked up within integrative planning concepts and projects, e.g. the development of natural floodplains, which provides flood retention on the one hand but also improvements regarding ecology, water balance and habitats on the other. In these integrative concepts, technical solutions will continue to have an important role in providing reliable flood protection for settlements and relevant infrastructure but they will be supplemented by nature based solutions wherever possible. In accordance with the principles of "good governance" and “risk governance”, the programme also includes a commitment to improve target group specific (risk)communication and to continually build on a wide and growing knowledge base, integrating input from NGOs, practitioners and administration as well as involving stakeholders in the implementation of measures on the ground. This way, the new strategy will allow the best possible use to be made of existing and potential synergies between the WFD, the FD and the Birds and Habitats Directives with a perspective that goes beyond all four.

3. Results and discussion

One lesson of the Anthropocene, which we are currently in the process of learning, is that the time, resources and knowledge needed to adequately protect and, where possible, restore our rivers and floodplains will far exceed the estimates of the past. With the continual emergence and discovery of new or hitherto unknown (*suppressed* and/or *hypothetical*) risks, it is clear that there is still quite a distance to cover until the process of resetting the current systems to deliver a fully holistic and dynamic risk governance regime is completed. With respect to the objectives of the WFD, the fact that this transition is far from complete is obviously contributing to the slow recovery rate of the status of water bodies[17]. It follows that framing the year 2027 as a "cliff edge moment" should be avoided on all accounts, especially in the light of the urgent need to not only to ramp up and accelerate but also, where necessary, to *perpetuate* the implementation of measures. The European Commission has already made it clear that the 2027 deadline in Article 4 (4) is by no means a "sunset clause" for the many binding provisions of the WFD[18]. Also, the prospect of setting less stringent objectives for a large proportion of water bodies is counterintuitive, to say the least: As well as potentially undermining efforts to harness the synergies discussed above, this would also go against the widely held view that, if anything, we need more, not less, ambitious targets in the future![19] In our opinion, the years from 2000 to 2027 should be understood (and presented to the public) as a *limited adaptation period* in which to address the extensive historical pressures (e.g. physical alterations, see chapter 2.2)[20] before entering into a henceforth *unlimited regime of fully integrated water resources management* in line with the risk governance approach.

Central elements of the risk governance approach are already enshrined in the relevant European Directives, making this an area of "common ground" with the potential for synergies. Harnessing these synergies can significantly increase the efficiency and broader acceptance of measures on the ground whilst increasing cost-effectiveness. Challenges facing practitioners in harnessing the potential of these synergies can and should be managed in a step-by-step way. A systematic approach that builds on experience and best practice examples can successively establish the knowledge, interconnected thinking and structures that open up the potential for (immediate) synergistic measures. Including elements that provide social and cultural benefits and engaging with local communities can enhance overall confidence in the measures proposed.

The overarching aim of the new Bavarian integrated strategy for river basin development is to balance and harmonise ecological, economic and social aspects of river basin management planning, anchoring the fundamentals of IWRM and risk governance even more firmly in day-to-day water management. Now, more than ever, the challenge is to bring stakeholders, politics and broader society fully on board. Despite the knowledge gaps that remain, the arguments for swift and urgent action are overwhelming. The overall system is currently in transition. Fortunately, from a Bavarian perspective, its elements are fundamentally "*fit for purpose*" – even if there is still "*room for improvement*" – and progress towards cooperative and synergistic coordination between river basin management (WFD and FD) and the Nature Directives is being made at all levels.

Despite partly different strategic approaches within the field of ecology and biodiversity – i.e. the WFD's dynamic progression towards Good Status and the Nature Directive's tendency towards static

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[17] In Bavaria the proportion of river water bodies achieving good ecological status was approx. 21 % in 2009 (Bayerisches Landesamt für Umwelt 2009), 15 % in 2015 (Bayerisches Landesamt für Umwelt 2015) and is now just under 19 % (personal communication, May 2021).

[18] In the "Fitness-Check", the European Commission (2019 a) states that "*After 2027, the possibilities for exemptions are reduced...*", in other words the WFD continues to apply beyond 2027 until or unless it is repealed, hence there is "no sunset clause" in the Directive.

[19] The European Federation of National Associations of Water Services sums up the dilemma as follows: "*The 2027 deadline for Member States to meet the requirements of the WFD stands, which means that the next River Basin Management Plans must live up to this challenge and provide both adequate ambition and financing.*" (EurEau 2020). Also, a closer look at the history of the WFD reveals that earlier drafts of the WFD (e.g. European Commission 1997) don't limit the number cycles in any way. In this sense, earlier WFD-drafts only requiring that "*the extension of the deadline, and the reasons for it, are specifically mentioned in the River Basin Management Plan*" (page 35) were more aligned with the FD and the Nature Directives than the version finally adopted in 2000.

[20] In fact, Member States had originally argued that this "grace period" should span at least 18 years (see e.g. Boef et al. 2016 page 6, von Vitorelli 2019 page 19).

preservation and preventing ecological degradation for terrestrial habitats – a more dynamic approach towards improvement is possible for riverine habitats. Integrated management concepts ("Ökologische Entwicklungskonzepte") for both water management and conservation issues for important river reaches of the Isar and Danube in Lower Bavaria illustrate this forward-looking approach (Schacht et al. 2013).

Whilst the long-term advantages of taking action cannot be properly gauged, it is the view of the authors that the benefits of "thinking big" and taking action *now* far outweigh the costs. Knowledge gaps are inevitable and will have to be managed or, where this is possible, closed along the way. Paul Crutzen (2010) was not only referring to global anthropogenic pressures when he stated: "*To develop a world-wide accepted strategy leading to sustainability of ecosystems against human induced stresses will be one of the great future tasks of mankind, requiring intensive research efforts and wise application of the knowledge thus acquired".*[21]

4. Conclusions

The challenges facing water management and nature protection span a wide range and the pressures of the Anthropocene are continuously increasing uncertainty and multiplying the risks. In this paper, we have explored the potential of synergies and common ground between the Water Directives, recently confirmed in their current form in the EU Commission's "Fitness Check", and the European Nature Directives. We have examined how the elements of risk governance enshrined in these Directives provide a suitable basis for better integration and harmonisation of the measures identified as necessary to achieve the respective objectives. Whilst harmonisation between the Directives represents an important opportunity for holistic integrated water resources management, the challenges and uncertainties are manifold, such as the different scales at which the Directives operate and differences in the strategic approaches within the field of ecology and biodiversity (i.e. dynamic progression towards Good Status vs. tendencies towards static preservation).

However, in general, well-established tools such as River Development Concepts ("GEK") have proved effective in the past and will continue to interweave components from different fields of action in the future, as will applying the elements of the adaptive and integrative risk governance approach already at our disposal in existing legislation and administrative practice. In this spirit, the Bavarian water management authorities and their partners in nature protection administration are joining in a concerted effort to optimise the potential of a wide range of synergies. Additional resources, capacity and expertise are being mobilised in the frame of a new Bavarian integrated strategy for river development, including concrete actions and commitments to accelerate and enhance the harmonisation of the relevant processes. To secure its long-term success, the programme will continually contribute to and build on a wide and growing knowledge base, integrating input from NGOs, practitioners and administration and involving stakeholders in the implementation of measures on the ground. Though the initial focus of the programme is on the immediate future, the "*demands of the Anthropocene can only be met if the continuous process already specified in the WFD is perpetuated and strengthened"* (Grambow et al. 2020). In the time between now and 2027, efforts will be maximised to accelerate the transition towards the envisaged holistic regime. The three pillars of the new Bavarian integrated strategy for river development will support that journey. The synergies, dialogue and continual learning connecting theses pillars will lay strong and lasting foundations for the future of Bavarian river basin management and ensure that many of the challenges of the Anthropocene impacting our rivers and floodplains can and will be met in the long term.

[21] Though Crutzen refers specifically to the "engineering community", it is actually a wide range of "communities" that have to face this challenge together, i.e. engineers, nature conservation associations, businesses, administration, etc. (see also Klinke and Renn 2012, page 2 "multiactor perspective").

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Extreme floods of the Danube in 2013 – track changes of the ecological state of the river applying the phytoplankton assemblage index

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Abstract

Extreme hydrological events have become more frequent and intensive in the Danube River Basin. The highest ever recorded discharge of the Danube at the entrance to Croatia (river 1424.85 km) was in June of 2013. The aim of this study was to evaluate changes in the ecological status of the Danube according to the phytoplankton functional approach and applying the phytoplankton assemblage index (Q-index). The lowest phytoplankton abundance and biomass were found during extremely high water discharge. A total of 119 phytoplankton species sorted into 20 FGs were found. Codon $\mathbf{T_B}$, represented by benthic diatom species, was the most successful during the whole investigated period and dominant in the conditions of extreme floods. The highest value of the Q-index (4.49) was established in the condition of extreme floods, indicating the *excellent* ecological state. The worst ecological state was in April, in the conditions of high nitrogen concentrations in riverine water and the low value of the Q index (2.48) indicating *poor* ecological status. Our results have shown that the assemblage index is a reliable instrument to assess the ecological status of large lowland rivers influenced by extreme hydrological events.

1. Introduction

At the end of the 20th and the beginning of the 21st-century climate change in the Danube River Basin has resulted in the strengthening of cyclonic activity, increase in air temperature, winter snow accumulation, annual rainfall, and ice regime softening (Mikhailova 2017). Consequently, the occurrence frequency of catastrophic floods and inundations increased. The extremely high flood events in the Danube River Basin of the recent past occurred in 2002, 2005, 2006, 2009, 2010, 2013 and 2014. Extreme floods happened in June 2013 on the upper and lower Danube and the strength and intensity of this flood event reminded of floods in 2002 (ICPDR 2014). The flood impact was devastating in Germany, Austria, Slovakia, Romania and Hungary, while remarkable consequences were observed in Bulgaria, Croatia and Serbia. At the Batina gauging station, on the entrance of the Danube River to Croatia, a peak of flood wave was recorded on the 11th of June with a corresponding discharge of 8.374 m^3s^{-1}. This was the highest ever recorded discharge of the Danube River at this place (in June of 1965, almost equal discharge of 8.360 m^3s^{-1} was recorded). It is estimated that the return period of this event was approximately 90 years (ICPDR, 2014). However, an increase in flood intensity and duration as a consequence of climate change is a projection of the future development of floods (ICPDR 2015). The question arises of how such extreme floods will influence the ecological condition of the river.

The ecological status estimation of surface waters in European countries is based on the assessment of biological elements, including phytoplankton, supported by hydromorphological, chemical and physicochemical elements (WFD 2000/60/EC). Traditional phytoplankton monitoring based on the taxonomic level of community structure is nowadays supplemented with phytoplankton trait-based approaches which grouped species with similar morphological and functional properties. Functional classification, proposed by Reynolds et al. (2002), assigning phytoplankton species into functional groups (FGs), was shown as a successful approach in monitoring the changes of phytoplankton worldwide and in different ecosystems, from shallow and deep lakes, reservoirs, estuaries to lowland rivers (Padisák et al. 2009). Based on the FGs classification, Padisák et al. (2006) developed the phytoplankton assemblage index (Q index) which provides 5 degrees of water quality. Up to now, the Q index was successfully applied to evaluate the ecological status of various types of lakes, e.g. to reconstruct the history of water quality in Lake Balaton (Hajnal and Padisák 2008) and for assessment of the water bodies from existed lake types in Bulgaria (Belikinova et al. 2014). However, little attention has been attended to the application of the phytoplankton FGs for evaluation of the ecological state of the rivers (Borics et al. 2007).

This study aims to show whether a phytoplankton approach based on functional traits and the Q index could be successful to evaluate the changes of ecological state in the Danube River in the extreme hydrodynamic condition as it was in 2013.

2. Material and methods

2.1 Study site

The Croatian part of the Danube River Basin accounts approximately 34,000 km^2 of its total drainage area of about 801,093 km^2. Flowing through the southern part of the Pannonian plain, river Danube in this part of the river course shows lowland river characteristics with a mean annual discharge of 2.085 m^{3}s^{-1} and mean annual water level of 2.63 m (data source: daily recordings in the period 1987–2008 at the gauge station at river 1,401.4 km). Natural floodplain area (covering more than 18 km^2) along the river section between 1,383 –1,410 km, known as a part of Kopački Rit Nature Park (Fig. 1) is one of the largest conserved floodplains along the long course of the river before its delta floodplains.

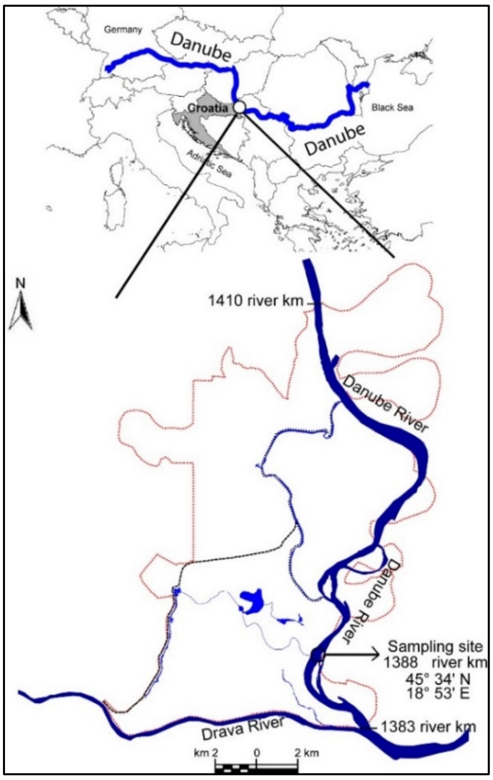

Fig. 1: Study area— sampling site in the Danube River

2.2 Sampling and analysis

Sampling was performed monthly in the period April-November 2013 at the site in the main river channel of the Danube at river 1,388.0 km (Fig. 1). Water temperature (WT), conductivity (Cond), pH and dissolved oxygen (DO) were measured *in situ* with a portable instrument (Multi 340i, WTW). Water transparency (SD) was measured by a Secchi disc. Chemical variables, ammonium (NH_4), nitrates (NO_3), nitrites (NO_2), total nitrogen (TN) and total phosphorus (TP) were determined according to standard methods (APHA 1992). Phytoplankton species were identified using a light microscope (Carl Zeiss, Jena) and standard literature for species determination (Hustedt, 1976; Hindak et al., 1978.). To determine the diatoms, samples were treated with H_2O_2 and HCl. Quantitative assessment of phytoplankton was done according to Utermöhl (1958) with an inverted microscope (Carl Zeiss, Jena Axiovert 25). Biovolume, calculated according to geometrical solids, was converted to biomass following Sournia (1978). Phytoplankton taxa were classified into the functional groups (FGs) proposed in the classification of Reynolds et al. (2002) revised by Padisák et al. (2009). Followed by Padisák et al. (2006) the relative shares of FGs to the total biomass multiplied by the factor number (F) and the sum of these scores is presented as phytoplankton assemblage index (Q index). The theoretical maximum of the Q index is 5, and the minimum is 0.

3. Results

3.1 Environmental parameters

Fluctuation of the Danube water level measured at river 1,401.4 km varied significantly during 2013 (Fig. 2). Higher water level characterized the first half of the year with the appearance of the extreme water level of 8.17 m, which occurred in June, followed by rapid decreased in water level in August to only 0.64 m. The lower water levels thereafter remained until the end of the year.

Notable values of the physical and chemical water properties established in the conditions of extreme high Danube water discharges in June 2013 included: the highest water depth (annual range 7.66 – 13.42) and concentrations of TP (0.037 – 0.312 mg L^{-1}); the lowest water transparency (annual range 0.44 - 1.25 m), DO concentration (annual range 8.15 – 12.92 mg L^{-1}), pH value (annual range 7.81 – 8.65) and conductivity (annual range 335 – 517 µS cm^{-1}). However, nitrogen load was maximal in April when the highest concentrations of ammonia (0.01 – 0.06 mg L^{-1}), nitrates (0.81 – 3.27 mg L^{-1}), nitrites (0.004 – 0.061 mg L^{-1}) and TN (1.94 – 31.29 mg L^{-1}) were recorded.

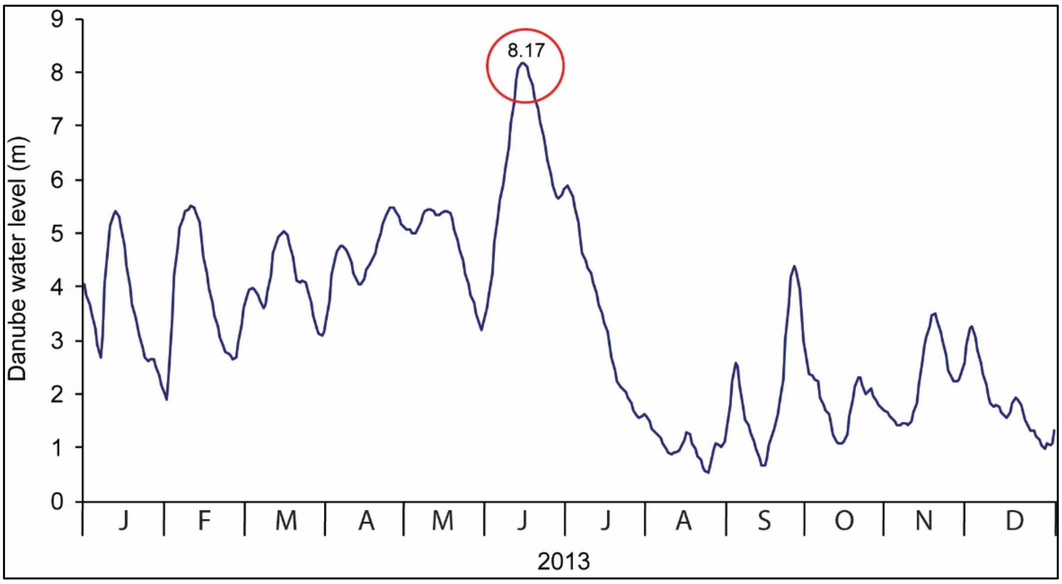

Fig. 2: The Danube water level oscillations during 2013 (data source: daily recordings at river 1,401.4 km)

3.2 Phytoplankton functional groups and assemblages index

Altogether, 119 phytoplankton taxa were registered during the study period and were sorted into 20 functional groups: **B, C, D, E, F, G, H1, J, L_0, MP, N, P, S1, S2, T_B, T_C, W1, W2, X1** and **X3** (Fig.3). Total phytoplankton biomass varied between 0.68 and 16.31 mg L^{-1} (mean value 4.39 mg L^{-1}). Diatoms from groups **T_B, D, C** and **P** were the most successful in the seasonal succession of dominant FGs and contributed more than 5% in the total biomass. The group **T_B** (species *Melosira varians* C.Agardh, *Craticula cuspidata* (Kutzing) D.G.Mann, *Diatoma vulgaris* Bory) was best developed with the highest contribution to the total biomass from May till September and achieved maximal relative biomass of 64.85% in June in the condition of extreme flooding. The codominant group during this period was **D** (species *Stephanodiscus hantzschii* Grunow, *Ulnaria ulna* (Nitzsch) Compère). Groups **C** (species *Cyclotella meneghiniana* Kützing) and **P** (species *Aulacoseira granulata* (Ehrenberg) Simonsen) occurred in summer months with low relative biomass.

Among Chlorophyceae, only species *Eudorina elegans* Ehrenberg from the group **G** dominated in phytoplankton community with relative biomass of 49.23% in April. Cyanobacterial species *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek belonging to **S1** group achieved relative biomass of 14.99% in October.

