The role of natural heritage for the sustainable future of the Danube region

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With an area of about 800.000 km^2 the Danube River Basin (DRB) covers about 10 % of Europe and about 20 % of the European Union. The DRB is home to about 80 millions of people living in 19 countries. Some of them are entirely situated within the Danube catchment such as Hungary, but also Romania, Serbia, Slovakia and Austria are located predominantly in the Danube basin. The host of the DIANET International Schools, Italy, covers only a small proportion. But the Soca/Isonzo catchment has many similar problems and potentials. It provides thus a perfect laboratory to study and discuss questions of natural heritage and sustainability and to develop adequate future perspectives.

The Danube basin is an important European macro-region for which the European strategy for the Danube region was developed and adopted in 2010 (EU-SDR). As European regional commissioner Hübner stated in 2008, this strategy aims at developing a targeted policy for the Danube that meets its ecological, transportation and socio-economic needs. All 14 countries with a share of more than 2000 km^2 of the catchment are participating in the European strategy for the Danube region. With its 2,870 km, the Danube is the second longest European river after the Volga and it is the most international river and river basin in the world. This international status is of course the result of diverse political and socio-economic histories, which have been interacting with nature for millennia.

THE DANUBE AS BIODIVERSITY HOTSPOT

The ecology and biology of the Danube are as diverse as its culture and history. The river and its adjacent floodplains are inhabited by about 2,000 plant and 5,000 animal species. The approximately 6,000 km^2 large Danube delta is considered as the largest remaining European natural wetland. Already in 1990 the Romanian part of the delta became a biosphere reserve, in 1998 the Ukrainian part followed. In 1991 it was designated as a Wetland of International Importance according to the Ramsar Convention. Since 1993 it is a world heritage place. About 5000 plant and animal species inhabit the delta which is a hotspot of biodiversity where, among others, boreal species and typical species of Central and Western Europe co-occur. Among the approximately 3,500 animal species a total of 473 vertebrates (74 fish, 9 amphibians, 12 reptiles and 325 birds) have been reported. About 60 % of the world population of Pygmy cormorant can be found here beside 5% of the Palae-arctic population of White pelican and 90 % of the world population of the Red-breasted goose (Sommerwerk et al. 2009).

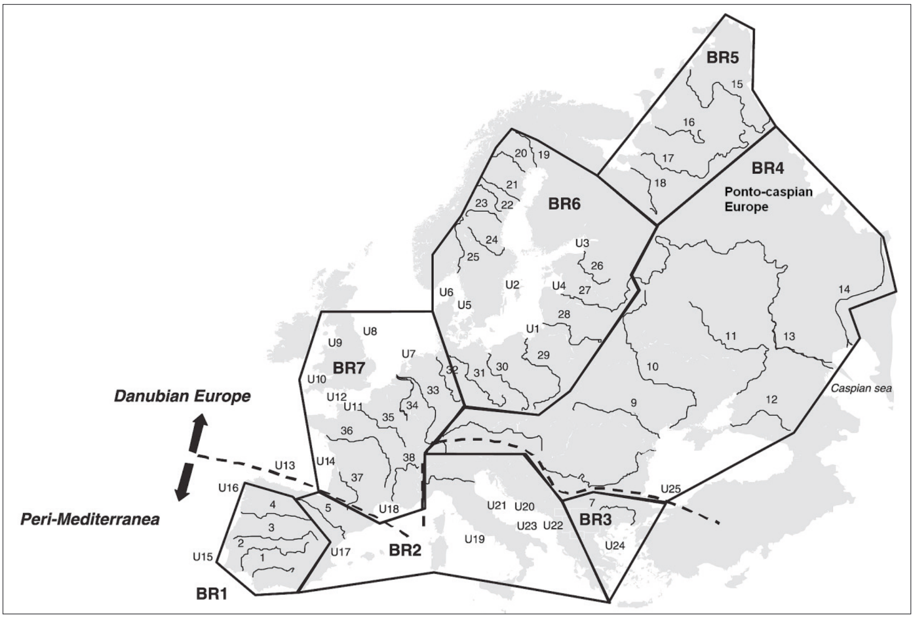

Fig. 1: In the fish regions of Europe the ponto-caspian fauna can be clearly distinguished from other regions (modified after Rejyol et al. 2007); BR4 = Ponto Caspian Europe; BR1-BR3: Western, Central and Eastern Peri-Mediterranea, BR5 = Northern Europe, BR6 = Central Europe, BR7 = Western Europe