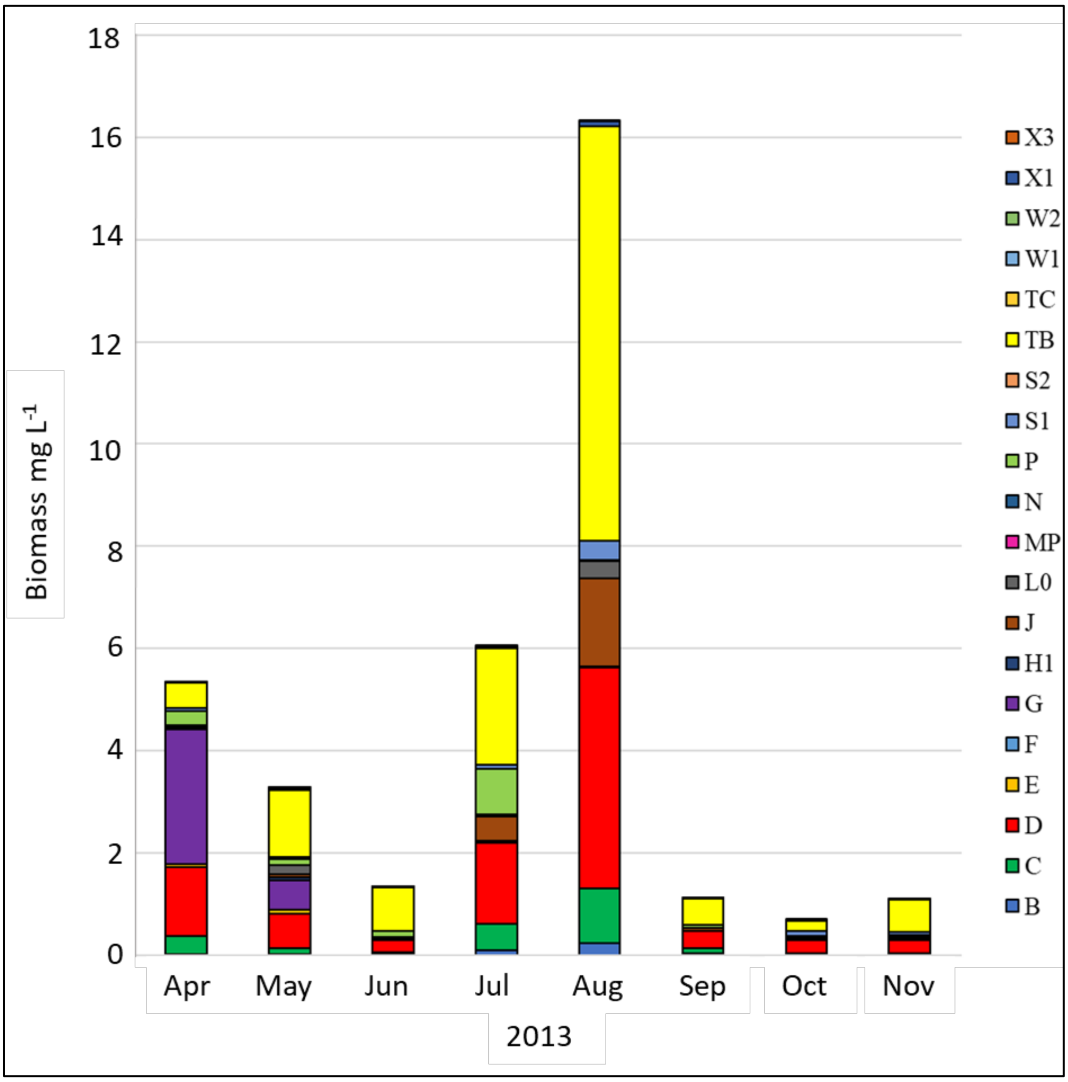

Fig. 3: Temporal variations in biomass of phytoplankton functional groups in the Danube River during the period April-November of 2013

The lowest value of the Q-index (2.48) was established in April indicating the poor ecological status of the river in the conditions of high nitrogen load, while the highest value (4.49) was found in the condition of extreme floods in June, indicating the excellent ecological state (Fig. 4).

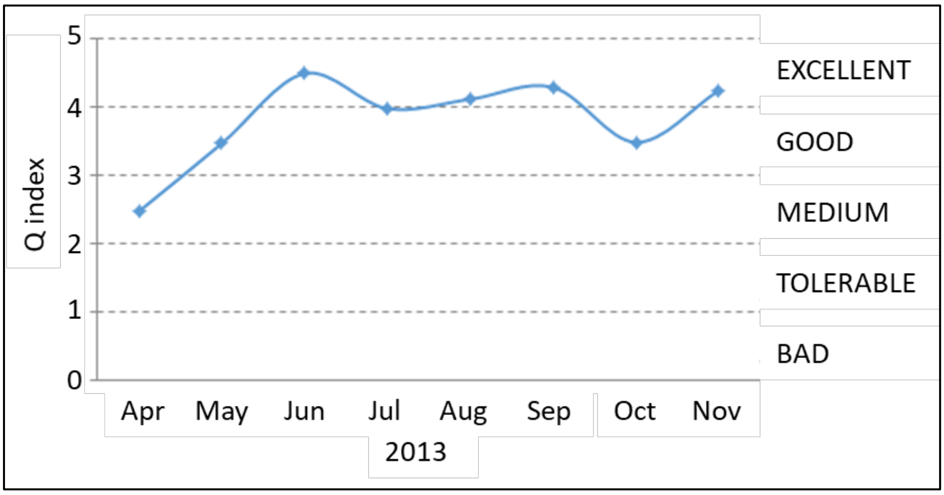

Fig. 4: Quality assessment of the River Danube based on the Q index

4. Discussion

Environmental conditions in June 2013 in the investigated part of the Danube River, characterized by extremely high water discharge, high concentration of suspended matter, low transparency and low light climate, was unfavorable for rapid growth and proliferation of phytoplankton. A greater water flux has negative effects on the algal development due to dilution and algae not having sufficient time to increase their populations (Salmaso and Zignin 2010). Therefore, very low phytoplankton biomass was established in comparison with the usual hydrological condition. The similar results were obtained in our previous research of phytoplankton during the extreme floods of the Danube in 2006 (Mihaljević et al. 2010).

Generally, diatoms make up a significant portion of the total phytoplankton biomass in the Danube River throughout the year (Várbíró et al. 2007). Our results showed that benthic diatom species from the group $\mathbf{T_B}$, characteristic for highly lotic environments (Padisák et al. 2009; Abonyi et al. 2012), were the most successful almost throughout the study period. Flow velocity is recognized as a driving factor controlling the structure of the phytoplankton community in the river habitat (Fraisse et al. 2013). Water turbulence affected and drifted epiphytic and benthic diatoms into the plankton. Therefore, the $\mathbf{T_B}$ group can be considered as a reference assemblage in the upper river segments (Borics et al. 2007) and has the highest factor number (F=5). Since the $\mathbf{T_B}$ group was dominant in extreme hydrological conditions, the Q index reached the highest value (4.49) indicating an excellent ecological state.

The centric diatoms from groups **D** and **C**, e.g. species *C. meneghiniana* and *S. hantzschii*, which are considered as „Danube type" phytoplankton (Schmidt 1994) were codominant with $\mathbf{T_B}$ group. Species from these groups are mostly euplanktic and are well developed in conditions of low water discharge during the vegetation period in large floodplain rivers (Stanković et al. 2012). The factor number for those groups is high (F=4) and consequently, the Q values exceed 4, indicating that this river section has frequently been in a good ecological state.

The worst ecological state was assessed in April 2013, in the conditions of extremely high nitrogen concentration in riverine water. It is well known that the Danube transports a large amount of nitrogen of which the largest part is attributed to nitrates, and according to the estimations for the period 2009-

2012, the total nitrogen emissions in the Danube River Basin were about 600,000 tons per year (Kovacs, 2015). Phytoplankton species are particularly sensitive to high nitrate concentration in the Danube water, which has been proven by our previous research (Mihaljević et al. 2013). The unusual development of volvocalean green algae from the **G** group, a sporadic species in a potamoplankton, established in April 2013, can be attributed to the species high metabolic activity that favour light-harvesting and nutrient uptake (Devercelli 2010). Due to the development of the **G** group characteristic for stagnant waters enriched with nutrients (Padisák et al. 2009), which has a low factor number (F=1), the low Q index (2.48) indicated poor ecological status.

5. Conclusion

Our results showed that monitoring of changes in the ecological state of the River Danube can be successful using the functional phytoplankton assessment and the Q index. Besides, the results obtained indicated that the impacts on the river environment caused by nutrient loads, particularly nitrogen, are still a major environmental problem in the Danube and can lead to deteriorating ecological conditions more than the consequences of extreme floods.

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Content analysis challenges of Danube river basin in the perspective of Anthropocene: A qualitative study

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Abstract

Anthropocene started to be perceived as a scientific discipline relatively recently. There is increasing recognition of the importance of practical or quantifiable advantages that governments derive from nature and rivers. Referred to as Nature's Gifts in the intergovernmental platform on biodiversity and ecosystem services conceptual framework. Danube river plays this international role in many countries. Hungary is situated within the heart of the Danube river basin, and seem many challenges put pressures on the Danube and its network of tributaries in manifold ways. The recognition that past, current and future challenges in river basins, it can help with planning and policy-making, this shows the importance and necessity of this research. The purpose of the present study was to determine the challenges of Danube river basin in the perspective of Anthropocene in Hungary. This research is based on the qualitative paradigm and using content analysis research method. Therefore, we provided a review of the most important research documents that are related to this topic, all collected from the Web of Science. The most important scholars, reports, and journals in the field are identified via documents and citations among them. Data analysis and coding of the study was conducted by employing the software MAXQDA-2020. however, this is the first attempt to construct this kind of research in content analysis related to the topic of challenges. Finally, the framework of the result of themes and sub-themes of the findings of the study and the relations between them was formed. The results revealed Pollutions, Environmental concerns and flood, transportation, people's awareness and knowledge, climate changes, infrastructure and basic factors, regional security, resource management and quality of water, and policies challenges are the main challenges of Danube river basin in the perspective of Anthropocene. It seems that Hungary should provide the necessary context for the participation of the private sector, local authorities and peoples to deal with these challenges. Further, it should design and implement long and short-term strategies in proportion to the challenges raised. Innovative solutions, education and environmental awareness and research grants will also be useful in addressing these challenges. We believe that the Content analysis procedures used in this paper provide an excellent tool to study such a relevant phenomenon.

1. Introduction

In Europe, almost all capital cities have at least one major river or lake crossing their urban landscape. The largest rivers of Europe, such as the Danube, the Rhine, and the Elbe, are home to a number of cities on their main channels, on their tributaries in their wider catchments, and on their estuaries (Mousazadeh 2018). International rivers are systems of land systems that play an important role in global development. From the point of view of the natural sciences, they are relatively independent geographical units. From the social science point of view, they are complex and complex management units. Due to natural processes such as tectonics, climate, and hydrology, their morphology and boundaries change frequently. The allocation of resources is a major factor influencing the management and development of a river basin area in different dimensions of space in a river basin.

In addition, international river basins play an important role in development, both regionally and globally (Ge & et al 2018: 1). The Danube Delta Biosphere Reserve (DDBR) is characterized by rich biodiversity and is home to more than 300 migratory birds, numerous ecosystems, and diverse cultural heritage. However, throughout the twentieth century, communities in the region have struggled with inadequate economic growth, poverty, and ecosystem degradation. This is partly due to the drainage of large amounts of water and the suppression of the cultural identity of small communities. It has also been challenged by the effects of climate change, rapid urbanization, and industrialization along the Danube River and an increasing number of tourists (Cristian et al. 2012). There are several policy processes in the EU that act as the driving force for managing the urban rivers and lakes works in a more integrated way (EEA 2016).

The EU Strategy for the Danube Region (EUSDR), or the Danube Strategy, has represented one of the EU's most important initiatives in relation to the Danube River's strong integration of large European regions and created a suitable framework for better and more open social, economic, environmental and cultural development (Mousazadeh and Izsak 2019). The purpose of this strategy is to strengthen territorial cooperation and interaction between the Danube region, ensure sustainable development of each region with better transport and social cohesion, protect the environment, raise education, culture, tourism, energy, labor market, etc. Local and regional initiatives serve as a motive for the sustainable development of the Danube region (Demonja and Fabijanić 2017). Proposed actions in this strategy specifically address the objectives to meet the challenges of changing the situation, developing sustainable use of resources (including water, nature, and land), and ensuring the quality of life. According to this strategy, the protection of ecosystems and natural assets, together with the vision of sustainable development, promotes the promotion of the quality of life and job opportunities for local people (EC, 2010). Because of their inherent propensity to change shape in response to environmental and anthropogenic conditions that differ over several time and spatial scales, rivers are one of the most complex elements among freshwater systems (Stecca et al. 2019).

River morphologies are changing rapidly on a global scale as a consequence of the direct and indirect impacts of human activities during the Anthropocene period. This jeopardizes the ecological services provided by rivers, such as flood control, navigational ease, and biodiversity (Hoitink et. 2020). In the Anthropocene Era, rivers must be formulated by dialogue and debate among a complex network of players, regulators, scientists, and natural and cultural values, where management goals are set and planned (García et al. 2021). The Anthropocene Era believes that modern humans will alter the Earth (Castree 2016; Szabó 2010). The human function as a transformative agent in rivers is already well-documented (Gregory 2006), and the environmental harm caused by the use and regulation of rivers for navigation, water consumption, and power generation is also widely acknowledged (Piégay et al., 2020). Many researchers have studied the effect of humans on river environments (e.g., Belletti et al. 2020; Scorpio and Rosskopf 2016). The present study is an attempt to analyze the challenges of the Danube river basin from the perspective of Anthropocene, as a qualitative study. For this purpose, the main research question is: What are the main challenges of the Danube river basin from the perspective of the Anthropocene?

2. Material and methods

To analyze the challenges of the Danube river basin from the perspective of Anthropocene, this paper adopted a qualitative approach. Qualitative studies are proper for creating a valuable contribution to our knowledge (Pung & Chiappa 2020). Due to the lack of knowledge about theoretical and basic principles in dealing with novelty subjects in research, the use of qualitative methods will be very valuable. The classical research method based on physical contact between the researcher and the participants in the event of the COVID-19 pandemic could be a factor in the increase in the number of patients. Because physical contact is one of the main causes of the corona outbreak (Dorga et al. 2020). Coordinated by changing all aspects of life with the COVID-19 the research method also needs to be changed. There are several kinds of qualitative data acquisition methods that vary using unstructured or semi-structured methods. Due to the exploratory nature of the present study, the study adopted a Grounded Theory Approach (GTM). Moreover, we suggest that Content analysis can be a good way to collect data.

3. Results and discussion

As we mentioned before, this paper adopts a content-analysis based literature review method to analyze the challenges of the Danube river basin from the perspective of the Anthropocene. Content analysis can be used to generate reliable findings due to the structured procedure (Seuring and Gold 2012). We applied six-stage refinement method as a part of MAXQDA software, which includes defining a study topic, setting inclusion and exclusion requirements, determining scanning databases, applying criteria, synthesizing related literatures, and reporting findings. Web of science was the online databases that were applied to search for relevant academic literature, as these databases have a wide range of resources. The initial search came out with 68 results in the Web of Science databases. The period of articles reviewed was from 2000 to 2020.

The collected data from the articles reviews were transcribed and the contents were analyzed multiple times. Eventually, themes were classified by the researcher and were then inserted into the MAXQDA software. Subsequently, the author revised all reviews regularly to guarantee that all themes were identified and implemented. In recent years, it has been observed that researchers have become more inclined towards qualitative studies and in a way, they emphasize the high value and credibility of qualitative studies in urban and regional research.

To guarantee a careful research process, nevertheless, it is necessary to be apparent about the role and interpretation of each particular MAXQDA code within the analysis methodology (Kuckartz & Rädiker 2019). This step is one of the most significant steps of grounded theory, which needs the active cooperation of researchers. Categories and coding play a crucial role in developed grounded theory (Kuckartz 2014). In this study, after transcribing the articles reviews and specified open coding, the data were grouped into the stratum of relevant axial codes. Axial coding authorizes the refined sub-themes to be put together to identify themes and connections. We believe that the analysis procedures used in this paper provide an excellent tool to study such relevant phenomenons in others research fields. Then, open and axial coding of the interviews was done using MAXQDA 2020 software. One of the most interesting steps in content analysis is to determine the relevant themes from the heart of the article's reviews. These themes and sub-themes on MAXQDA software are a consensus of the whole research (Devan et al. 2020: 90).

In the next step, as the final part of content analysis referring to transcribed articles reviews that have been approved by the researcher the main and sub-themes, are specified by using MAXQDA 2020 software. The results of the content analysis are presented in Table 1. The nine themes are shown in Table 1 present the main challenges of the Danube river basin from the perspective of the Anthropocene. The main challenges include Pollutions, Environmental concerns and flood, transportation, people's awareness and knowledge, climate changes, infrastructure and basic factors, regional security, resource management and quality of water, and policies challenges.

Table 1: Results of content analysis

Themes	Frequency
Pollutions	52
Environmental concerns and flood	38
Transportation	47
People's awareness and knowledge	36
Climate changes	41
Infrastructure and basic factors	28
Regional security	25
Resource management and quality of water	43
Policies challenges	39

4. Conclusion

The current study is unique and timely as it contributes to filling the gap in the field of challenges of Anthropocene. This paper presents a comprehensive review of the challenges of the Danube river basin from the perspective of the Anthropocene. This paper is one of the first to investigate the challenges of rivers from the perspective of the Anthropocene. The paper provides a fundamental and comprehensive understanding of the river challenges in the Anthropocene era, which will not only be a useful guide for new researchers in the relevant area but can also provide some deeper highlights for decision-makers. To achieve the research objective and answer the research question, we used the content analysis method. Thus, after reviewing the articles by the coding method in the MAXQDA environment, the challenges were identified. These main challenges included Pollutions, Environmental concerns and floods, transportation, people's awareness and knowledge, climate changes, infrastructure and basic factors, regional security, resource management and quality of water, and policies challenges.

Albeit qualitative studies are proper for creating a valuable contribution to our knowledge, especially gratified to exploring the content analysis and dynamics of context in regional and urban research, especially phenomenological research. Also, researchers emphasize the high value and credibility of qualitative studies in tourism research, future research can examine research-related themes based on quantitative studies. In summary, all stakeholders, including us as researchers, have a duty of big liability: to help redirect and strengthen the environment to meet the challenges posed during the Anthropocene era, that is fit and adapt and a future that is steadily changing and full of the new crisis.

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A retrospective of ten years of the botanical exploration in Nature Park Kopački rit (Croatia)

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Abstract

Nature Park Kopački rit, located in north-eastern Croatia along the part of the Middle Danube section, is recognised as one of the most preserved fluvial-wetlands in Europe. An intensive botanical research and monitoring of rare and threatened flora and habitats were done in the area of Nature Park Kopački rit over a ten-year period (2010-2020). Flora of Nature Park Kopački rit comprises 595 taxa (species and subspecies) of liverworts, mosses, pteridophytes and angiosperms. Bryophyte flora is represented by 40 species (9 liverworts, 31 mosses), and vascular plant flora by 555 species (9 pteridophytes, 546 angiosperms). Allochthonous flora is represented by 56 species of which 26 are invasive alien species.

1. Introduction

Public Institution Nature Park Kopački Rit started in 2010 with implementation of the Action Plan for Conservation of the Aquatic and Wetland Habitats in Nature Park Kopački rit, as the multiannual permanent activity. Over a ten-year period, from May 2010 to September 2020, an intensive field floristic researches were done, combined with monitoring of rare and threatened flora, as well as terrestrial, aquatic and wetland habitats. An important achievement of these activities is an updated inventory list of flora and broadened knowledge on habitats.

2. Material and methods

2.1 Study area

Nature Park Kopački rit is located in north-eastern Croatia, in the angular area formed by the confluence of the Danube and the Drava River (Figure 1). This is a large fluvial-marshy floodplain formed during the late Quaternary (Bognar 1990). The altitude range is 72-86 m a.s.l. The appearance of the whole area and an overall biodiversity depends on the flooding intensity of the Danube River, while the Drava River has much less importance.

The area is interwoven by side arms, dead arms, oxbow lakes, channels and numerous ponds. The largest water body is the Kopačko Lake (surface of 200–250 ha in the period without flooding), and the deepest one is the Sakadaš Lake with a mean depth of 7 m. The lakes are interconnected with rivers through a network of natural channels (Mihaljević et al., 1999). The inflow of the Danube floodwaters towards the Kopačko Lake is distributed by the 6 km long Hulovo Channel. In the northern part, floodwaters are distributed by the 16,4 km long side arm Vemeljski Dunavac.

Danube flooding and water stagnation are major pedogenetic factors of specific soil type characterised by fine texture and low hydraulic conductivity. Excessive wetting by floods and high level of subsurface water enable conditions for the development of hydromorphic soils (Tadić et al. 2014). In the land use structure of Nature Park Kopački rit, freshwaters and marshland covers 40% of the total Park area, forests 30% and agricultural land 20% (Rožac et al. 2018).

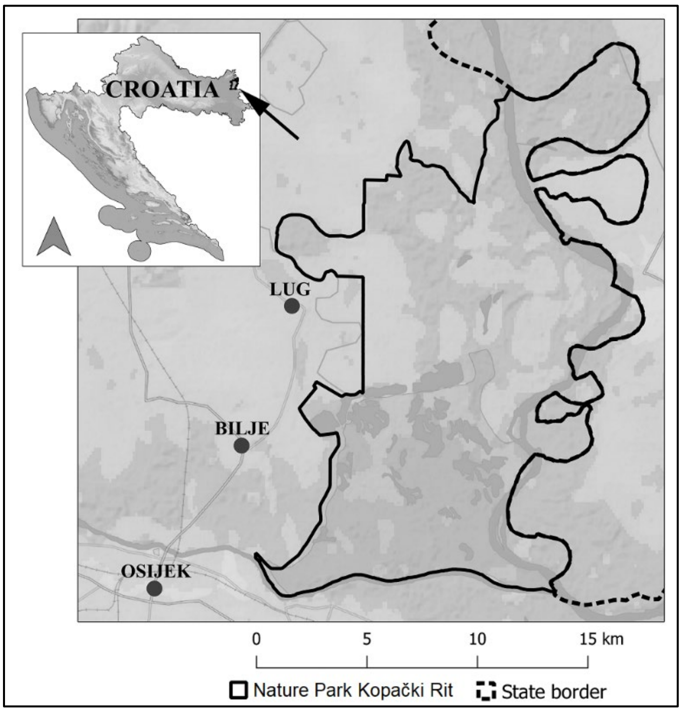

Fig. 1: The geographical location and boundaries of Nature Park Kopački rit

Regarding the phytogeographical position, Kopački rit belongs to the Eurosiberian – North American region, and to the Pannonian sector of the Central European province. This is a transitory region between the vegetation of the *Carpinion betuli* alliance and forest steppe zone of the *Aceri tatarici – Quercion* alliance (Nikolić et al. 2005). According to classification of Croatian vegetation (Škvorc et al. 2017), the freshwater aquatic and wetland vegetation belongs to the orders: Lemnetea, Potamogetonetea and Phragmito-Magnocaricetea, while the forest vegetation belongs to the alliances: *Salicion triandrae* (willow scrubs); *Salicion albae* (willow and poplar forests); *Alno-Quercion roboris* (alder-oak riparian floodplain forests), and *Carpinion betuli* (oak-hornbeam forests).

Due to its great biodiversity and ecological values, Kopački rit was firstly protected in 1967 (Rožac et al. 2019). Actual nature protection status in category of Nature Park was established in 1999, at total surface of 23,126 ha, including the middle Danube reach between river km 1,412 and 1,382. In 1993, the Kopački rit was designated on the List of Wetlands of International Importance under the Ramsar Convention (inscription number: 583). It is included in two areas of the ecological network Natura 2000 in Croatia, under the EU Birds and Habitats Directives: Special Protection Area (SPA) HR1000016 Podunavlje i donje Podravlje, and Site of Community Importance (SCI) HR2000394 Kopački rit. The latest achievement in nature conservation is the establishment of UNESCO Transboundary Biosphere Reserve Mura-Drava-Danube, proclaimed in July 2012, with Nature Park Kopački rit as the best preserved natural floodplain of the entire Reserve.

2.2. Floristic study

A detailed chronology of the floristic studies in the area of Kopački rit (Rožac et al. 2018), specifies that earliest records date in 18th century, when Count Luigi Ferdinando Marsigli in the sixth volume of monograph: "Danubius Pannonico-Mysicus", published in 1726, recorded several plants from the mouth of the Drava River. Diversity of the aquatic macrophytes and habitats along the Danube reach in Croatia and floodplain water bodies in Nature Park Kopački rit were studied in the period 2003-2006.

A total of 158 macrophyte species were reported or 32% of the total of 496 species recorded for the vascular flora of Nature park Kopački rit in the period 2010-2013 (Ozimec and Topić 2018).

Public Institution Nature Park Kopački rit started in 2010 with implementation of the Action Plan for Conservation of the Aquatic and Wetland Habitats in the Nature Park Kopački rit, as the multiannual permanent activity. Over a ten-year period, from May 2010 to September 2020, an intensive field floristic investigation of the bryophyte and vascular plant flora was done. Agricultural and strictly ornamental plants have not been part of this investigation and are not presented in the results.
As an achievement of the advanced field surveys, carried out from 2010 to 2018, an updated list of the vascular flora of Nature Park Kopački rit has been published with a total of 522 taxa, including 114 newly recorded taxa (Rožac et al. 2018).

3. Results and discussion

An overall flora of Nature Park Kopački rit comprises 595 taxa (species and subspecies), 337 genera and 116 families of the aquatic and terrestrial liverworts, mosses, pteridophytes and angiosperms (Table 1).

Table 1: Taxonomic analyses of the flora of Nature Park Kopački rit

Taxonomic category	**Family**	**Genus**	**Species and subspecies**
Liverworts (Marchantiophyta)	7	8	9
Mosses (Bryophyta)	12	22	31
Pteridophytes (Pteridophyta)	6	6	9
Angiosperms (Magnoliophyta)	91	301	546
Dicotyledons (Magnoliopsida)	73	234	409
Monocotyledons (Liliopsida)	18	67	137
Total	116	337	595

The bryophytes were represented by 40 species: 9 liverworts and 31 mosses, which made 5,0% of the total 798 taxa currently known in the bryophyte flora of Croatia (Šegota et al. 2020).

The vascular plant diversity comprised 555 species: 9 pteridophytes and 546 angiosperms (409 dicotyledons and 137 monocotyledons), which made 11,0% of the total of 5,027 taxa (species and subspecies) recorded for the vascular flora of Croatia (Nikolić 2020). Among the vascular plants, the most abundant families were: Asteraceae (47 taxa), Poaceae (45), Lamiaceae (37), and Cyperaceae (30). The most diverse genera were: *Carex* (17 taxa), *Ranunculus* and *Veronica* (10 each), and *Potamogeton* (9). During the field investigations, some of the previously recorded species were failed to be found or confirmed, like *Acorus calamus, Marsilea quadrifolia*, and *Typha minima*. Knowledge on the diversity of orchid family (Orchidaceae) expanded from two previously recorded taxa to nine taxa of the forest and meadow orchids.

Allochthonous flora was represented by 56 species (10.1%), of which 12 species (21%) were archaeophytes and 44 species (79%) were neophytes. According to geographic origin, most of the allochthonous plants (29 species or 51,8%) have the North American and South American origin, followed by 13 species (23.2%) of Asian origin, 9 species (16.1%) of Eurasian origin, and 3 species (5.4%) of Mediterranean origin. The richer allochthonous flora shows disturbance intensity caused by anthropogenic activities.

Invasive alien plants were represented by 26 species (4.7%) or 40.6% of 64 taxa registered in the Croatian flora (Boršić et al. 2008). Three species: *Asclepias syriaca, Elodea nuttallii* and *Impatiens glandulifera*, are listed on the List of invasive alien species of Union concern (Boršić et al. 2018).

An assessment of the conservation status of vascular plants has been made. The number of threatened species is 60 or 11% of total vascular flora of Nature Park Kopački rit (Table 2). They are included in Red Book of Vascular Flora of Croatia (Nikolić and Topić 2005), under the following IUCN threat categories: 6 as Critically Endangered, 13 as Endangered, 17 as Vulnerable, 10 as Near Threatened, 9 as Data Deficient, and 5 as Least Concerned.

Table 2: The list of plant species included in Red Data Book of Vascular Flora of Croatia

IUCN Threat Category	Plant Species
Critically Endangered (CR)	*Carex bohemica, Limosella aquatica, Scirpus mucronatus, Scirpus supinus, Typha laxmannii, Typha minima*
Endangered (EN)	*Alisma gramineum, Allium angulosum, Carex nigra, Dactylorhiza incarnata, Eloeocharis ovata, Gentiana pneumonanthae, Hibiscus trionum, Hippuris vulgaris, Hottonia palustris, Lemna gibba, Marsilea quadrifolia, Pseudolysimachion longifolium, Salvia nemorosa,*
Vulnerable (VU)	*Alopecurus aequalis, Alopecurus geniculatus, Carex riparia, Carex vesicaria, Cyperus flavescens, Cyperus fuscus, Cyperus glomeratus, Cyperus longus, Cyperus michelianus, Fritillaria meleagris, Glyceria fluitans, Iris sibirica, Lindernia procumbens, Orchis purpurea, Platanthera bifolia, Stratiotes aloides, Wolffia arrhiza*
Near Threatened (NT)	*Anacamptis pyramidalis, Butomus umbellatus, Carex acutiformis, Cephalanthera damasonium, Ophioglossm vulgatum, Platanthera chlorantha, Poa palustris, Salvinia natans, Scirpus maritimus, Trapa natans*
Data Deficient (DC)	*Campanula trachelium, Chenopodium rubrum, Kickxia elatine, Lathyrus palustris, Littorella uniflora, Orchis laxiflora* subsp. palustris, *Phleum paniculatum, Rumex amritimus, Sparganium minimum*
Least Concerned (LC)	*Acorus calamus, Allium vineale, Poa annua, Serratula tinctoria, Vitis vinifera* subsp*. sylvestris*

Five vascular plant species: *Lindernia procumbens, Marsilea quadrifolia, Salvinia natans, Trapa natans*, and *Typha minima* have protection status under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), and are listed in Appendix I of the Convention. Only on species, *Marsilea quadrifolia* has protection status under the EU Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (The Habitats Directive), and is listed in Annex II of the Directive.

Wet meadows from the vegetation alliance *Cnidion dubii* are still present in the area of Nature Park Kopački rit, that confirm recorded presence of diagnostic species: *Allium angulosum, Euphorbia lucida, Gentiana pneumonanthae, Iris sibirica*, and *Pseudolysimachion longifolium*. This habitat type is listed in Annex I of the Habitats Directive as: 6440 Alluvial meadows of river valleys of the *Cnidion dubii*.
The threats to the plant and habitat diversity in Nature Park Kopački rit are: increased fluctuations in flooding intensity of the Danube River, lack of rainfalls, increased summer air temperatures, extension of dry season, accumulation of bedload, natural succession of the wetlands, and dispersal of the invasive alien plant species, which can threaten the native flora.

4. Conclusion

Nature Park Kopački rit is located in north-eastern Croatia, in the part of the Middle Danube section. The floristic diversity, with 40 bryophyte species and 555 vascular plant species, confirms significant ecological values of this floodplain area. Regarding the plant conservation status, 60 taxa are included in the Red Book of Vascular Flora of Croatia. Non-native flora is represented with 53 taxa, among which 26 are invasive alien plant species. Comprehensive knowledge on flora and habitats provide an important tool for planning and implementation of measures and activities with an aim to conserve and protect rare and threatened plants and their habitats in Nature Park Kopački rit.

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In search of the elusive sterlet (*Acipenser ruthenus*) in Slovenia

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Abstract

One of the aims of the MEASURES project (Danube Transnational Program, Interreg) in Slovenia was to determine the wintering (W) and feeding (F) habitats of migratory fish species that inhabit the rivers in Slovenia (sterlet (*Acipenser ruthenus*), nase (*Chondrostoma nasus*), barbel (*Barbus barbus*), cactus roach (*Rutilus virgo*) and vimba bream (*Vimba vimba*)) with an emphasis on sterlet habitats in the Mura and Lower part of Sava River. The aim was to identify the most efficient method for scientific sampling and monitoring of migratory fish species, as well as mapping their habitats in Danube tributaries as the basis for future conservation actions.

The Sterlet is the smallest representative of Danube sturgeons, and used to regularly occur in the Slovenian part of the Mura and Sava Rivers, while the Russian sturgeon (*Acipenser gueldenstaedtii*; Govedič et al., 2018) was less common. However, their populations declined dramatically and only one sterlet catch has been confirmed in the last 20 years in Slovenian rivers, with the fish origin traced to Austria (Govedič et al., 2018). There were additional records reported before 2000 by local fishermen, but those cannot be confirmed, as photographic records do not exist.

Potential habitats were identified and described in 2018 and 2019 as part of the MEASURES project by scanning the river with a sonar and sampling the sediment and macroinvertebrates. The locations were then classified into the 3 potential habitat groups (W, SP (spawning) and F). In the second step, feeding habitats were sampled using longlines, but no target fish species has been found. The underwater visual census method was also tested to identify wintering habitats, but due to the strong, diverse layered current the prime habitats have not been reached. The sampling of wintering locations using fixed trammel nets was the most successful method tested, resulting in the highest diversity of fish, including 3 of the target species.

1. Introduction

An analysis of historical distribution and presence of various sturgeon species in all Slovenian rivers was undertaken by reviewing mediaeval texts mentioning catch records (Govedič et al. 2018). Sterlets (*Acipenser ruthenus*) used to be a regularly occurring fish in the Slovenian part of the Mura and Sava river. However, due to river regulations, their natural populations declined dramatically. After almost 20 years with no sign of their presence (Govedič et al. 2018), two sterlets, supported with credible photo material, have been confirmed. One from the Drava River in December 2020 and one from the Mura River in February 2021. The origin of both fish is unknown (personal communication 2021).

The Mura River with its tributaries has one of the highest fish biodiversities in Slovenia and Europe (Povž 2016). This is likely due to the preserved connectivity with the Drava and Danube River. In the MEASURES project the wintering and feeding habitats of other migratory fish species were determined, such as the nase (*Chondrostoma nasus*), barbel (*Barbus barbus*), cactus roach (*Rutilus virgo*) and vimba bream (*Vimba vimba*), for which most of the data was already collected with electrofishing by the Fisheries Institute of Slovenia.

The aim of the MEASURES project in Slovenia was to identify the most efficient method for scientific sampling and monitoring of migratory fish species and to potentially confirm the presence of sterlet in the Mura and lower Sava River. Slovenia, as well as the whole Danube River basin, lacks scientific methodology to survey sterlets and their habitats, which is an essential requirement for future conservation actions.

2. Material and methods

2.1 Identification of potential habitats

Wintering habitats are habitats found in deeper parts of the river, such as holes and depressions, used for overwintering by many fish species, due to the stable physicochemical and hydrological conditions. In these habitats water temperature is constant and higher than surface water, while the flow is usually slower. Terrestrial predators are rare. In such conditions, where only minor and slow body movement is needed, fish can reduce their energy demands and survive the winter (Cunjak 1996).

The sterlet is a typical benthic fish that prefers slow-flowing river segments with productive water, rich in prey items (Holčik 1989). While occupying their **feeding habitats**, sterlets feed mostly on insect larvae, amphipods, snails, leeches, fish eggs, etc. (Fieszl et al. 2011).

Potential habitats are those areas in which hydrological, morphological and biotic characteristics align with the target fish requirements, but the presence of fish has not been directly confirmed via sampling. Potential wintering and feeding habitats were determined on the Mura and Sava Rivers based on satellite imagery and field surveys. After reviewing the satellite imagery, a field survey was performed and the exact GPS coordinates for every potential habitat were determined. On habitats which were accessible by boat the site characteristics data (sediment type, water depth, bank vegetation cover, bank vegetation shading of the watercourse, bank structure and incline) were selected for evaluation. Most suitable locations were chosen for fish sampling. On feeding habitats macroinvertebrates were sampled, to confirm the presence of sterlet prey items.

Past electrofishing studies were reviewed to determine fish diversity and abundance in the general vicinity of the targeted potential wintering and feeding habitats.

2.2 Location

The Sava (10.870 km2) and the Mura (15.500 km2) are, alongside the Drava (15.500 km2), the largest and most important Danube tributaries in Slovenia. The Mura's peak flow occurs in late spring and summer, caused predominantly by snowmelt (snow flow regime). The Sava has a rain-snow flow regime with peak flow in spring months, due to the snowmelt and a second, smaller peak in the autumn (Bat et al., 2003).

2.3 Fish sampling methods

For sterlet sampling different methods were tested, both passive and active, based on the sterlet seasonal behaviour and habitat characteristics, as well as experiences with their sampling from abroad. Due to the seasonally limiting hydro-morphological conditions of Slovenian rivers (fast water flow in spring and autumn and with precipitation connected high water levels) and plentiful debris scattered on the river bottom, fish surveys on feeding and wintering habitats were implemented only when conditions were appropriate to navigate the rivers safely.

On potential feeding habitats drift nets and longlines were used. Potential feeding habitats and macroinvertebrates were sampled in July and August of 2019.

Drift net sampling is a passive method where trammel nets are drifted along the bottom of recognized potential feeding habitats. One part of the net was fixed on the boat and the other one was held by a team member on the riverbank. The boat slowly moved with the water flow in the direction of the riverbank, making a loop. A 15 m long and 1,2 m wide net was used with a mesh size of 22 mm in the inner and 150 mm for both external nets. The fishing unit consisted of three team members on the boat and one on the riverbank.

Longlines are another passive method, and written records of their use to catch sterlets on the Danube in Serbia dates back to 1956 (Unknown author, 1956). Fishermen in the lower part of the Danube still used this method in the second half of the 20st century for catching different sturgeon species (Friedrich, 2012). However, nowadays this method is forbidden. Due to the fast flow of the Mura and Sava Rivers, 10 m long longlines with 10 hooks of different sizes (2/0 and 4/0) were used. Rainbow trout fillets were chosen as bait. At each location 2 longlines were set in the afternoon and lifted in the morning. The fishing unit consisted of four members on the boat.

At each fish sampling location 3 macroinvertebrate samples (at a depth of approx. 20cm-30cm, 50cm and 100+ cm respectively) were taken. The sampling was done by kick-sampling for the first two shallower samples and with the Van Veen grab for the last deeper sample. After collection, the benthic macroinvertebrates were enumerated and identified to the family level.

On potential wintering habitats two methods were used: visual census and fixed trammel nets.
Potential wintering habitats were sampled in January and February 2020.

Visual census is an active method and one of the least invasive methods to verify sterlet and other migratory fish species at their wintering habitats. The method is qualitative, designed to provide information on the presence of wintering fish in different micro-locations in river pools or depressions. A certified river diver with professional filming equipment and experience was hired. Dive sites were chosen according to depth and flow velocity. The research unit consisted of one diver and a team of two members on the riverbank for assistance and safety reasons.

Fixed trammel nets were placed in deep holes and depressions which were accessible by boat and suitable for potential wintering of migratory fish (sufficient depth and low water flow). Net length was 25 m, height 1,2 m with a mesh size of 40 mm for the inner layer and 200 mm for the outer layers. The micro-locations of the nets were chosen with the help of sonar imagery (Humminbird Helix 7 CHIRP SI GPS G2N and XNT 9 SI 180 T transducer). This (passive) method was adapted to conditions of the Mura and Sava Rivers (numerous and heterogenic habitats, fast water flow) by using additional weights, anchors and a shorter net length.

3. Results and discussion

In the survey a total of 163 km of Mura River were examined, from the border with Austria to the border with Croatia and 7 km of the Sava River, from Brežice to the border with Croatia.

3.1. Potential feeding habitats

The drift net method was tested on one potential feeding habitat on the Mura River. The method is not suitable for Danube tributaries such as Slovenian rivers, because they are not used for navigational purposes and are full of boulders and submerged tree trunks. Additionally, the fast water flow made it difficult to safely manoeuvre the boat and sample at the same time. The conclusion is that the method is not suitable for fish sampling in Slovenian rivers.

Longlines were used on 25 potential feeding habitats on the Mura River and 5 on the Sava River. Ten longlines were removed by fishermen (mistakenly identifying them as illegal) and due to the disturbances, these locations were excluded from our analysis. At the remaining 15 locations 5 fish were caught on the Mura River and 2 on the Sava, but no migratory fish species targeted in the project. In some cases, the bait was eaten by smaller fish, which did not end up getting caught. Size specific hooks were used to target bigger fish. The average size of caught fish was 43,15 cm, which is also the approximate size of sterlets found in Slovenia in the past (around 40 cm; Povž et al. 2015). In the future other more natural baits should be tested, such as earthworms and aquatic larvae of various insects. From telemetric surveys on the Danube River, it is clear that sterlets are using different feeding habitats and are migrating between them regularly. Longlines are not the most successful method to use when searching for sterlets moving between their numerous feeding habitats.

In all potential feeding habitats, a great number of Trichoptera larvae, Chironomidae and Gammaridae, as well as Asellus sp., Mollusca, Oligochaeta, Annalida, Insecta, Nematoda and Hirudinea were detected. These genres are also present in the stomachs of sterlets caught in the Danube (Djikanović et al. 2015), therefore, based on the variety of different taxa, there is potential for sterlet to occur at these sites.

3.2. Potential wintering habitats

From the potential wintering habitats, the most appropriate ones, based on depth, boat accessibility and low water flow, were selected. The visual census survey on the Mura River was conducted and the method of fixed trammel nets on the Mura and Sava Rivers was tested.

For the **visual census**, certified river diver with professional filming equipment and experiences was hired. Three pools and one depression in the main river channel were surveyed. In the latter, due to the flow velocity, the diver had difficulties staying on and moving slowly on the river bed, so no fish species were detected. I other, calmer locations 2 fish species not targeted in the project (*Gymnocephalus cernuus* and *Carassius carassius)* were detected. Although no migratory fish species was seen, the method was confirmed as successful in numerous rivers in Slovenia in the past, at depths where other methods and tools described in this extended abstract could not be used (www.cicfilm.com 2020).

With **the trammel net** method 12 nets were set on the Mura River and 4 on the Sava River. On the Mura 40 fish from 10 different species were caught, 3 of them were target species. At locations with the greatest depth (SL_Ma_118, SL_Ma_119, SL_Ma_155, SL_Ma_157), two nets were set. At SL_Ma_155 one net was set where the water flow was homogenous and the second one where the water flow was turbulent. Most fish were caught in the first net. On locations (SL_Ma_118 and SL_Ma_157) where water flow was also turbulent, the nets got tangled and filled with different material, such as branches, leaves and stones. At these locations no fish was caught. No suitable potential wintering habitats for sterlet in Slovenian part of the Sava river were found due to the hydro-morphological characteristics of the river (riprap river banks and artificial pools with fast water flow), nevertheless 2 locations were selected, both close to the Croatian border, where the conditions were most similar to the natural state of the river. No fish was caught.