The large biodiversity of the Danube is the result of the historical evolution of the basin and the river, respectively. This can be demonstrated, for instance, for the fish communities. At present the Danube is inhabited by 15 or 20 % of European freshwater and estuarine fish species. This large diversity is related to the role of the Danube during the Pleistocene. By then, the lower Danube and the Mediterranean peninsulas were refuges for warm-water preferring species while in northern and central Europe only cold water species survived. During the interglacials and after the glaciation many species dispersed upstream and back to central and Western Europe via the existing river network or wetlands. Other species remained in distinct habitats and contribute nowadays to the comparatively high number of endemic species of the DRB or the ponto-caspian region. The Middle Danube is for several fish the western limit of natural distribution. This can be seen also in the lower number of native freshwater fish species in the upper stretch of the Danube section, compared to downstream. Sommerwerk et al. (2009) summarize for the upper Danube a total number of 59 fish species which rises to 72 species in the middle Danube. In the Lower Danube and particularly in the delta also estuarine species occur making the total number of up to 115 species. Among European fish regions only the central Mediterranean region is inhabited by a higher number of fish species than the Danube. This is true for the number of native species as well as the number of endemic species which occur only in a restricted region of a specific catchment (Reyjol et al. 2007).

Many of the plant and animal species found in the delta have been and are important natural resources for economic use as food, building materials and medicines, which attracted people to settle here since ancient times. The impressive diversity of habitats, fauna and flora in a relatively small area makes the Danube Delta a vital biodiversity area in Europe, and a natural genetic bank with value for global natural heritage. Evidence of human settlements in this area date back millennia. They were and still are mainly based on the use of the natural resources, developing traditional economic activities and specific cultural and social habits. At present, about 14,000 inhabitants live in the delta, however, the population number is decreasing, apart from the larger towns of Sulina and Tulcea. About half of the people live from traditional fishery, forestry and agriculture. In the last years tourism has increased. Thus, ecological and societal assets meet, as well as challenges and conflicts, which need to be addressed when developing plans and projects for the future.

Although not considered as natural heritage in a strict sense soils are important natural resources. Soils and their protection are often not adequately taken into account by European or international legislation. They fulfill many essential functions directly or indirectly useful for societies such as support for agriculture, filtering of water or biodiversity (Keller et al. 2012). Preserving their quality is nevertheless an explicit target of the European Strategy for the Danube Region as part of pillar 2, protecting the environment. Within the Danube catchment the fertile soils make especially its middle and lower part one of the most important European areas for agriculture. It is estimated that sustainable biomass production could be increased by 30 % in the Danube region which makes it an important backbone of a knowledge-based bio-economy in Europe (Fischer et al. 2012). An investigation of the "Quality of soils" accomplished by the US Department of Agriculture on a global scale concluded that large areas in the Middle and Lower Danube have the highest land quality within a 3-tiered scheme. Soil resilience was one of the two indicators used to asses land quality. It defines the ability of the land to revert to a near original production level after it is degraded, for instance by present agricultural management with a high use of fertilizers, pesticides and machines. In the classification of the US Department of Agriculture land with low soil resilience is permanently damaged by degradation. Soil Performance as second indicator mirrors the ability of the land to produce under moderate levels of inputs in the form of conservation technology, fertilizers, pests and disease control. Land with low soil performance is generally not suitable for agriculture[1].

CURRENT ENVIRONMENTAL STATUS

The Danube River Basin and its biodiversity have changed, due to a multitude of past and ongoing human activities. This is proven by a wealth of data which has been collected for decades in the different Danube countries and for 20 years now on an internationally comparable basis to fulfill European and basin-wide legal requirements. In 1994 the Danube River Protection Convention was signed in Sofia, Bulgaria. It came into force in 1998 and the International Commission for the Protection of the Danube River was established to implement it. The main targets of ICPDR are: (a) safeguarding the Danube's water resources for future generation; (b) reducing excess nutrients and organic pollution as well as the risk from toxic chemicals; (c) establishing healthy and sustainable river systems, and (d) mitigating flood damage.

In 1996 the Trans-National-Monitoring-Network (TNMN) was established to gather data about the environmental situation, in particular pollution. As a result of the implementation of the European Water Framework Directive (WFD) the Joint Danube Surveys were first conducted in 2001 with a follow up

1 http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/nedc/training/soil/?cid=nrcs142p2_054011

in 2007 and a third Survey in 2013 (JDS 1 – ICPDR 2002, JDS 2 – ICPDR 2008, http://www.danubesurvey.org/ – accessed 25th August 2014). The first Danube River Basin District Management Plan published in 2009 summarizes the ecological assessments in line with the WFD and defines the joint program of measures to be implemented in the forthcoming years (ICPDR 2009).