Croatian partners in the project (Karlovac University of Applied Sciences) also sampled on the Sava River and set the nets in similar locations. With the same methodology and strategy, they set 15 nets and caught 20 sterlets and 27 other fish, altogether 8 fish species, 4 of them were target fish species. At their deepest location (CR_Sa_3), 15 sterlets were found, which is similar to the deepest location on Mura River in Slovenia (SL_Ma_155), where the highest number of different fish species were observed.

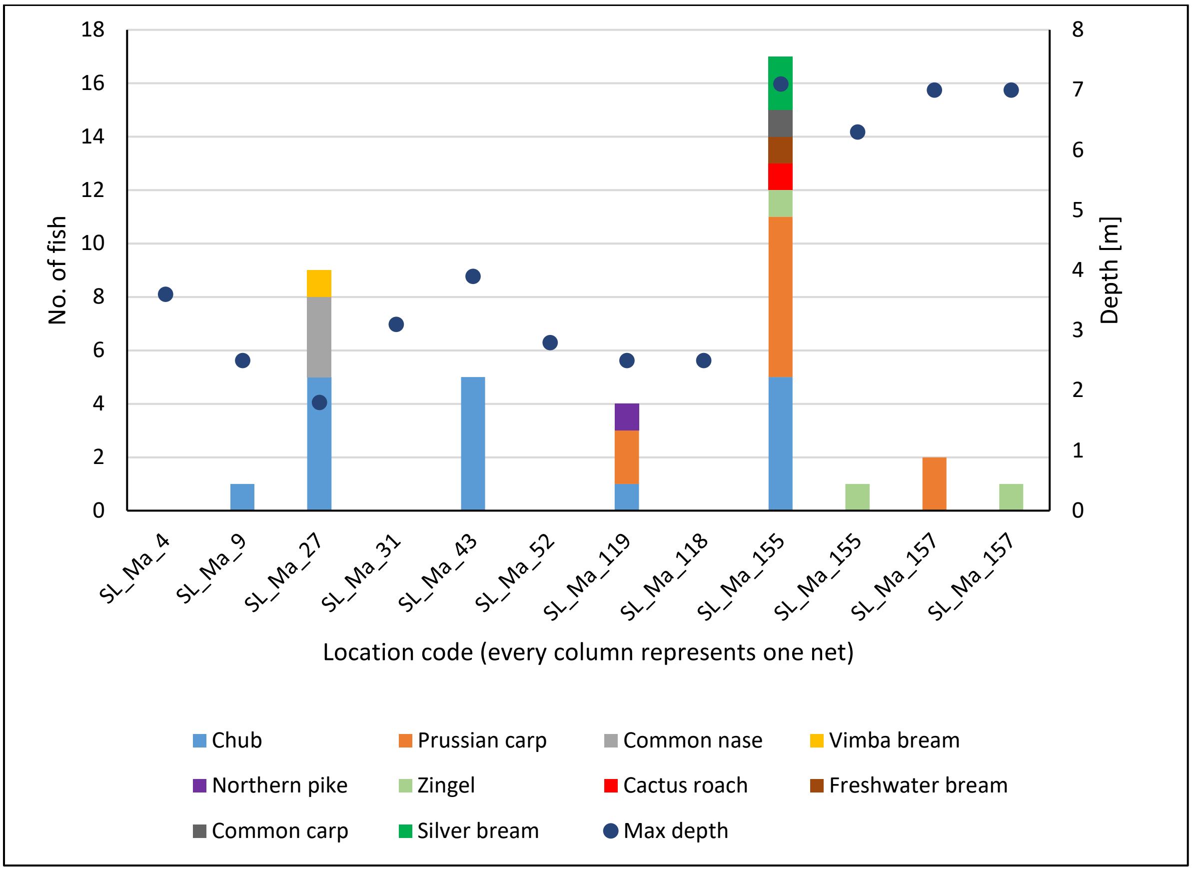

Fig.1: Number of fish caught on the Mura River (Slovenia) using fish fixed nets on potential wintering habitats based on the location depth

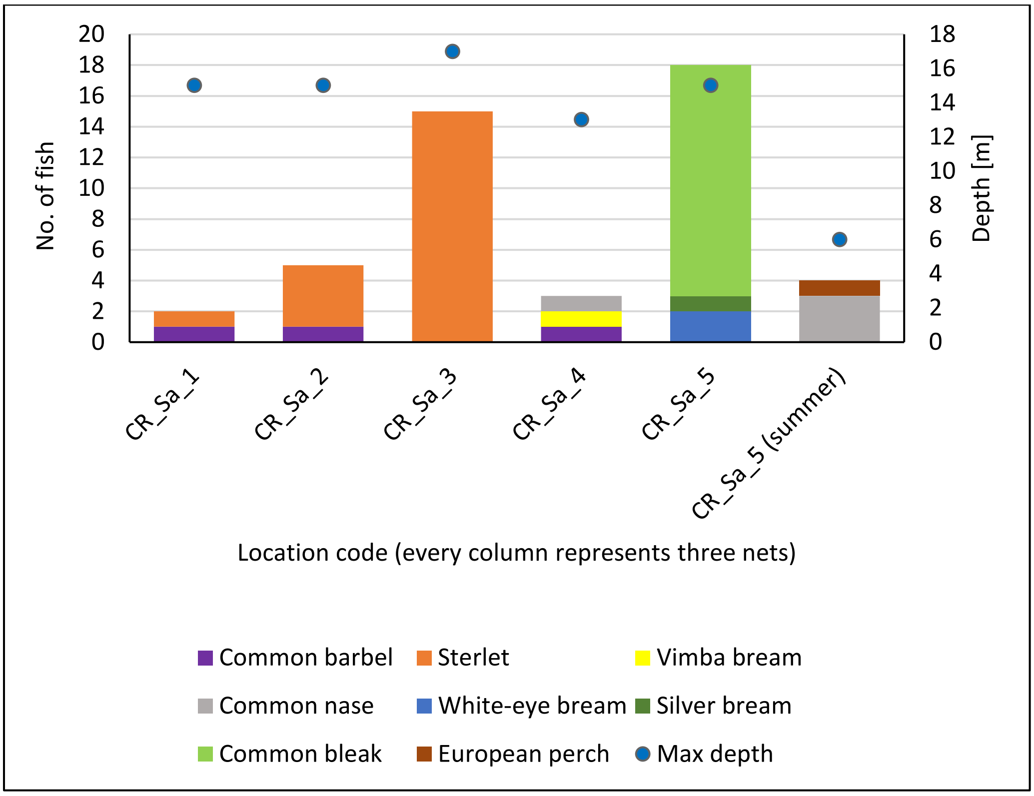

Fig.2: Number of fish caught on the Sava River (Croatia) using fish fixed nets on potential wintering habitats based on the location depth.

4. Conclusion

Survey is not conclusive enough to determine which method would be the best fit for the scientific survey of sterlet habitat use on rivers in Slovenia, since their densities are too low to detect even with targeted methods. As most other fish during the summer, sterlet actively search for food and migrate from one feeding habitat to the other. With low numbers of sterlets in the river, scarce historical data and a generalist diet, it is almost impossible to predict which feeding habitat to survey. Using passive methods, such as longlines, lowers the possibility to catch the fish, but unlike some active methods, such as electrofishing, longlines cause no harm to non-target fish species (smaller and herbivorous fish).

Wintering habitats are less frequent in rivers and their quality can be determined by water flow, depth and boat accessibility.

For the active visual census method, the survey effort is too large to enable a river wide sampling of all potential wintering habitats. The results are therefore incomplete, only quantitative and less informative. However, the by-product of this kind of sampling is an educational video which has an important role, enabling the general public to connect with and understand the underwater world of their local rivers. This cannot be achieved with most other scientific survey methods. Most success with fish sampling was achieved using the passive method of fixed trammel nets. In Slovenia 3 target fish species were detected and Croatian team, using the same adjustments of the method, caught 4 target fish species, including sterlets. Since movement of fish is slowed in winter, fish did not strongly entangle in the net so all the fish in the survey also survived. With a relatively large mesh size a smaller, non-target fish species were prevented from entangling in the net.

The pressure to regulate the riverbanks is less prominent on the Croatian side of both rivers and consequently greater quality of habitats and fish diversity is preserved there (Potočnik et al. 2020). Numerous regulations, narrowing and straightening of the river channels, elimination of oxbow lakes, side channels and floodplains prevent sterlets from spawning, feeding and overwintering in greater numbers in Slovenian rivers, so additional long-term surveys are needed to confirm their presence. Modern methods in future surveys, such as eDNA and especially telemetry are proposed. Schenekar et al. (2020) could not confirm sterlets in the Volga River with eDNA, due to the potential low number of fish as well as small water samples. Since the numbers of sterlets in Slovenian rivers are also low, telemetry would be a more successful method. Nevertheless, a telemetry survey should also be accompanied by river renaturation measures and establishment of a sterlet hatchery, to help us conserve and bolster the almost extinct sterlet population in Slovenian rivers.

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Determining high quality landscapes in support of environmental planning at local and community level

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1. Introduction

In all situations and sites, whether global or local, there is an uneasy balance to strike between the continued stability of natural systems and the welfare of communities who depend, directly or indirectly, on the exploitation of resources. Environmental problems cannot be solved only by technical knowledge and statutory procedures alone, and the planners must be crucially aware of the broader political, social and cultural structures which influence their ability to respond. As a general principle, economic and community development must work within the constraints set by biophysical systems. The interpretation of thus differ in the world, between developed and developing countries, but within the context of highly modified European countries with variety of economic development, natural resources and culture it is helpful to distinguish between main levels of sustainability, such as:

- Productive sustainability- refers to the use of an area‘s natural resources;
- Aesthetes sustainability- refers to the maintenance of an area’s natural and cultural heritage;
- Socio-economic sustainability - refers to the establishment of an economically viable community within the area.

Thus, to halt environmental deterioration in Europe, the government departments, environmental protection bodies and local authorities need to work together and with the wider community, to implement an agreed biological and landscape diversity strategy and be prepared to target efforts which is complicated and time consuming process. It is particularly valid for areas with natural heritage and beauty, where part of natural areas with prime biodiversity should be targeted for priority action both on national and international level (Nowicki at al. 1996). When there is need for the decision-makers, practitioners, investors to document the impact and effectiveness of a range of management strategies, environmental change and effect over the landscapes have to be investigated. In the UK for the evaluation of natural heritage in rural areas there is a long lasting experience in application of two levels of analyses – the first related to assessment of practical achievements and second the extent to which the investment projects were able to foster and encouraged momentum for conservation (Countryside commission 1984).

In relation to regional development and management of the nature reserves and landscapes requires set up of several objectives:

- Encouraging measures designed to conserve and protect existing landscape features and wildlife habitats on private and publicly owned-land.
- Establishment of new landscape features on private and publicly owned-land;
- Promotion a wider appreciation of the need of to take action to conserve landscape and wildlife
- Ensuring that institutions, and individuals that want to carry out conservation measures could receive relevant advice and assistance

- Involving voluntary groups, societies and local people in the work for protection the existing landscapes.

The nature of landscapes worthy of selection as protected landscapes is varied from country to country. But there are general ten general principles for selection of protected landscapes, according to the IUCN guide (Lucas 1999), as follows:

- The landscape is a product of harmonious interaction of people and nature;
- The landscape is an outstanding value, beauty and interest;
- The landscape contains elements which contribute to the conservation of nature;
- The landscape preserves the evidence of human history in monuments, buildings and traces of past land-use practices;
- The landscape's continuing use provides living space and livelihood for resident populations;
- The landscape can provide for inspiration, recreation and tourism;
- The landscape offers education on and promotes public understanding of conservation and cultural values;
- The landscape provides opportunities for research;
- The landscape is living model of the sustainable use of the land and natural resources;
- The landscape is large enough to ensure the integrity of the landscape pattern.

Thus, there is an attempts to answer the question can we really place a value on the environment and there is an argument that by using the three environmental valuation factors – provider of resources, habitats and a sink for waste – it is possible to undertake an evaluation and audit to calculate the value of a piece of environment (Coles 1995). The article is in support of the notion that in spite of the fact that in practice this evaluation and valorization it is much more difficult than it sounds because conventional valuation is tied with the market economy and monetary values, environmental valorization is possible by relying on more on subjective values, preferences and is tied with culture, philosophy, experience and preferences.

For the purpose of the paper, the author support well established understanding that Landscape is always be appreciated is of value only it is of some use to the community (Weedle 1969). The article contributes the sustainability arguments which stress the need to view environmental protection and continuing economic growth as mutually compatible activities and not necessary confliction ones. Here it is argued that the actions should be taken where the best of our wildlife and landscape be found and observed prior to development of the management plans on local level. The article will present with a part of the results of landscape assessment of the one of the Nature Parks in Bulgaria (Rila Monastery Nature Park) as a model for evaluation of the landscapes in support of local development and community valorization.

2. Material and methods

2.1 Techniques in landscape planning

There is no single panacea for the regulation of natural resources and different countries have adopted different packages of legislation to address environmental planning. But there is certain common approach recur and type of menu of potential mechanisms, which may be selected according to the nature of the development site in order certain degree of influence be achieved (Selman P. 1992) The list in the menu includes: Education of landowners; Provision of information and advice; Financial incentives and penalties (especially taxes and grants); Restrains on undesirable uses (planning consents); Removal of property rights on open market and Removal of property rights by compulsion (compulsory purchase and nationalization)

The methodology used for the landscape assessment is following a practice when environmental planners select more than one of the listed above mechanisms, and more specifically provision of information and advice, change in property rights and education of landowners. The methodology aims fulfillment of two main tasks: first it gave a more penetrating investigation, providing an objective basis to a specific reasoning about individual values; secondly in recorded the values in such a way that they could be explained and communicated to others. Landscape's' use may be recognized in several ways – it may form the basis of a pleasant built environment or it might be used as a recreational area, or it might be recognized as touristic attraction. It was suggested also that two separate aspects or values must be examined and then combined as a final value. The first aspect is identification of various attributes present in a landscape and the measurement of the extent to which they are present in a landscape, can be used to understand an inherent landscape quality. The second stage is related to measuring the extent to which the landscape is appreciated or utilized is related to the expressed or acknowledged value, understood as acquired value. The acquired value is additional value which landscape acquired as a resource to be exploited. The total measure of landscape value is obtained when these two values are combined to give aggregate value.

The author claimed that the methods to capture and evaluate the natural and cultural values in a way that ensure sustainable development and proper maintenance of their character, preserve their biological diversity and provide the visitor with a distinctive sense of place is urgently needed.

2.1.1 Landscape assessment

The methodology for Rapid Landscape Assessment (Radovanova, Samardjieva 2003) had been done to fill the existing gap of poorly studied impact of the landscape on the human psyche. The case that will be presented was carried out on the territory of Rila Monastery Nature park which was confirmed as valuable reserve by the governmental and regional authorities several times – first time when was declared as first People's Park in Bulgaria, then a National Park and recently as Nature Park. The last designation was with respect to the restitution of private land to the Rila Monastery. Rapid Landscape Assessment (RLA) was developed as part of the USAID – supported Biodiversity Conservation and Economic Growth project for preparing a management plan for the territory being declared a Nature Park. The territory of the park is 25 000 hectares and is laid in Rila Mountain with a unique biological diversity – flora, fauna, landscapes and historic heritage. The ecological assessment was planned in order to support the development of management plan and was an interactive, inter-disciplinary and participatory process, engaging representatives of major stakeholders in the area.

The work started with identification of group of specific indicators preliminary to the field work and observations. The indicators have been included in questionnaires, which were used on both evaluations – on the terrain and in the cabinet. In case of natural landscape evaluation, these indicators characterized particular features of the surface such as: interesting rock formations, vegetation, rare plant and animal species, the presence of tourist attractions and presence of human interactions and infrastructure. Semi-structured questionnaires had been developed about quality of the landscape with questions and indicators for natural landscapes' quality based on basic concepts and principles of landscape planning and valorization of the territory. This approach was seen as a solid base for collection of valuable information which can be used for both the assessment on local level and for the development of local management plans and community development plans.

A small group of landscape architect, forester and sociologist carried out on-site survey and made a 100 photographs which later on have been used for a cabinet evaluation by a bigger group of experts. The group of experts responsible for assessment of natural resources has been carefully selected as respondents in terms of their experience and knowledge. Additional factor for respondents' selection was the test for equal understanding of the terms used. The landscape quality indicators proposed by the author in the questionnaires had been presented to the core group of experts in the area of landscape architecture, forestry, nature conservation, urban planning and design, environmental experts working at local authority, environmental non-for government organization and university

3. Results and discussion

The author argue that environmental planning and management can be successful only in case it is based on gathering of valuable scientific information and preliminary evaluation of the existing resources. Conservation of nature, biodiversity, landscape and cultural heritage is seen as a holistic process that could be successful only by application of co-creative approach. Here part the overall ecological assessment, rapid landscape assessment, will be discussed, such as the landscape evaluation normally is neglected and the importance of quality of the landscapes is often underestimated.

The landscape assessment of the territory was planned for pre-defined purposes of the development of management plan of Rila Monastery Nature Park in two stages, as followed:

Stage A - Assessment of the landscape quality on the terrain. This was the initial stage, started with the selection of landscape quality indicators, such as interesting rock formations; vegetation; rare plant and animal species; presence of tourist attractions; presence of human interactions and infrastructure. The implementation of the terrain assessment of the landscape along specially tracked routes for the site visits, related to the most interesting areas of interest – beautiful views, flora and landscapes. This part of the landscape assessment had been fulfilled by a small group of experts – landscape architect, forest engineer and sociologist. The indicators - picturesque, natural, stable, unique, landscape diversity, typicality, vulnerability, accessibility - had been preliminary identified.

Stage B -Assessment of the landscape quality by using a set of photographs chosen from these made on the terrain evaluation. A number of specially selected photographs characterizing the territory were presented to the group of ten experts from the field of landscape architecture, nature conservation and forestry Assessment of the quality of landscapes according to their individual elements had been evaluated towards indicators - picturesque, natural, stable, unique, landscape diversity, typicality, vulnerability, accessibility. This stage had been fulfilled by a bigger group of experts and representatives of different stakeholders – local authority, NGOs, science, SMS, environmental activists and local people and was done in the cabinet – on the base of sample photos 28 from the total 100 made on the site.

Part of the results of the Stage A assessment, natural landscape of Rila Monastery Nature Park is presented as indicative for of the high quality landscape, such as:
1) Almost all the studied landscapes - 84, 8% - are highly picturesque and expressive;
2) Almost all landscapes - 90, 62% - are of high stability and durability;
3) Most of the surveyed landscapes in all the surveyed categories - 84, 37% - are evaluated as highly natural and well preserved;
4) Most of the landscapes - 81.5% - have a high degree of originality and uniqueness.

Taking into account the assessments on both stages A and Stage B, the complex evaluation of the quality of the landscapes investigated had been made. Landscapes had been grouped in three groups, according to their quality
– Category I. Landscapes with very high quality;
Category II. Landscapes with high quality and
Category III Landscapes with average quality.

The results show that more about half of the territory of the park (53,2%) has very high quality (Photo 1. Ribni ezera lake (Fish Lakes) and Photo 2. Protected flora. These are examples of the of unique beauty of sub-alpine lake and meadows with a different view to the surrounding tops located in the territory of the Rila Monastery Nature Park. About one third (28,1 %) are included in the second category such as evaluate with high potential in terms of quality (Photo 3. View from Kirilova poljana to the tops (Kiril's meadow) and Photo 4. Barbecue site near Ilijna River). These places are within the most often visited places in the park and represents fragile sensitive ecosystems because of tourist impact. Relatively small part of the area – 18,7% - possess to the third category with average quality landscapes (Photo 5.Tiha Rila (Silent Rila) and Photo 6. Neglected tourist site near Tiha Rila). Theese are nice landscape, but already affected by tourist impact and with eglected infrastructure available.


Examples from Category I. Photo 1. Ribni ezera lake (Fish Lakes) and Photo 2. Protected flora


Examples for Category II. Photo 3. View from Kirilova poljana to the tops (Kiril's meadow) and Photo 4. Barbecue site near Ilijna River


Examples from Category III. Photo 5. Most visited places in Tiha Rila (Silent Rila) and Photo 6. Neglected touristic place

4. Conclusion

Improving, exploting the existing landscapes and employing the new land uses in a cost effective manner, requires deep knowledge about the qulaity of the landscapes. The outhor support the idea that only healthy ecosystems with rich bio-diversity can provide renewable resources for both nature preservation and local community development. The high quality landscapes are inevitably important part of the management plans on local and community level and that is why the assessment of the quality of landscapes is crucial. Not surprisingly, almost whole territory of the Nature Park "Rila Monastery" is covered by beautiful and highly impressive landscapes with magnificent views towards the tops of the mountain, rivers lakes, flora and fauna. Thus, the precise determination in quality would be very helpful for management purposes and for effective land use and identification of touristic routes.