The ICPDR identified five significant water management issues (SWMI), three of them relating to different types of pollution. Organic pollution increases from up- to downstream countries and is mainly caused by the emission of only partially treated or even untreated wastewater from agglomerations, industry and agriculture. From a total of 6,224 agglomerations of more than 2,000 population equivalents situated in the DRB, in about 2,900 agglomerations wastewaters are not collected at all. About 170 industrial facilities emit directly into the Danube and its tributaries and a further approximately 180 indirectly via urban sewers. Nutrient pollution is identified as another significant problem of the Danube River. Often, the sources of nitrogen and phosphorous are the same as those of organic pollution, such as urban wastewater which contributes especially to phosphorus emission. In addition, there is diffuse pollution from agriculture which is particularly high for nitrogen. The use of nitrogen fertilizers is in the middle and lower DRB countries lower than the

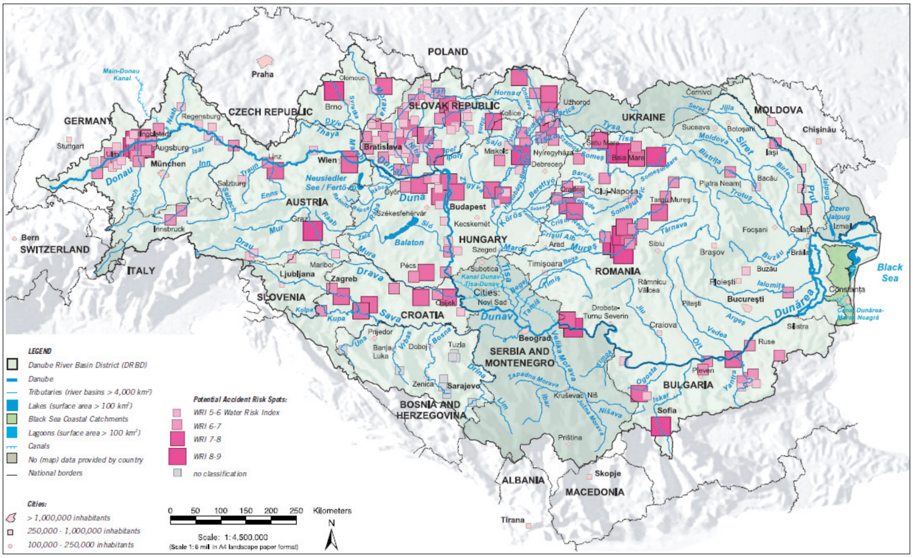

Fig. 2: Potential accident risk Spot in the DRB. The map shows the Water Risk Index, the darker the color and the larger the size of the squares the higher the risk index (Source: ICPDR 2009)

EU average and also lower than in the countries of the Upper Danube. Furthermore, the density of livestock per hectare is lower in the middle and lower Danube countries.

As for the assessment of pollution from hazardous substances, knowledge gaps still exist. These substances comprise man-made chemicals, naturally occurring metals, oil and its compounds, endocrine disruptors and pharmaceuticals. Hazardous substances are emitted and released by industry and agriculture or stem from mining operations. In addition, the risks of accidental pollution and of substances which are stored in the soils from past industrial activities or waste disposal have been identified. An inventory of accident risk spots was elaborated. By 2009 a total of approximately 650 risk spots were reported in the entire river basin and 620 were evaluated. A hazardous equivalent of 6.6 million tons has been identified as potential danger. As figure 2 shows the number of risk spots is especially high in the Middle Danube and its main tributary Tisza.

Apart from pollution, hydromorphological alterations have been recognized as a Significant Water Management Issue in the DRB. Hydromorphological alterations result from the interruption of river and habitat continuity, the disconnection of adjacent floodplains and the hydrological alterations e.g. due to water abstraction, impoundments or hydropeaking. The longitudinal color-ribbon