Lessons learned achieved in the case presented could be seen in two aspects: first aspect was related to the importance of pre-defined indicators related to the needs for land use. Second aspect is that the method undertaken by expert's leader approach with the presence of a person to offer and to provide help and advice on conservation work is very important for the suucess of every management plan. The methodology and results presented is as a good practice for collaborative work between professionals within a multidisciplinary team as a way for collection of valuable scientific information about quality of natural amenities. The case is also an good example for a tool designed to be applied in relatively short time, by testing specific criteria, according not only to the physical characteristics of the landscapes in nature, but also by assessing quality of landscapes according to socio-psychological impact of the landscapes on the respondents.

The approach for Rapid Landscape Assresment (RLA) undertaken is prove to be valid for collectuon for up to date valuable information on site and could be applied in different naturar sites, river beds, rural or urban areas. This is an necessary and mportant step in further towards need of zoning, planning and development of management plan for the purpose of both conservation and use of a high quality natural land. Local development and community valorization near the nature parks or along the water bodies and rivers like Danube River is possible, if it is based on solid knowledge, understanding, evaluation and appreciation of the quality of resources available.

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Hydrological indicators of the riverbed incision along the free-flowing Danube River reach from Budapest to Slankamen relevant for the lateral connectivity between the river channel and floodplains

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Abstract

Hydrological regime plays a primary role in the sustainable management of floodplains, as floodplain ecosystem dynamics and balance are largely dependent on the dynamics of the flow regime of rivers. In the 1980's a drying process of floodplains on the lower Danube reach in Hungary became evident while in the 2000s continuous unimpeded water supply of the main canal network in the Danube-Tisza-Danube water supply and drainage canal system became an alarming problem. In view of these problems, the present analysis aims at: 1) recognising hydrological indicators of the incision and/or aggradation of the riverbed, 2) estimating the extent of these processes and the rate of change of the riverbed in time based on these indicators, as well as 3) estimating possible consequent changes in the frequency of extremities. The study has shown that the lateral connectivity is at risk along the whole reach as the deepening of the riverbed still continues and according to some parameters (e.g. the gradient of decrease of mean water levels) is even increasing.

1. Introduction

The motivation for this analysis stems from the observed drying of the floodplain forests along the Hungarian reach of the Danube River that became evident in the late 1980ies and problems in water supply of the main canal network in the Danube-Tisza-Danube canal system in Serbia in the last two decades. Since the floodplain ecosystem dynamics and balance are strongly related to the dynamics of the flow regime of a river, the causes of the drying process of Hungarian floodplain forests (Zsuffa 1993) were sought through the comprehensive hydrological statistical analyses (Kalocsa 1992) published first in Kalocsa and Zsuffa (1997). All these statistical analyses indicated the lowering of the water levels in the active channel of the Danube River, which was explained by the incision of the riverbed. River training works and dredging were recognized as the main reason for the incision.

To the authors' knowledge, no comprehensive analysis of the changes in the water regime for the entire alluvial reach of the middle Danube has been made to date. To fill this gap, authors analyse available time series of the water level and discharge data for the free-flowing alluvial reach of the Danube River. The investigated reach is more than 300 km long, and spans from rkm 1581 in Dunaújváros, Hungary to rkm 1255 in Novi Sad, Serbia.

Fig. 1: Map of the free-flowing alluvial reach of the Danube River with the locations of GSs and main nature reserve Danube floodplains

The overall aims of this study are expected to reveal the causes of the disruptions in lateral connectivity between floodplains and the main river channel.

2. Statistical analyses

2.1 Data and software

Statistical analyses were performed by using time series of water levels and discharges in the 70 years long period between 1950 and 2019. The official water level and discharge data of the Hungarian Hydrological Forecasting Service and the Republic Hydrometeorological Service of Serbia for 5 gauging stations (GS) on the free flowing alluvial reach in each country were analysed. These are: Dunaújváros (rkm 1581), Dunaföldvár (rkm 1560), Paks (rkm 1531), Baja (rkm 1479) and Mohács (rkm 1447) in Hungary, and Bezdan (rkm 1425), Apatin (rkm 1402), Bogojevo (rkm 1367), Bačka Palanka (rkm 1299), and Novi Sad (rkm 1255) in Serbia. The annual extremes and means were used to analyse trends in change of minima, means and maxima, while the daily data from GS at Baja and Apatin in the same period were used to analyse trends in change of occurrence frequency of extremities. More precisely, the eventual changes of the inundation frequencies of the protected floodplain areas have been determined

On the Hungarian part of the investigated reach, there is the Gemenc Region of the Danube Drava National Park near Baja, most of it is a floodplain. Similarly, Kopački rit and Gornje podunavlje Nature Reserves in Croatia and Serbia respectively are in the Apatin region. All three areas are a part of the Mura-Drava-Danube Biosphere Reserve and they are protected on the national level in the three countries (Hungary, Serbia and Croatia) (Fig. 1). Parts of these areas belong to the Natura 2000 Network as well, and they are listed as wetlands of International Importance under the Ramsar Convention. Threshold levels for inundation of the Gemenc floodplain, Gornje podunavlje and Kopački rit were taken from Tamás & Kalocsa 2020, the Official Gazette of Serbia, and Tadić et al. 2014, respectively. Annual discharge data were analysed for GS at Baja, Bezdan and Bogojevo.

For data organization and trend analyses, MS Excel was used. Further statistical analyses were performed using XLStat (Addinsoft 2021) as well as U.S. Army Corps of Engineers Hydrologic Engineering Center’s (HEC) Statistical Software Package (HEC-SSP).

2.2 Analysis methods

Since extensive river training works were performed along the studied reach to facilitate navigation along the Rhine–Main–Danube corridor, the statistical analysis started with testing of the homogeneity of annual time series of minima, means and maxima for all stations. The Kolmogorov-Smirnov test was used. The testing was performed using XLStat (Addinsoft 2021). This was followed by the distribution fitting analysis that was carried out in the HEC-SSP. All trend analyses of the annual values were done using a linear regression with LSQ method in MSExcel*.* The same software was used for further analyses, which included the investigation of the exceeding frequencies of the inundation thresholds of the protected floodplain areas along the reach, and the analysis of average water level changes.

3. Results and discussion

As already mentioned, it was necessary to test homogeneity of time series first. The homogeneity test was performed for the confidence level $\alpha = 0.05$. Test results for water levels are presented in Table 1. It is readily noticeable that the homogeneity of the time series is seriously affected along the entire reach except at Novi Sad, where the backwater effects of the Iron Gate I HPP start to play a role in the shaping of water levels, especially during low water flow (Babić-Mladenović et al. 2013).

The causes of the inhomogeneity are:

1) river training works, especially numerous cutoffs along the Hungarian stretch, which shortened the reach, changed energy balance and sediment transport capacities,
2) the extensive dredging activities in Hungary in the second half of the 20th century (Tamás 2006) and
3) 69 upstream reservoirs, which were built between 1950 and 1980 (Habersack et al. 2016).

All these activities led to a significant sediment deficit and morphological changes of the riverbed that affected the homogeneity.

Annual minima are the most affected as they have the greatest *D*- and the smallest *p*-values (Table 1). Between GS at Dunaújváros and Paks, where the mentioned extensive dredging activities were carried out, the *p*-values are not traceable/detectable (they are < 0.0001). What is interesting is that the time series of annual maxima are homogeneous almost along the entire reach, except at Dunaújváros, presumably because the effects of the regressive erosion are persistent.

Kolmogorov-Smirnov test for the distribution fitting has shown that all annual data - minima, means and maxima fit Pearson III distribution the best. The test was conducted with $\alpha = 0.05$. Due to limited space, values of Pearson III statistics and Kolmogorov-Smirnov test statistics are presented in Table 2 only for four GS that are relevant for the assessment of the connectivity of the floodplains with the main river (Table 2).

Time series of annual minimum, mean and maximum water levels for the 70 years long period between 1950 and 2019 (Fig. 2) clearly indicate that the observed decreasing trend of annual minimum and mean values on the Hungarian reach (Kalocsa 1992, Kalocsa & Zsuffa, 1997 and Goda et al., 2007) continued (Fig. 2). Savić and Bezdan (2009) observed also the decreasing trend on the Serbian section at the Bezdan GS. Time series in Fig. 2 show that this trend exists along the entire length of the free-flowing middle Danube reach, except for annual minima at Novi Sad where Danube enters the Iron Gate reservoir.

The most prominent decreasing trend is at the upstream part of the reach from Dunaújváros to Paks where the bed material changes from the fine gravel to the coarse sand. It exists for both annual extremes and the means. The decrease reduces for minima and means along the sand-bed alluvial reach starting from Baja GS. However, gradients for maxima do not show this regular behavior. It is interesting to notice that the annual mean water levels exhibit the fastest decrease (compare "a" columns in Table 3 and all three graphs in Fig. 2). Since the annual minimum, mean and maximum discharges show no trend – they are constant, or almost constant (parallel to the time axis, see Fig 3), the continuous lowering of the annual water levels can be explained by the incision of the riverbed.

Table 1: Results of the homogeneity testing, a = 0.05

Gauging Station	Minima			Means			Maxima		
	D-value	*p*-value	can be considered homo geneous	*D*-value	*p*-value	can be considered homo geneous	*D*-value	*p*-value	can be considered homo geneous
Dunaújváros	1.000	< 0.0001	NO	0.943	< 0.0001	NO	0.343	0.033	NO
Dunaföldvár	0.971	< 0.0001	NO	0.857	< 0.0001	NO	0.257	0.197	YES
Paks	0.714	< 0.0001	NO	0.543	< 0.0001	NO	0.159	0.837	YES
Baja	0.457	0.001	NO	0.400	0.007	NO	0.114	0.976	YES
Mohács	0.457	0.001	NO	0.429	0.003	NO	0.086	1.000	YES
Bezdán	0.371	0.016	NO	0.371	0.016	NO	0.114	0.976	YES
Apatin	0.429	0.003	NO	0.371	0.016	NO	0.114	0.976	YES
Bogojevo	0.429	0.003	NO	0.429	0.003	NO	0.171	0.683	YES
Bačka Palanka	0.257	0.255	YES	0.357	0.038	NO	0.121	0.976	YES
Novi Sad	0.229	0,320	YES	0,171	0.683	YES	0.114	0.976	YES

Table 2: Pearson III distribution statistics and Kolmogorov-Smirnov test statistic for distribution fitting

Gauging Station	Minima				Means				Maxima			
	Mean	StDv	Skew	K-S test stat.	Mean	StDv	Skew	K-S test stat.	Mean	StDv	Skew	K-S test stat.
Baja	81.70	0.52	0.26	0.078	83.85	0.64	0.51	0.074	87.64	1.17	0.45	0.058
Mohács	80.17	0.50	0.19	0.066	82.32	0.65	0.40	0.082	85.90	1.10	0.39	0.069
Apatin	79.46	0.50	0.32	0.054	81.67	0.62	0.43	0.059	84.89	0.97	0.43	0.056
Bogojevo	78.01	0.47	0.32	0.059	80.03	0.61	0.47	0.077	83.05	1.13	0.26	0.053

Table 3: Minima, means and maxima trends Z = a YEAR + b*

Gauging Station	Minima			Means			Maxima		
	a	b	R^2	a	b	R^2	a	b	R^2
Dunaújváros	-0.0254	140.42	0.77	-0.0270	145.13	0.68	-0.0105	115.42	0.03
Dunaföldvár	-0.0385	164.30	0.81	-0.0370	162.98	0.75	-0.0208	134.04	0.09
Paks	-0.0210	126.83	0.58	-0.0223	131.30	0.39	-0.0149	120.38	0.05
Baja	-0.0129	107.35	0.27	-0.0156	114.80	0.24	-0.0070	101.45	0.01
Mohács	-0.0110	102.02	0.21	-0.0183	118.54	0.23	-0.0112	107.98	0.03
Bezdán	-0.0105	101.56	0.20	-0.0139	110.45	0.21	-0.0020	90.39	0.00.
Apatin	-0.0101	99.56	0.17	-0.0131	107.58	0.18	-0.0006	86.11	0.00
Bogojevo	-0.0090	95.97	0.15	-0.0140	107.84	0.22	-0.0079	98.66	0.02
Bačka Palanka	-0.0026	79.83	0.02	-0.0082	92.80	0.11	-0.0016	82.27	0.00
Novi Sad	0.0051	62.06	0.06	-0.0049	83.98	0.04	-0.0009	78.73	0.00

Further statistical analysis included study of the multi-annual averages of minimum and mean water levels. The 10 year averaging period provided the best insight into the incision dynamics (Fig. 4). During the first decade after World War II (1950-59) either no changes (in the upstream reach with numerous cutoffs) or the increase in minimum and mean water levels (in the downstream sand bed reach) was observed. This could be explained by the fact that there were no river training works during the War. The post War growth of economy required better flood protection and the improvement of the water and ice conveyance as well as the navigability along the Danube River became an issue. This intensified river training works on both Hungarian and Serbian sections, which promoted continuation of temporarily stopped decrease in water levels. This is in line with the results of 15-years averaging by Kalocsa & Zsuffa, 1997 and Goda et al., 2007 on the Hungarian reach.

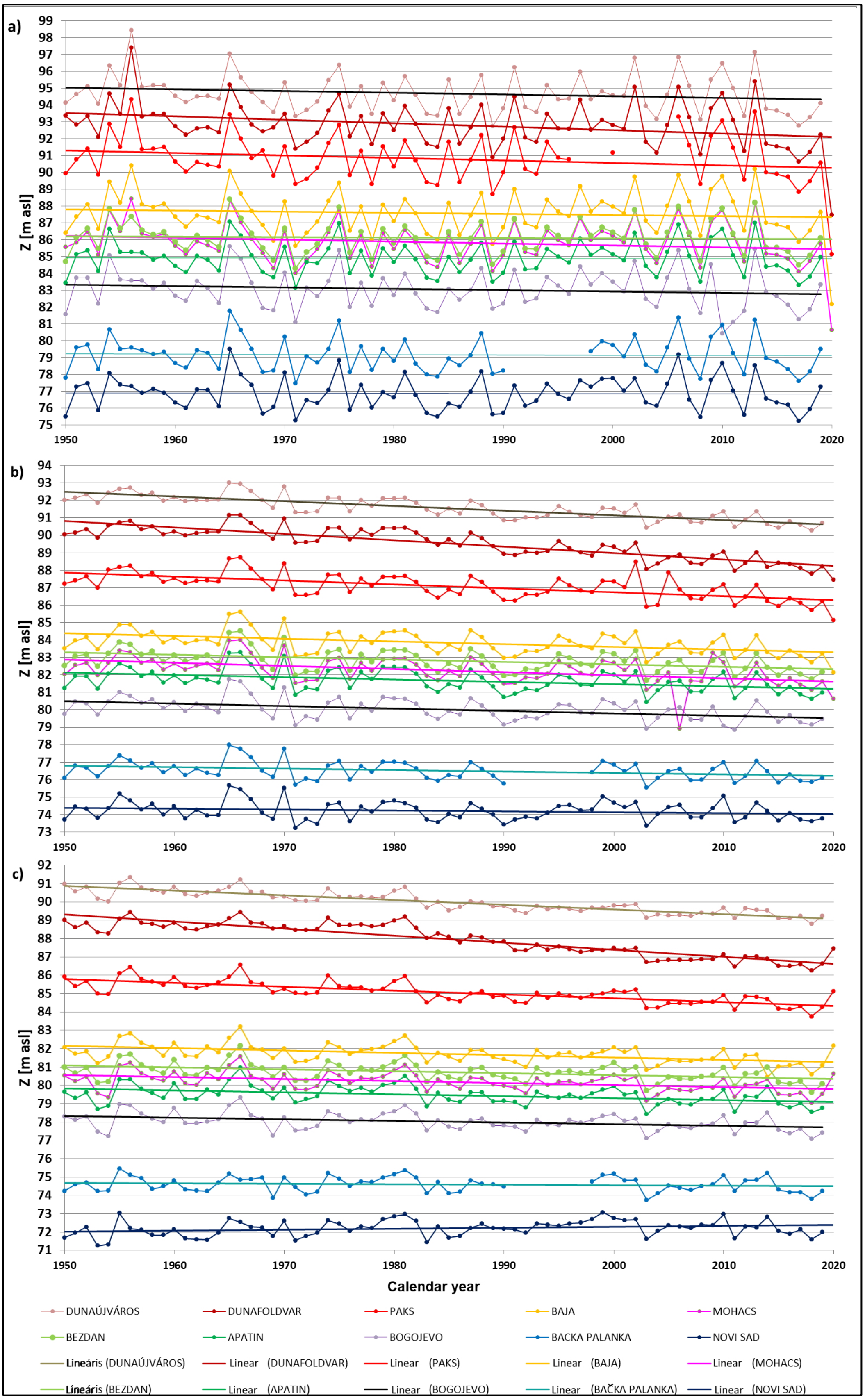

Fig. 2: Annual a) maximum, b) mean and c) minimum water levels with linear trends

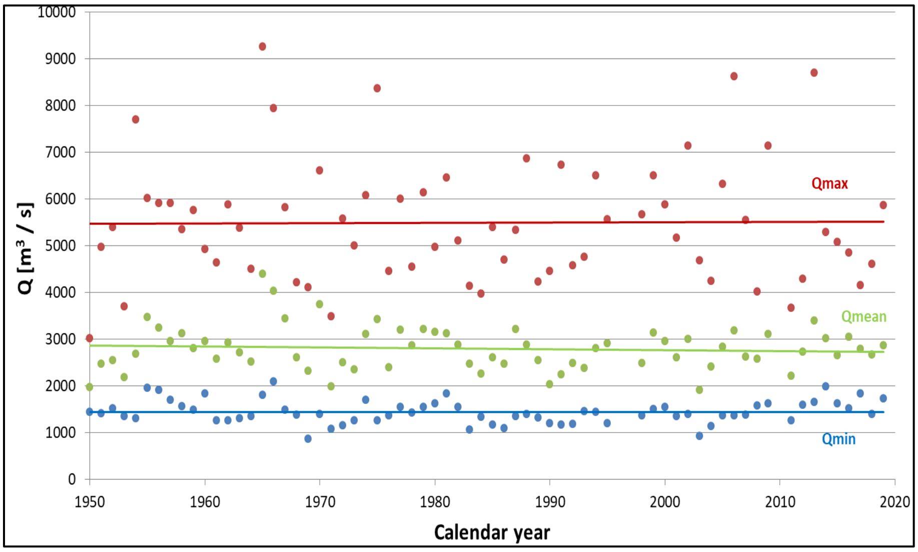

Fig. 3: Discharge minima, means and maxima at Bogojevo

Similarly to Mohács, the minimum water levels in the Serbian reach were lowering at an almost constant rate from Bezdan to Bogojevo. Changes were almost stable at Bačka Palanka, while the increasing water levels in Novi Sad started to decrease in the last two decades. Unlike minimum levels, which exhibit almost steady decrease, the mean levels manifest gradient steepening in the last decade.

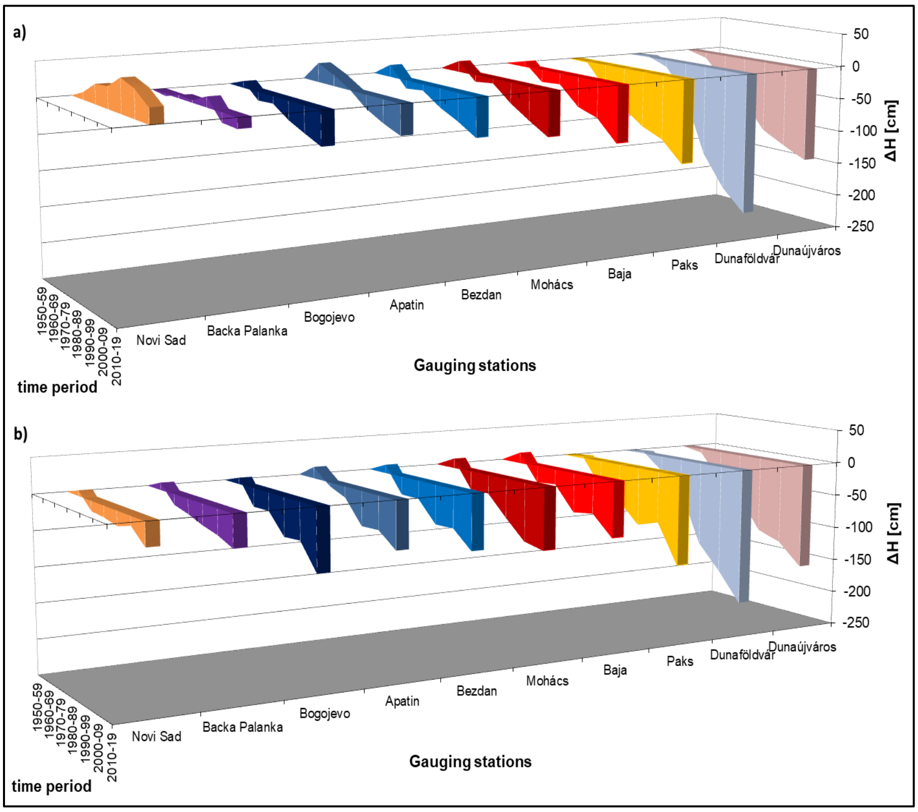

Fig. 4: Changes of a) annual minimum and b) annual mean water levels, 10-years averages

The effect of changes in the riverbed (of the active river channel) on the lateral connectivity can be best described by the changes in frequencies of the exceedance of threshold levels of inundation of the protected floodplains (Fig. 5) during 70 years.

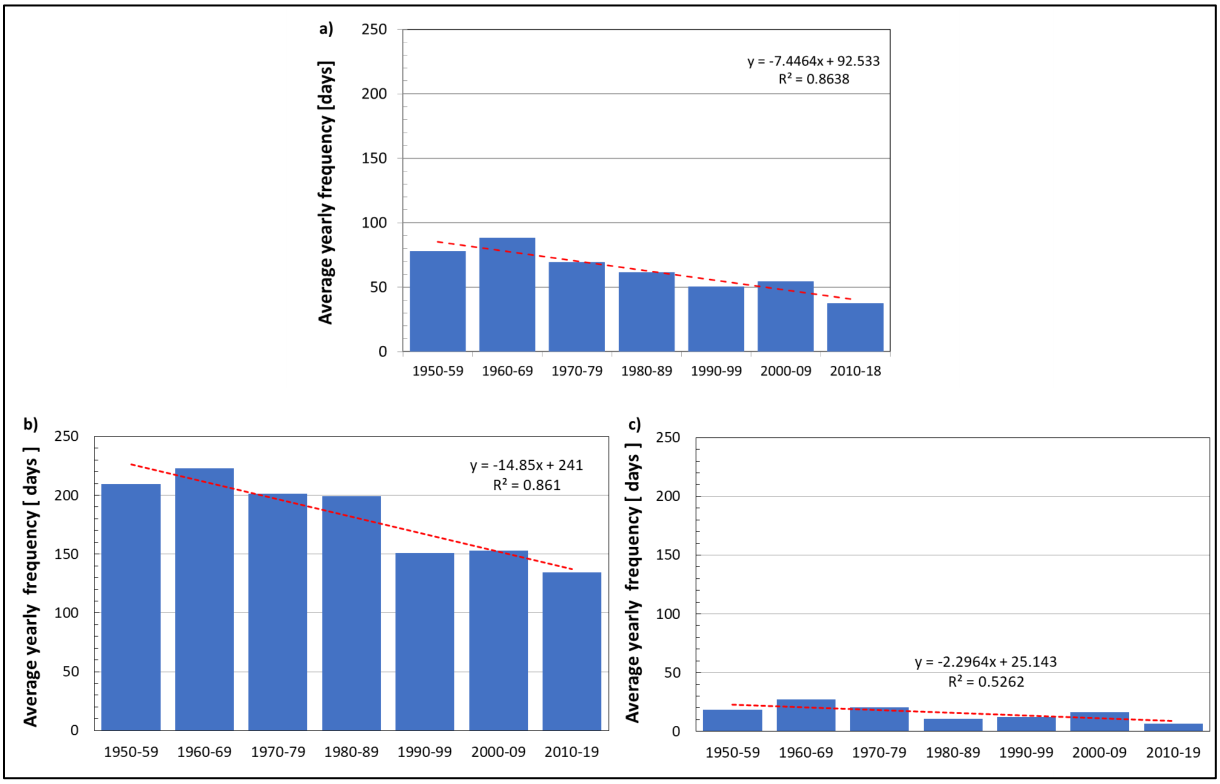

Fig. 5: Ten-years averaged frequencies of inundation threshold exceedance for a) the Gemenc floodplain in Hungary (Z = 85.3 m a.s.l. at Baja), b) Kopački rit in Croatia (Z = 81.5 m a.s.l. at Apatin) and c) Gornje podunavlje in Serbia (Z = 84.5 m a.s.l. at Apatin)

It is readily noticeable that the inundation frequencies most drastically decrease in Kopački rit, which has the lowest inundation threshold elevation among the three investigated protected floodplain areas. The inundation is 2 months shorter at the end of the 70-years period than in the beginning, decreasing from over 200 to a yearly average of 134,3 days. In Gemenc, this decrease is on average 1 month from 1950 to 2019, being now only 37 days, also comparable to previous findings: 172 days average inundation of the Gemenc area in the beginning of the 20th century, decreasing at an alarming rate to 58 days at the end of the 20th century (Kalocsa & Tamás 2003). Because of much higher elevations, the inundation frequency of Gornje Podunavlje is considerably lower, not being so much affected by the recent changes, but still decreasing.

4. Conclusion

According to the Water Framework Directive (WFD) the „good status" of the Danube River reach must be achieved. As the river and its floodplains constitute a complex ecological system, this can only be done through the harmonisation of the nature protection aspect reconstruction projects, WFD programmes of measures, flood management measures and navigation development.

If traditional river training activities continue, riverbed erosion will persist or increase in the future, resulting in slow, but continuous drying of floodplains that are very important nature conservation areas. Consequently, the majority of floodplain reconstruction works' effects might become negligible, while navigation problems will remain unsolved.

In the EU Floods Directive, natural flood management is an important issue, with a focus on increasing water retention capacities by e.g. the re-connection of rivers with their floodplains and the restoration of wetlands which can store flood water and help "slow the flow" of flood waters. In this respect, lateral connectivity is one of the most essential issues, as it is for the species inhabiting floodplains and rivers. However, floodplain lateral connectivity is already severed by the decreasing frequency and extent of inundation. The studied hydrological regime is the most important determinant of floodplain habitats.

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New Emphasis on Water Clarity as Socio-Ecological Indicator for Urban Water – a short illustration

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Abstract

Water clarity is quantified for more than 200 years by the visibility of a disk lowered under water. The perspective on water transparency, however, changed since the early days of limnology from being a physical parameter of optical water property to an ecological indicator tracking algal turbidity due to man-made nutrient addition (eutrophication), identifying an overall success of sustained lake restoration in the late 60ies to 80ies or ecosystem health in recent time. Whatever the many different interpretations for good or bad water visibility have been found across the 130-year history in limnology, water transparency today gained new attention since natural assets such as ponds, lakes, floodplain waters, streams or rivers became a popular design element in modern urban planning aimed at human well-being in densely populated cities. Water visibility, also called water transparency, which can be used as criterion for water quality, but ideally should be backed by further ecosystem measurements in aquatic science, is also used to judge the recreational use of blue-green urban spaces by public awareness. In the recent study about oxbow lake Alte Donau in Vienna, we identified critical values of water transparency in view of lake science and human judgment. With lake restoration, the increase of water transparency to 1.5m Secchi depth was accompanied by a trophic shift from eutrophic algal turbidity to mesotrophic condition of macrophyte dominated clear water state. This critical Secchi depth of 1.5m corresponds further to a "littoral lake bottom view" satisfying bathing aesthetics by human perception. A further increase of water transparency to at least 3.5m, however, is found by empirical lake measurements for supporting sustained growth of bottom-dwelling macrophytes (*Chara* species) at the expense of tall growing *Myriophyllum spicatum*. The latter requires underwater cutting as this near surface canopy building macrophyte is causing nuisance for recreational purposes. Thus, a water transparency (Secchi depth > 3.5m) allowing the growth of underwater near-sediment meadows of Charophytes is recommended for stabilizing sustained lake restoration, but exceeds by far the requirements of water transparency that is satisfying people's awareness judging good water quality by bathing aesthetics. We conclude, that water transparency is the only common limnological parameter that the public can use by human perception for assessing water quality or a progress of a lake restoration. A good status of water transparency close to ecosystem reference conditions attracts public awareness to take advantage of various ecosystem

services enhancing well-being in urban life – it thus offers a great opportunity to the public to raise socio-ecological consciousness concerning urban green-blue spaces.

1. Introduction

Man-made ecosystem degradation accelerated in recent decades (Crutzen 2002; Dalby 2016) and became most obvious in urban areas. The Danubian floodplain in Vienna is threatended by simplification of the ecosystem structure (Sanon et al. 2012; Haidvogl et al. 2013; Hohensinner 2019), biodiversity loss (e.g., Funk et al. 2009; Hein et al. 2016), and overusing natural systems for recreation purposes (e.g., Arnberger and Eder 2012). Alte Donau, a former river stretch of the Danube River, is the most well studied urban lake in the capital city of Austria, Vienna. The ecosystem faced drastic changes mainly by losing its natural connectivity from the main river during river regulation from 1868 onward, and further eutrophication from 1987 to 1994 due to the degradation of the riverine landscape into urban areas (Dokulil et al. 2018a) and global warming in recent decades (Teubner et al. 2018a). Early Secchi disc readings for Alte Donau go back to the late 80ies and were measuered under mesotrophic nutrient state conditions, when nutrients were mainly utilzied by dense meadows of bottom-dwelling Chara. The time series of Secchi depths (Donabaum and Riedler 2018) related to algal turbidity and other limnological measures covers up to 32-year study for this urban oxbow lake and is well documented for the whole management measuere period (Dokulil et al. 2018a; Teubner et al. 2020) or for specific short-term observations (e.g. Dokulil and Mayer 1996; Teubner et al. 2003). Water quality shits over time include man-made nutrient enrichment in the late 80ies to early 90ies due to the inclusion of the riverine landscape in the urban area, followed by lake restoration with an ecosystem shift from a nutrient-rich, algal-turbid water body to a nutrient-poor, clear-water macrophyte controlled system. In addition to the ecosystem response due to wax and wane of nutrients, global warming triggered lake penology by an earlier warming in spring, a prolonged warm season promoting thermophilic zooplankton species (Teubner et al. 2018a) but also hampered restoration efforts by decreasing water transparency during the extreme hot season with water temperatures above 21°C (Teubner et al. 2020). The aim of this Alte Donau study is to illustrate new emphasis on water transparency as socio-ecological indicator.

2. Material and methods

Alte Donau is a shallow groundwater seepage lake of 2.5m mean depth (7m maximum lake depth), 1.6km² lake area and 3.8 x 10^6 m^3 lake water volume (Fig. 1). Monthly sampling was the regular scheme throughout the more than two decades of lake observations. Lake morphometry, long-term restauration measures including long-term development of various biota from planktonic ciliates and other microbes to fish, macrophytes and water birds as well as a synthesis about lake restoration are described in detail in Dokulil et al. (2018a). Data treatment concerning nutrients, Secchi depth, phytoplankton (Teubner et al., 2018b), primary production (Dokulil and Kabas, 2018) and impact of climate (Teubner et al. 2018a; Teubner et al. 2020) are documented also in earlier publications. The interpretation of Secchi depth readings by light attenuation profiles is described in Teubner et al. (2020). Among others, it aimed at identifying the depth layers of specific ambient light requirements for photosynthetic domains (phytoplankton and submerged macrophytes), including the depth at 1% (minimum light requirements for phytoplankton growth as euphotic depth), 3% (minimum light requirements for macrophytes as maximum macrophyte colonization depth), and 12% (preferred light requirements for phytoplankton development) of surface ambient light.

3. Results and discussion

Measuring water transparency by disk visibility in the water body goes back to observations in the ocean (and not lakes) in 1815 to estimate the bottom distance in marine and coastal environments for safe navigation (time-line in Fig. 2). Lowering items such as a disk to measure visibility under water was introduced by Von

Kotzebue, while about 50 years later, Secchi (1866) established this method by profound marine experiments, now well known as Secchi depth measurement (Aarup 2002; Vincent and Bertola 2012; Täuscher 2015). According to the time-line in Fig. 2, this first epoch of Secchi depth measurements focused on the optical property of water. Forel (1892, 1893), the founder of the new science branch limnology, introduced Secchi depth reading to lake science (Fig. 2) and also started to understand lakes as ecosystems, meaning that lakes are more than geological shaped holes filled with water.

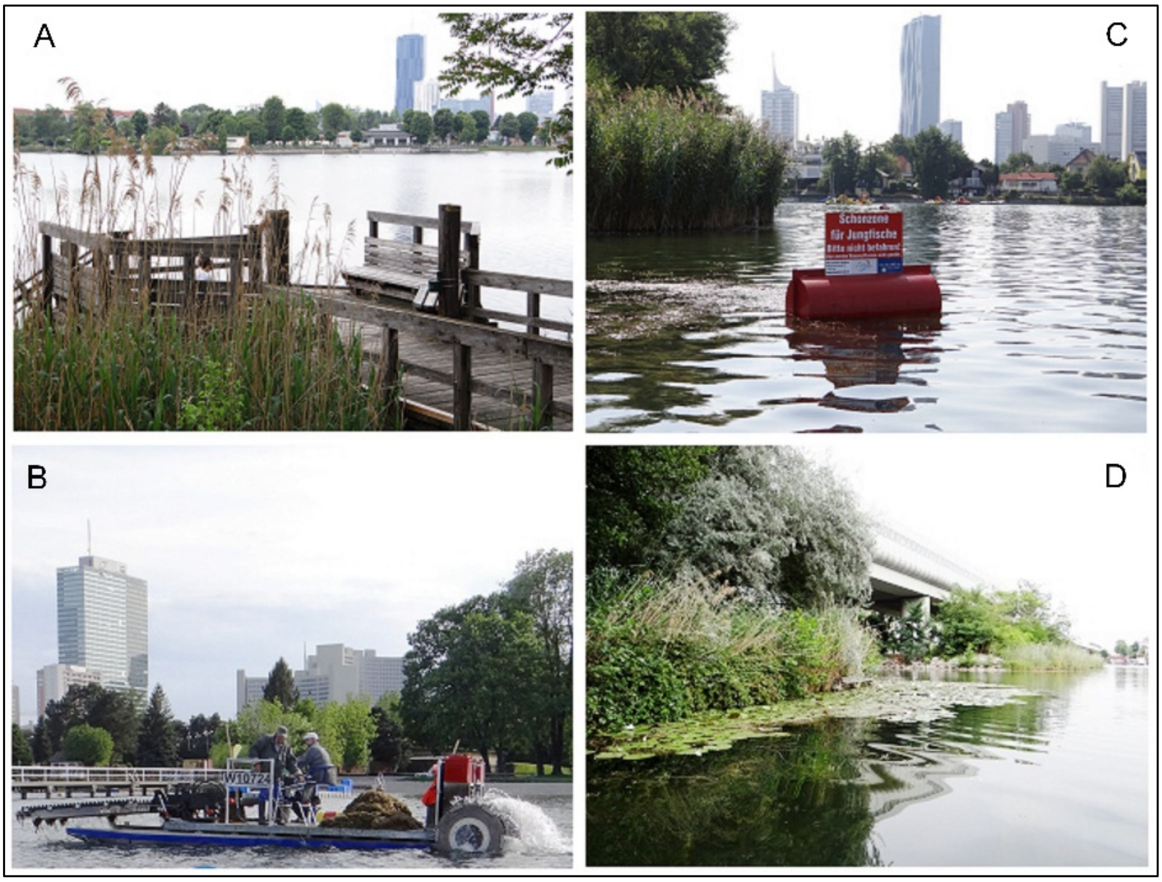

Fig.1: Alte Donau – an urban oxbow lake in the capital city of Austria, Vienna. (A) Reed belt mainly consisting of Phragmites australis and Typha were re-planted on banks. Public wooden bathing platforms give access to the open water for free, providing cultural ecosystem services in this urban recreation area. (B) Boat for managing underwater-macrophyte cutting with harvested "weed", mainly of tall-growing Myriophyllum spicatum. (c) Littoral zone with signs on buoys to stay away respecting nature: "Schonzone für Jungfische. Bitte nicht befahren. Hier werden Wasserpflanzen nicht gemäht." (translation: Protected area for young fish. Please stay away. Aquatic plants are not mowed here." (D) Viaduct of Vienna subway crossing the oxbow lake, (A-D) Photos taken in 2015, source: www.lakeriver.at.

With the eutrophication of lakes, water-clarity went beyond being an optical parameter of lake physics but was also applied in lake biology. Trophic classifications schemes in the late 60ies to 80ies were expanded to link an increasing algal biomass yield by eutrophication (Vollenweider 1968; Carlson 1977; Forsberg and Ryding 1980; Nürnberg 1996) with gradual deterioration of water-clarity. In turn, increasing water-transparency became the key target of lake restoration (e.g. Meijer et al. 1999; Hilt et al. 2006; Søndergaard et al. 2007; Gulati et al. 2008; Dokulil et al. 2018a) - it offered indicating an overall success of lake restoration. In addition, research about photosyntetic yield in lakes became of utmost interest at that time, including measurements of underwater light attenuation and light utilization by photosynthetic plankton (e.g. Harris 1978; compare with photosynthetic measurements for Alte Donau in Dokulil and Kabas 2018). Thus, the second epoch of water transparency measurements focussed on phytoplankton growth, photosynthetic light utilisation building up biomass (Fig. 2).

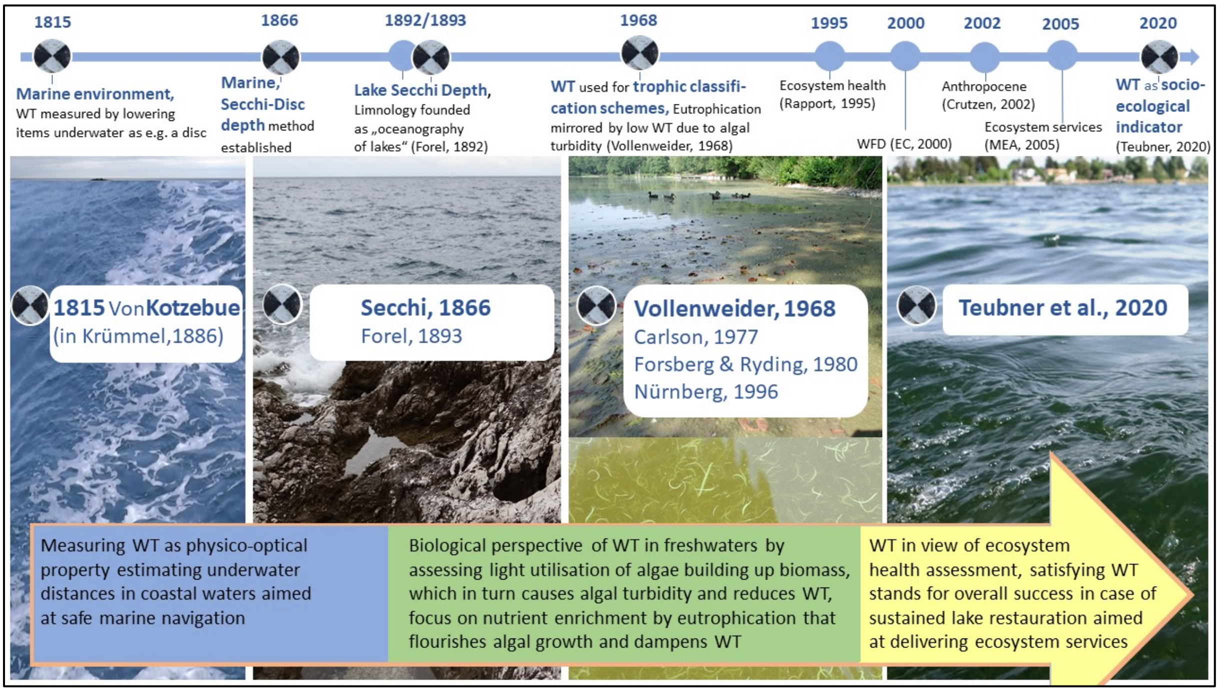

Fig. 2: Time line of identifying water transparency (WT) as physico-optical measure in marine environments in the beginning (WT epoch 1), as key parameter for assessing man-made nutrient enrichment in lakes during eutrophication periods (WT epoch 2), and as socio-ecological indicator in urban waters in recent time (WT epoch 3). Further abbreviations: Water Framework Directive (WFD), European Council (EC), Millennium Ecosystem Assessment (MEA).

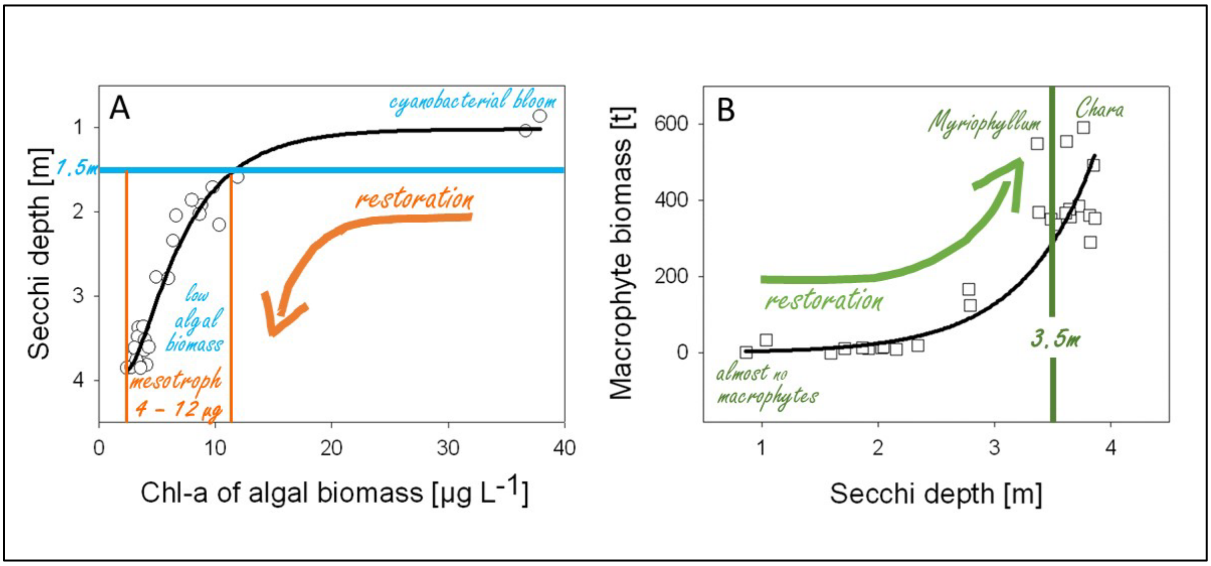

Fig. 3: The different ecological perspectives of water transparency during sustained restoration measures of oxbow lake Alte Donau: Water transparency indicated by Secchi depth (A) as response function of phytoplankton biomass (cyanobacteria and algae), where water turbidity increases with decreasing algal biomass (measured as Chlorophyll-a in µg L^{-1}) and (B) as light utilization factor increasingly stimulating the growth of underwater macrophytes (biomass as dry weight in t for the whole lake). A: High values of phytoplankton biomass during the period of nutrient enrichment, here expressed by the chlorophyll-a (Chl-a) concentration, were mainly built up by Cyanobacteria. Secchi depth below 1.5m coincides with the shift from eutrophic to mesotrophic status (range from 12 to 4µg Chl-a according to ÖNORM M6231 2001, which corresponds to the phytoplankton biovolume ranging from 2.4 to 0.8mm³ L^{-1}, see Fig. 9.10 in Teubner et al. 2018b). A Secchi disk water transparency of 1.5m ("lake bottom view") is judged as good water quality by human perception for bathing aesthetics (Smith et al., 1991). B: The critical threshold of 3.5m Secchi depth stimulating the growth of bottom-dwelling Chara species at the expense of tall-growing Myriophyllum spicatum, exceeds by far the threshold of good water quality by human perception but is most important for sustained restoration (dense stands of M. spicatum with canopy formations near the water surface are nuisance for recreational purposes such as boating or swimming). Water transparency is indicated by annual data of Secchi depth from 1993 to 2019 for A and 1993 to 2018 for B.

The peak of man-made phosphorus enrichment in Alte Donau was 1992-1994 (Donabaum and Riedler 2018; Dokulil et al. 2018b; Teubner et al. 2018b), and thus about 20 years later than the Vollenweider eutrophication study (Vollenweider 1968). The beginning of restoration measures in Alte Donau (initialized by phosphate precipitation in the water column; Donabaum and Dokulil 2018) coincides with the new era of ecosystem approach which went far beyond the algal blooms, namely developing ecosystem assessment strategies to understand ecosystem health (Rapport 1995), defining environmental reference conditions (Water Framework Directive in EC 2000) and in turn to understand the benefit of healthy ecosystems to human well-being by defining ecosystem services (MEA 2005). This new emphasis in applied lake science describes water transparency as socio-ecological indicator (Teubner et al. 2020) and refers to the third epoch interpreting Secchi depth readings (Fig. 2). Here, Secchi depths were not necessarily linked to bottom-up development of phytoplankton biomass or turbidity caused by phytoplankton only (phytoplankton often causes mainly turbidity in lakes as on average the abundance of phytoplankton cells, filaments or colonies is with about 10^6 L^{-1} much higher than those of other planktonic life forms, such as meta-zooplankton reaching on average abundances which are about 4 to 5 orders of magnitude lower, unpublished data; further, B: due to phytoplankton pigments, phytoplankton cells are pre-dominant filters of visible light with only one exception, the green light). The ecological perspective of Secchi depth interpretation can be also linked to the outcome of food web structure (e.g., Qu et al. 2021) (top-down control, identifies the “clearance” in the water column), related to ecosystem functioning in a broader sense. Judgment of water clarity by public perception is further of great importance for communicating the success of restoration or urban planning in modern city life mentioned before and thus underpins the relevance of water clarity also in view of sociological issues.

The two sides of one coin of water clarity, i.e., the two main ecological perspectives of water transparency during sustained restoration measures of oxbow lake Alte Donau are shown in Fig. 3. The graphs are underlying the assumption that lowered phytoplankton biomass (estimated by Chlorophyll-a, which is the ubiquitous pigment in all photosynthetic plankton organisms) in course of eutrophication, reduces light attenuation caused by decreasing algal turbidity and is thus responded by increasing water transparency (Fig. 3A). At the same time, with increasing Secchi depth the macrophyte biomass increases too. Thus, the growth of macrophytes at the expense of phytoplankton is mediated by the increasing light availability into deeper water layers, i.e., higher water transparency (Fig. 3B). A Secchi depth of 1.5m, which refers to minimum requirement of water clarity according to bathing aesthetics, coincides with the transition from a eutrophic state with mainly cyanobacterial blooms (Dokulil and Teubner 2000; Ibelings et al. 2021) to mesotrophic conditions of macrophyte dominated clear-water state. Further control mechanisms of water transparency alongside restoration are not explicitly shown here, but can be expected on the ecosystem level (see chapters 8-16 about biology, ecology and production for Alte Donau in Dokulil at al., 2018a). The control of algal growth is expected to become accomplished not only by shifting the nutrient allocation from algae towards macrophytes, but also e.g. by allopathic substances which are built by macrophytes supressing algal development. Further, macrophyte canopies can provide shelter for zooplankton and thus enhance the grazing effect. The latter both examples might illustrate that an increase of water clarity can also be accomplished on various levels within the ecosystem than just displayed in Fig. 3, but it would be challanging to detangle the different contributions to algal supression quantitatively.

Water transparency is understood as socio-ecological indicator for Alte Donau and thus points in two directions, namely to further ecosystem health (1) and ecosystem services (2) as summarized in Fig. 4. Concerning the ecological perspective, naturally high water clarity can be expected in pristine floodplain ecosystems of high habitat structure and high biodiversity. In turn, high biodiversity contributes to strengthening ecosystem functioning (Meyer et al., 2016), which can be most beneficial for urban floodplains that are threatened under various pressure (Funk et al. 2009; Sanon et al. 2012;

Haidvogl et al. 2013; Borgwardt et al. 2020; Preiner et al. 2020; Reitsema et al. 2020; Weigelhofer et al. 2020; Perosa et al. 2021). Concerning the sociological perspective, enhanced water transparency in Alte Donau attracted human perception to take advantage of ecosystem services enhancing quality-of-life in the city, which in turn increased public awareness of protecting nature in this urban blue-green spaces (see Hozang 2017, 2018; Teubner et al. 2020). Provisioning, regulating and cultural ecosystem services can be delivered as illustrated in Fig. 4 and benefit in many ways from a healthy state of the lake ecosystem indicated by high water clarity.

Fig. 4: Water transparency as socio-ecological indicator with implications for ecosystem health and ecosystem services. Urban waters with naturally high water clarity are close to the high habitat structure and biodiversity of pristine floodplain ecosystem (reference conditions), which in turn strengthens the ecosystem functioning. In addition, a high water clarity attracts human perception about a healthy environment to take advantage of ecosystem services enhancing quality-of-life in the city and in turn increases public awareness of protecting nature in urban blue-green spaces. Provisioning (e.g. harvesting fish), regulating (e.g. improving urban microclimate by evapotranspiration of floodplain ecosystems) and cultural (e.g. manifold recreational use of the oxbow lake) ecosystem services benefit from a healthy state of the ecosystem in many ways. Critical values of Secchi depth (> 1.5m and >3.5m) were derived from fig. 3. Photos from: www.lakeriver.at.

4. Conclusion

In conclusion, water transparency is identified as a key parameter which is important far beyond how we see it in limnology. It is the only parameter that the public can use by human perception for assessing the water quality or the progress of a lake restoration. In turn, a good status of water transparency close to ecosystem reference conditions attracts public awareness to take advantage of various ecosystem services enhancing well-being in urban life. In this view "green-blue" spaces are ranked higher for a better quality-of-life in cities than "green" spaces.

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Floodplain restoration with dyke relocations in the Middle Tisza District, Hungary

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Abstract
The river regulation and dyke construction works were finished on the Hungarian section of the Tisza River in the early 20th century. These measures created a new situation for the Hungarian flood protection. Over time, we had to face with new problems after the river has been situated between the dykes. The major challenges are that the river can only deposit the transported sediment between the embankments and the percentage of floodplain forests has increased tenfold over the last hundred years. These processes reduce the conveyance capacity of the floodplain areas and also increase flood peaks. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the runoff on the floodplain area.

The presentation introduces the current challenges along the Hungarian section of the Tisza River and also focusing on the upcoming climate change induced flood related issues. It presents the characteristics of the Tisza River which are endangered by hydrological extremes. Further aim is to demonstrate the applicability of a two-dimensional hydrodynamic model to study the effects of the dyke relocations. The presentation also introduces the modelling results of the pilot action on the Danube FLOODPLAIN project which is focusing on reducing the flood risk through floodplain restoration along the Danube River and its tributaries.

The Hungarian pilot area is located in the Middle Tisza District. Extreme flood events are often impact this region.

1. Introduction

The river regulation and dyke construction works were finished on the Hungarian section of the Tisza River in the early 20th century. These measures created a new situation for the Hungarian flood protection. Over time, one had to face new problems after the river has been confined between the dykes (Somlyódy 2011). The major challenges are that the river can deposit the transported sediment between the embankments. The other problem is that percentage of floodplain forests has increased tenfold over the last hundred years as a consequence of which morphology and pattern of the watercourse has been changed (Szlávik 2003). One of the largest increases in flood waves is caused by the rise of invasive species, which pose a serious challenge to the water management. The most invasive plant along the Tisza is the Amorpha fruticosa (Csiszár et al. 2013). These processes reduce the conveyance capacity of the floodplain areas and also increase flood peaks. As a result of these processes a lower maximum flood discharge can produce the highest ever measured water level.

Mauser et al. (2018) have studied the potential effects of the climate change on the hydrological cycle. It has been revealed that extreme weather conditions will became more frequent in the near future. This can increase the occurrence of floods and drought periods. This is also confirmed by the fact that several extraordinary floods have occurred on the rivers over the past decades in the Danube River Basin. Each of the flooding levels that emerged centennial flood waves caused significant human and economic damage in 2000 along the Tisza River. Vizi et al. studied the impact of increasing flood peaks caused by climate change, which is further increased by declining conveyance capacity.

The No. 2007/60/EC Directive requires almost all river basin districts to identify areas there is a significant potential flood risk to handle the increasing flood risk along the European Rivers. The identified flood risks are needed to be reduced as much as possible to ensure greater human and economic security. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the conveyance in the floodplain area. The other challenge is to develop a new agricultural and forestry practices related to the use of the landscape to improve the conveyance capacity, while taking into consideration the Water Framework Directive and the maintenance of ecosystem services (GDWM 2018).

The HEC-RAS hydrodynamic modeling software was used to assess the impact of the measurements. It has become an important tool of Hungarian water management in recent years.

2. Material and methods

2.1 Study area

The Tisza is the second most significant river in Hungary. The Tisza's full gradient is 30 m (5 cm/km) in Hungary. Based on the MTDWD's hydrometric data, the minimum discharge of the river is 46.9 m^3/s, and the maximum discharge is 2 610 m^3/s at Szolnok. The long-term average discharge is 532 m^3/s at this river section.

The measurment's site are located in the middle of the Great Hungarian Plain. The area of the floodplain between Kisköre and Szolnok is 9,197 ha, of which 7,440 ha is agriculturally usable area. This river section of the Tisza River is between dikes for more than 100 years. The area represents a well preserved complex of wetlands and forest ecosystems. The floodplains and wetlands of this river section are uniquely valuable ecosystems in global terms, although few areas are still in their natural or near-natural state. Protected floodplain areas provide habitats for endangered species, help to even out flood peaks and reduce flood damage by storing surplus water.

In 1930, the extent of forest was only 591 ha, it had already risen to 2809 ha in the 1960s. The increase in the area of floodplain forest did not stop in the following years, it increased to 3,334 ha in 1980 and reached 5,576 ha by 2014. During the establishment of the forests, it was expected that afforestation would not cause significantly higher sediment deposition, thus not reducing the water absorption capacity of the floodplain. Among alien tree species, the typical plants of floodplains are american ash (Fraxinuspennsylvanica) and green maple (Acernegundo). Among their chick species is the Amorpha fruticosa. These species are a major threat for foresters as the floodplain provides them with optimal living conditions. With their abundant seed yield and fast growth and good germination ability, they make it extremely difficult for native plants to regenerate, and they also increase the roughness of the area, thus forming a run-off barrier in the areas.

The central elements of interventions have been dyke relocations in the last decade. In the Middle Tisza District, 3 dyke relocations have taken place and one (Fokorúpuszta) is still in progress (Fig. 1.).

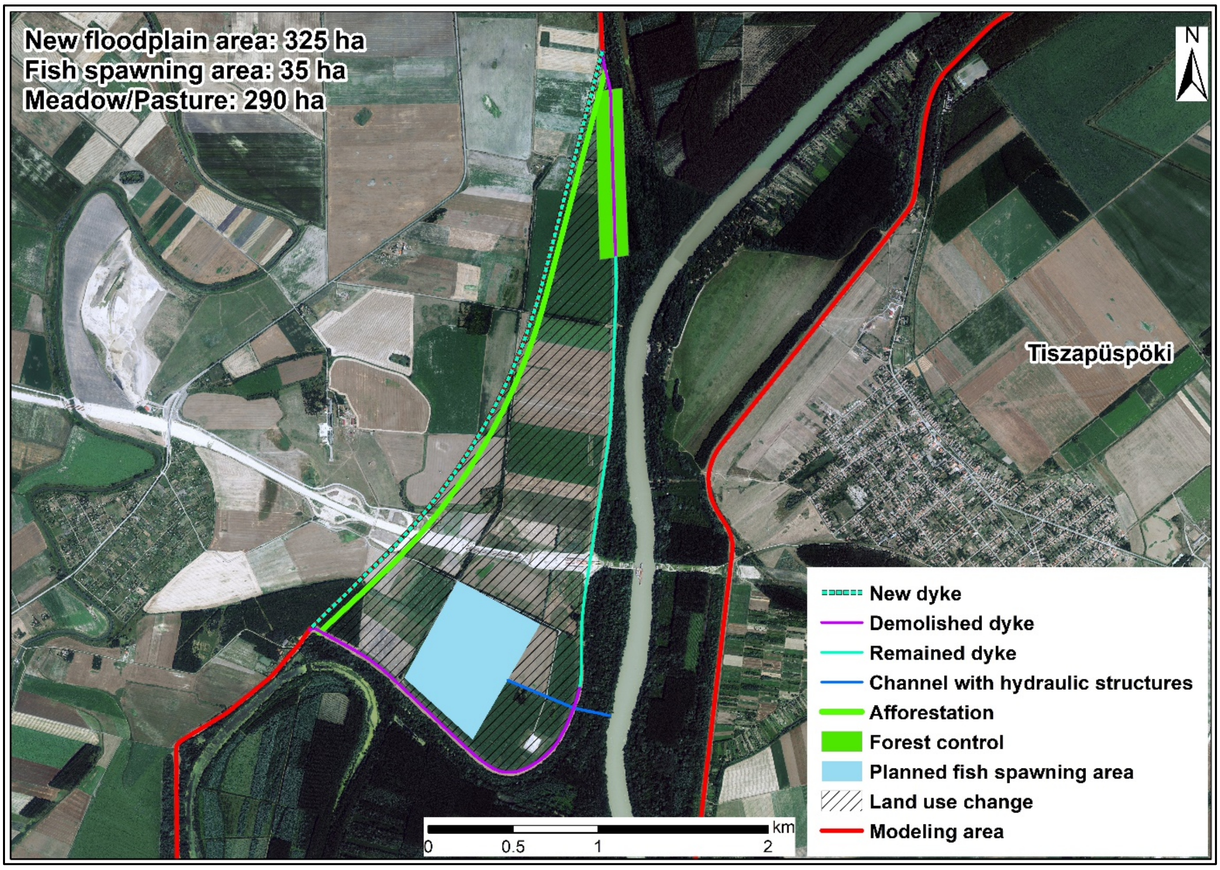

Fig.1: Location of the new dyke relocation near Szolnok

In the area, we tried to identify the optimal restoration measures (dyke relocation, land use change and afforestation technique) which can improve runoff. The approach of an integrated river basin management has a high priority in Hungary. By identifying optimal interventions, flood protection can be brought closer to other water-related sectors. The study areas can serve as a good example at river basin level.

2.2 Hydrodynamic model

The HEC-RAS modelling software was developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The program has been successfully used for one and two dimensional modelling in the United States of America for all major rivers (US Army Corps of Engineers 2016).

The model includes an approx. 160 km long river section of the Tisza from Kisköre (403 river km) to Csongrád (246 river km). The model has two main parts: a 2D mesh between Kisköre and Szolnok, and a 1D river section between Szolnok and Csongrád. That 1D section was needed to have enough space between the pilot site and the downstream boundary. We did not increase the computation time as much with this solution as if we had increased the 2D mesh. The 2D mesh only included the floodplain area between the dykes, so there were no significant settlements in the pilot area.

The dyke relocations was studied in each case. Some different model variants were made to study the dyke relocations. The original state (OS) version does not include any dike relocation and afforestation measure which were done in the last five years. This calibrated base model geometry represents the condition of the river in the early 2000's. We incorporated the new dyke relocation measure into the restored (R1 or R2) versions. Our main aim with R2 to increase the effects of the restoration measures without harming the flood protection. The current state (CS) version already includes the relocations before the Fokorúpuszta dyke relocation (Fig. 2).

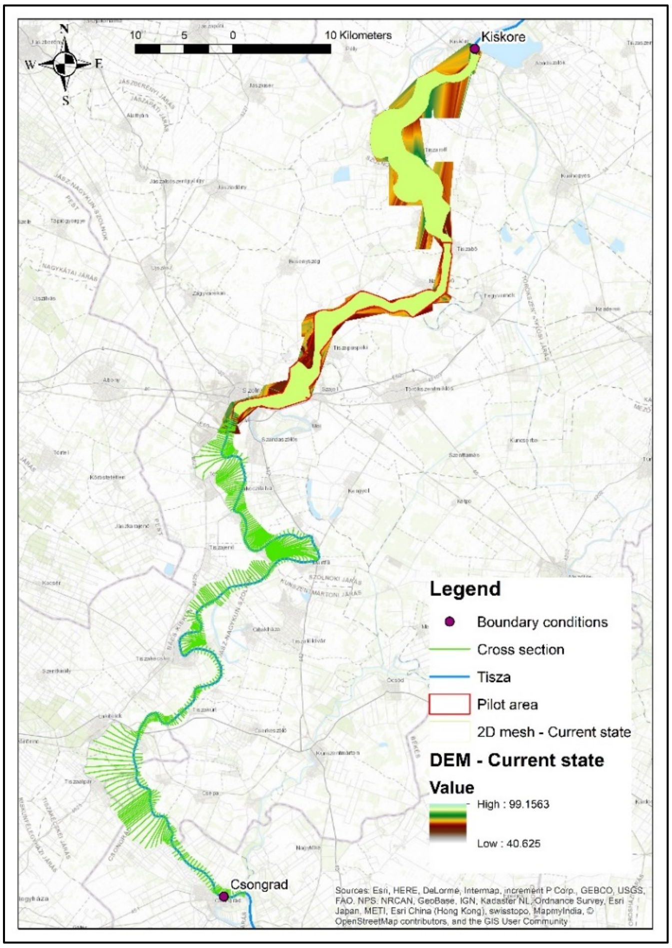

Fig.2: Current state model version

The geometries have a 2D flow area with 25x25 meters wide computation point spacing. The default Manning's value is set during the calibration and validation.

We used real events as a basis of our hydrological data. The MTDWD has made monitoring along the Tisza River. The following events were simulated: HQ2, HQ10, HQ100. Each HQ is based on the same flood wave. We have the official HQ values for Kisköre, which is the upstream boundary condition in the model.

The main challenge was that there was no substantial flood wave since the dyke relocations were finished on the Middle Tisza region. The original state scenario was needed for that purpose. We used the flood wave of 2000 for calibration with an old geometry, representing the characteristic of the early 2000's. This flood wave produced the highest water levels in the Middle Tisza. The calibration of the model was accomplished gradually, starting with the shorter sections (1D and 2D separately). We assembled the individual sections and then performed the river sections. We had 3 calibration station: Tiszaroff, Tiszabő and Martfű. The average difference between the computed and the observed data is 5-10 cm at each control point which was considered as a good result.

3. Results and discussion

The dike relocation created a new situation in the flow conditions. The floodplain can transfer more water, and higher velocity also can be formed compared to the current state (Fig 3). An oxbow lake is also reconnected with this version, which helps to improve the conveyance capacity in the floodplain. An important topic is the management of the invasive species to maintain the adequate flow conditions along the river.

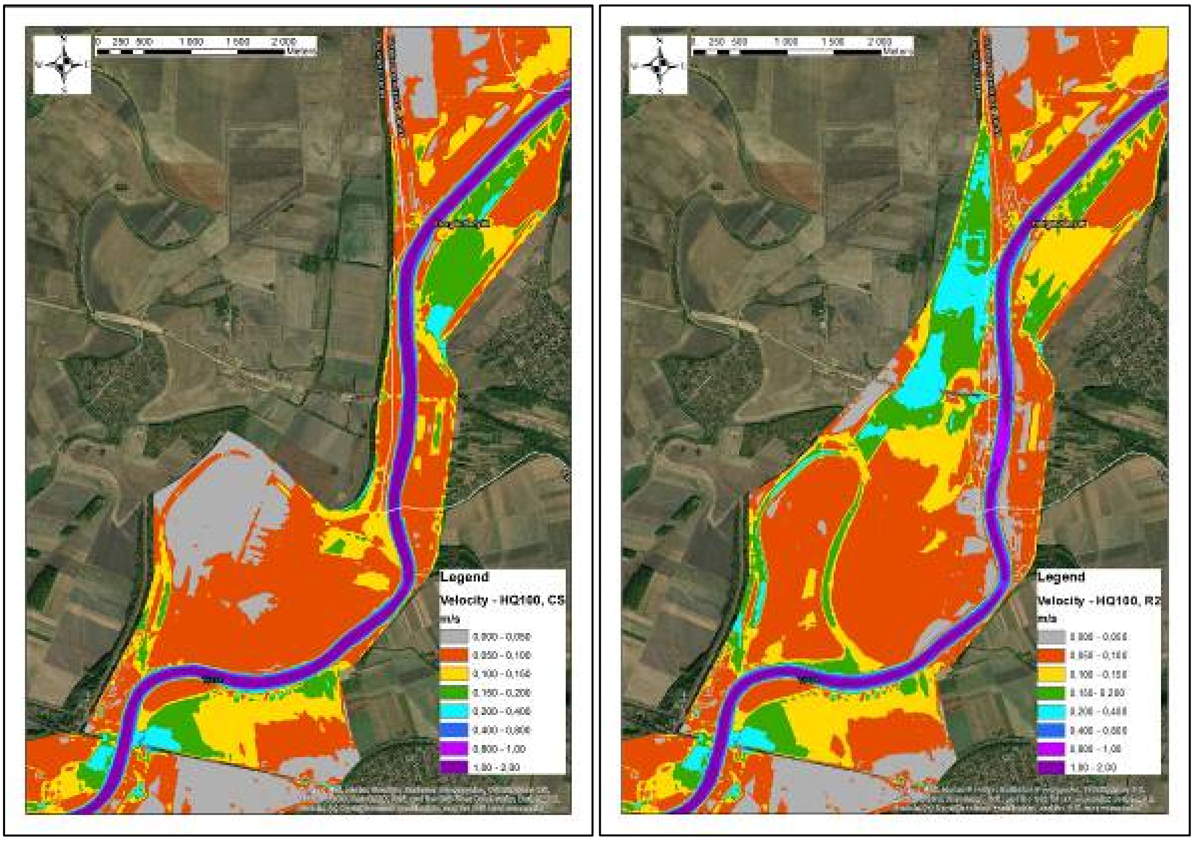

Fig.3: Velocity with CS (left) and R (right) scenarios

The river gained more space with the dike relocation. This can be seen in the water depths formed near the new floodplain area. Examining the HQ100 flood wave, a 5-10 cm water level decreasing occurs with this implementation. Fig. 4 show the water depth with scenario R2

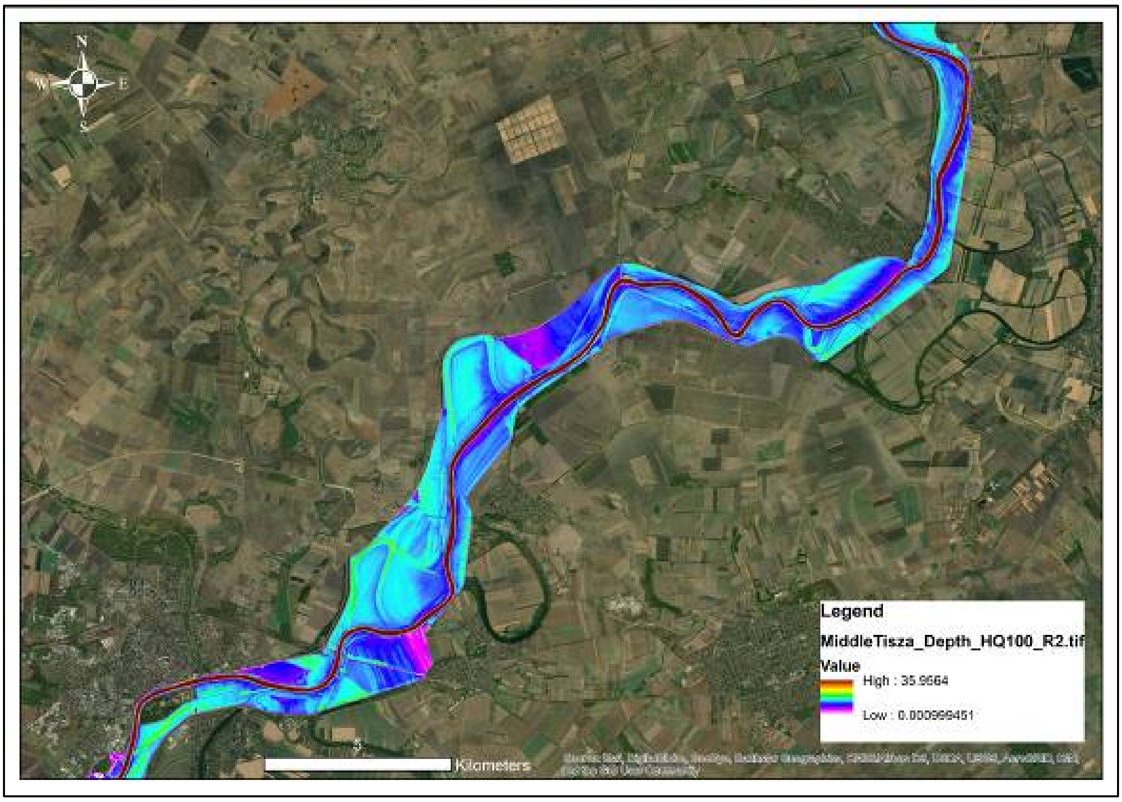

Fig. 4: Water depth for the HQ100 flood wave and the R2 scenario

The initially specified purposes of restoration were partly met: the conveyance capacity and the floodplain area were increased and show the significant effect in flood volume storage. However, the decrease of the flood hazard with the two restoration scenarios only can be considered as a local effect.

4. Conclusion

The flood peaks along the river Tisza have shown an increasing trend over the last decades. The process began during the dyke construction works in the 19th Century. The river was confined in a narrower floodplain area between the dykes. That is the only area where the river can deposit the carried sediment. Due to this process and the increasing size of the dense forest areas, the water conveyance capacity of the floodplain was reduced. In response to these processes, the MTDWD started dyke relocations. The integrated water management practice was also promoted on the new floodplain areas.

In addition to increasing the conveyance capacity, more emphasis was placed on the design of optimal land uses. Primary runoff areas continue to serve the purpose of flood protection in the floodplain with increased conveyance. On the other hand, creating the fish spawning areas were both ecologically and economically beneficial and did not pose any flood risk.

During the pilot study, different measures could be taken into account in determining geometry (e.g. dyke) and land use (forest areas, grassland). The main challenge was to calibrate the model sufficiently. The last significant flood wave was in 2013 along the Tisza. The dyke relocations were finished after this flood wave, so we did not have a new flood wave with the current dyke course to calibrate or validate for the current status. That is why we created an original state version with the old dykes along the pilot area. We could calibrate the model for this version, and compare the new geometries with this.

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Human impact on the Lower Sector of Jiu River Floodplain

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Abstract

The Jiu River Floodplain and the main channel that crosses it (the Jiu River) have undergone important changes over time. These changes were induced by humans in order to "facilitate" their existence. The human stress in the Jiu River Floodplain has targeted: the construction of buildings by expanding settlements (Craiova city – urban sprawl); changes in land use; opening ballast quarries to extract sand and alluvial gravel; tailings (Ișalnița); or raising defensive levées (after every significant flood). All these human-induced changes influenced the geomorphological processes within the river banks and in the floodplain, its biodiversity, and even the nutrient cycle (through agricultural practices, or industrial pollutants of the river).

In this study, I discuss the case of the Lower Sector of Jiu River Floodplain, located in Dolj county, on the left side of the Danube, using Landsat 5 and Sentinel 2 satellite images to detect changes and some statistical data. I also used an unmanned aerial vehicle (Dji Phantom 4 Pro v. 2.0 Drone) to survey the floodplain at a very low altitude to accurately identify those changes. After creating maps, I tried to quantify the human impact within the Jiu River Floodplain through different indices of human pressure.

1. Introduction

The Lower Sector of Jiu River Floodplain is located in Dolj county, South – West of Romania, on the left bank of the Danube (Fig. 1). The floodplain has a length of 95 km, between Filiași and Jiu confluence with the Danube, and a maximum width of 12 km. Its altitude varies from 21 meters to 200 meters. Most of the floodplain surface is flat, but there are some regions with very steep slopes (31 degrees is the highest slope). Because of its flatness, the surface of the floodplain can be easily used in agriculture or for expanding human settlements. Within the floodplain there are also some industrial spaces.

Studies about how the human activities have impacted the Jiu river floodplain were written by Albă et al. (2017). The authors evaluated human impact of the urban expansion on the Jiu floodplain in the Western side of Craiova city and concluded that ”over the past 150 years the Jiu floodplain has undergone some complex morphological changes that have led to the replacement of the marshes and ponds that characterized it until the middle of the 19th century with land suitable for urban constructions” (Albă et al. 2017). Earlier works suggested that human may have had a voluntary and involuntary influence on the floodplain (Savin 1990). The voluntary impact was the building of the Ișalnița dam and also the building of the defense léeves on both banks of the Jiu river.

The involuntary impact, or maybe ”unimaginable”, was related to agricultural practices and expanding the human habitat.

Human impacts on rivers have been classified a ‘direct changes’ within channels or to riparian vegetation versus ‘indirect changes’ to land use, such as vegetation changes, agriculture, urbanization, and mining (Brookes 1994; Brierley and Fryirs 2005).

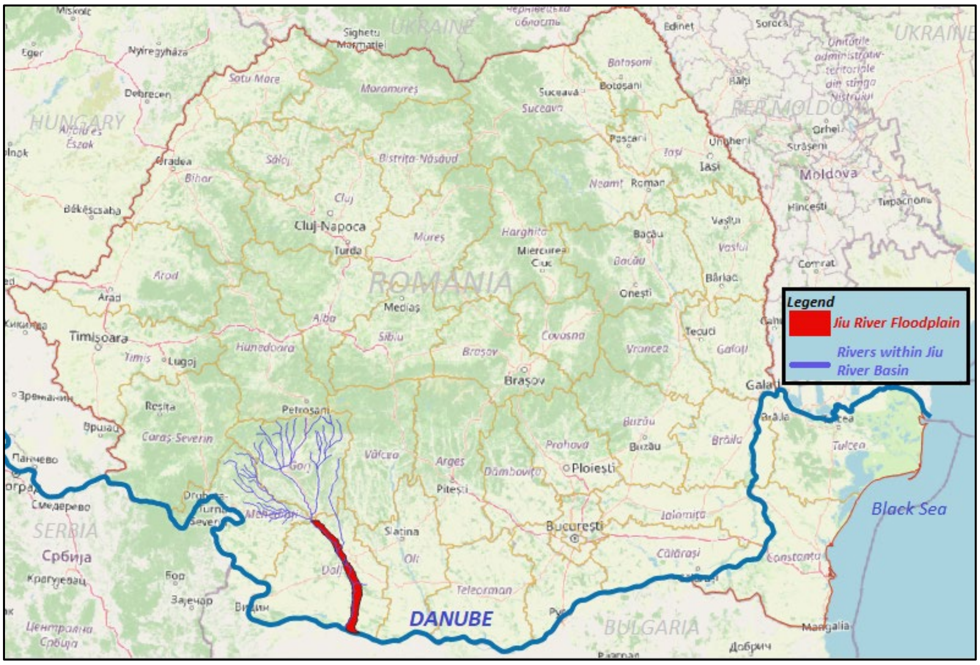

Fig. 1 Jiu River Floodplain - position within Romania

2. Material and methods

2.1 Detecting changes with satellite images

Landsat 5 TM satellite images, for 1990, and Sentinel 2, for 2020, were processed in order to observe the evolution of land use and coverage.

The Landsat 5 TM satellite provides seven spectral bands with wavelengths between 0.45 µm and 2.35 µm, at a resolution of 30 m, including a thermal band with a resolution of 120 m. The Landsat 5 TM images were downloaded from: https://earthexplorer.usgs.gov/.

The Sentinel 2 mission of the European Space Agency provided us with satellite images with a resolution of 10 m. The Sentinel 2 images are available through the Copernicus Program and were downloaded from the website: https://scihub.copernicus.eu/.

The images were processed in ArcGIS Desktop 10.6.1 software. First Landsat 5 false-color image, 432, was created running Composite Bands function, then I draw some region of interest (ROI) in order to create a signature file. Then, I run Maximum Likelihood Classification and obtained a new raster dataset that classifies the land cover.

The Sentinel 2 images were combined also in false color, but the bands used were 843. They were processed in the same way as the Landsat 5 images.

2.2 UAV survey

The analysis of the human impact on the Lower Sector of Jiu River Floodplain involved the collection of some image data by flying over the area of interest using an unmanned aerial vehicle, guided by remote, respectively the Drone Dji Phantom 4 Pro v. 2.0. The drone is equipped with a controller without a display, but to which a mobile device that operates with Android or IOS system can be applied. To control the drone it is necessary to install the DJI GO 4 application. The gimbal has 3 axes of stability (pitch, roll and yaw), the range being from -90 ° to + 30 ° in pitch mode, and the maximum angular velocity is 90 ° / s (pitch). The drone has a LiPo 4S battery that weight 468 g, with a capacity of 5870 mAh, which allows it to have a flight autonomy of approximately 30 minutes. The Dji Phantom 4 Pro v. 2.0 drone is equipped with a 1-megapixel 1-inch CMOS sensor.

3. Results and discussion

After I applied the above mention methods some results were obtained, most of them suggesting that humans have an important role in the process of transformation of the aspect of the Jiu River Floodplain (Fig. 2, Fig. 3).

Fig. 2: Dust storn within Jiu River Floodplain, near Ișalnița dam – due to the to unconsolidated tailings dumps (Photo: author, May, 2021)

Fig. 3: Ișalnița power plant – located in the Jiu River Floodplain, and other human interventions (Photo: author, May, 2021)

Evaluation of the human impact on the Jiu River Floodplain was also made by means of remote sensing. In 1990 (Fig. 4), the human impact on the floodplain was a little different as it is nowadays. The urban an rural sprawl was less intense…

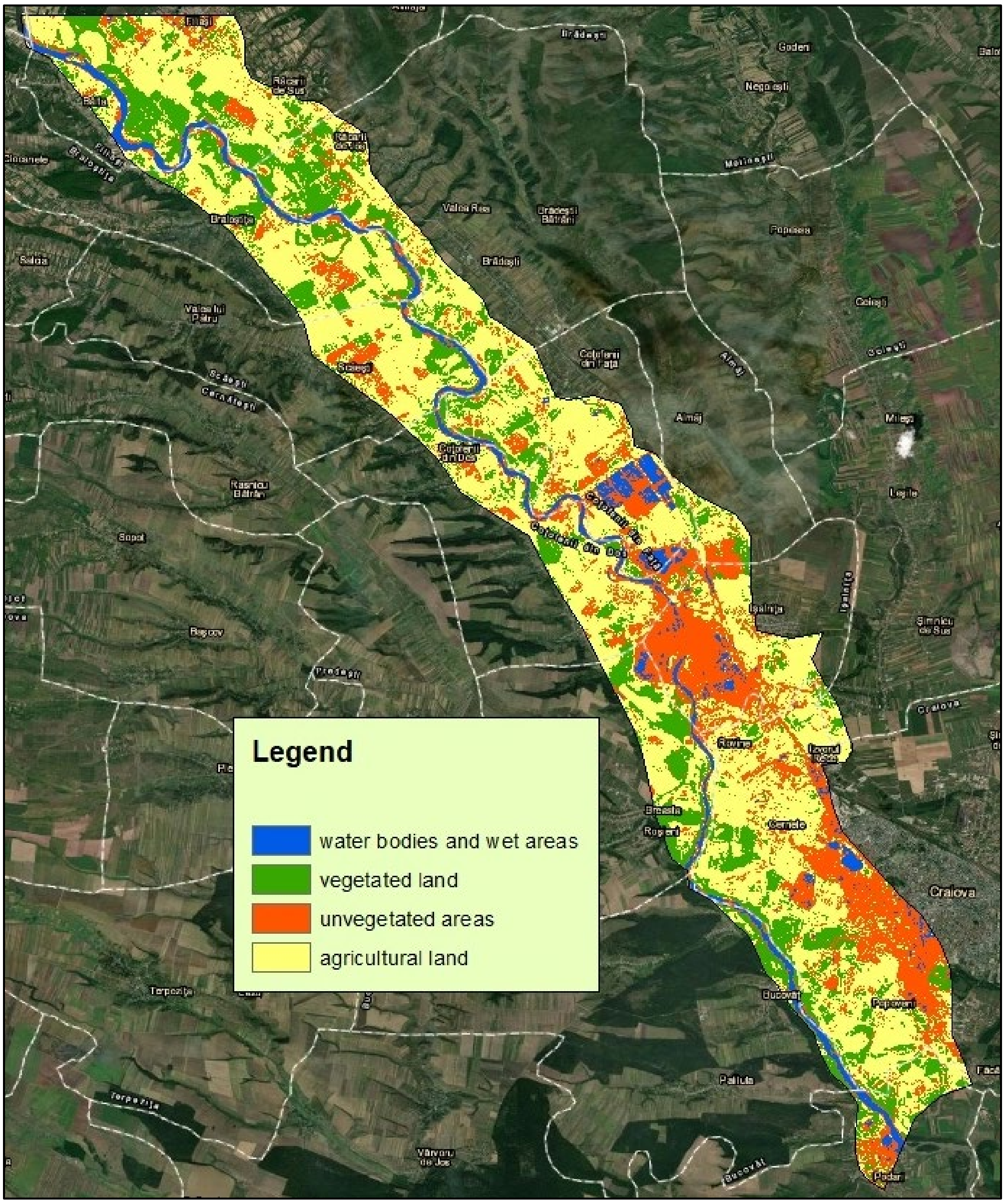

Fig. 4: Types of land cover – MLC – Landsat 5, 1990 – Jiu River Floodplain – Filiași – Craiova sector

4. Conclusion

This study focuses on the negative impact of the human on the natural environment of the Jiu River Floodplain.

The human impact on the Jiu river floodplain is very easy to be observed. The most important human ”fingerprints” on the Jiu river floodplain are:

- the urban and rural sprawl;
- the agricultural pressure exerted through different types of crops (tilling and pesticides);
- improper disposal of waste;
- topography changes due to sand and gravel quarries and due the drainage works.
- air pollution within the floodplain due to unconsolidated tailings dumps and because of the thermal power plant (Ișalnița).

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