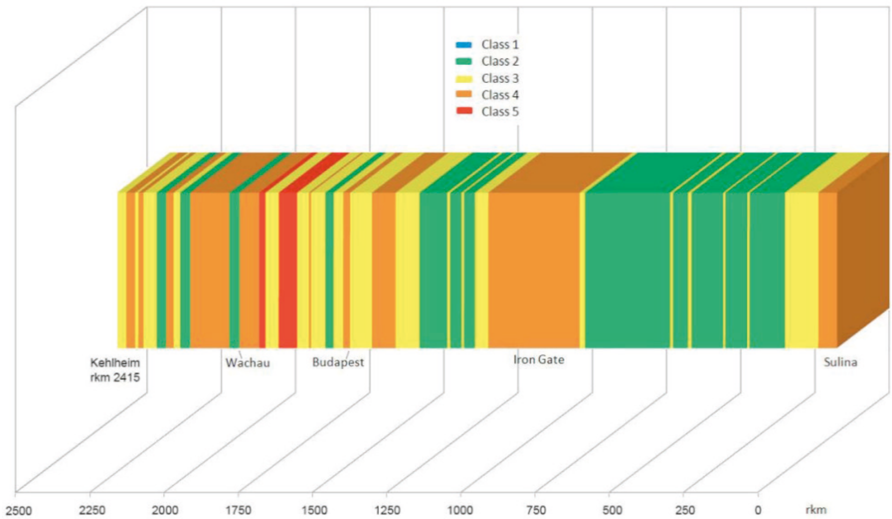

Fig. 3: Assessment of the hydromorphological status of the Danube in 5 classes from class 1 (high) to class 5 (bad hydromorphological conditions; JDS 2, ICPDR 2008)

visualization displayed in figure 3 follows the 5-tiered classification scheme of the Water Framework Directive on a scale of 1 to 5, with 1 being the best and 5 the worst. About 1/3 of the Danube was classified as 2 and fulfills the ecological requirements of the WFD. These sections are situated mainly in the lower part of the river showing the existing ecological potential. However, 30 % are identified as class 3, 28 % as class 4 and 3 % as class 5. Especially the Upper Danube is severely affected by hydromorphological changes.

This high intensity of hydromorphological pressures in the Upper Danube is in large part owed to the high number of hydro-power dams. Of the 78 dams which are situated directly in the Danube only three, Gabcikovo and the two Iron Gate dams, are downstream of Vienna. Nevertheless these barriers have severe ecological consequences and impact the sediment regime of the river. Only 22 hydro-power dams in the Danube are already passable for migrating aquatic animals.

A recent status report of the ICPDR lists invasive alien species as further emerging environmental problem. The status and ecological impacts of these alien species is not yet fully evaluated and has to be subject to future surveys and assessments. For the dispersal of non-native and potentially invasive species the connection of different European river systems via shipping canals has major consequences. When the Rhine-Main-Danube Canal was completed in 1992 it opened an invasion corridor which can be considered as an artificial connection of the Black Sea and the North Sea.

One of the most striking examples for invasive species is the dispersal of Neogobiidae from their native habitats in the Lower Danube to the Upper river stretch and to many other European river systems in the last 20 years. Two of these fish species, *Neogobius kessleri* and *Neogobius melanostomus*, were found in the Austrian Danube in the 1990s and have occurred since the 2000s in the German section. They have meanwhile spread over the whole river system and developed high abundances. A third species is occasionally found in the Austrian Danube (*Babka gymnotrachelus*), a fourth occurs frequently in the Hungarian Danube but has not yet been found further upstream (*Neogobius fluviatilis*). It is assumed that all these fish species were and still are transferred with ships, either with the ballast water or the outside walls.

While these fish species are mainly examples for movements from the East to the West the Rhine-Main-Danube-Channel is also a migration path in the opposite direction. The Asian clam *Corbicula fluminea* occurs natively in South and East Asia, Australia and Africa. It was transferred to North America probably in the 1920s and later on to South America and Europe. It was found in the 1970s in Portugal and then spread eastwards to Spain, France, the Netherlands and Switzerland. It now extends to the Danube in Romania and was found in the second Joint Danube Survey in 93 % of the investigated sites (ICPDR 2008).

ICPDR identified also the preservation and enhancement of the almost extinct Danube sturgeon stocks as a matter of high importance. Sturgeons are flagship species of the DRB and valuable indicators for the water status and the health of the Danube ecosystems. The decline of the populations is a result of the disruption of migration routes and habitat change. In addition, their high economic value has caused overexploitation for centuries and illegal marketing since their trade was restricted some years ago in accordance with the CITES convention (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Restoring the former vital sturgeon fishery in the Lower Danube and Danube delta is an ecological as well as an economic aim. Differences in the targets however, have caused severe conflicts between these two interest groups. Sturgeon conservation illustrates how biodiversity conservation has also to take into account socio-economic needs.

The occurrence of non-native species – the invasive as well as the unintentionally and intentionally introduced ones – together with species extinctions due to overexploitation or habitat change in the last three centuries altered the diversity of the Danube fish community. Of 13 European freshwater fish which have gone extinct since 1700 two are from the lower Danube (*Alburnus*

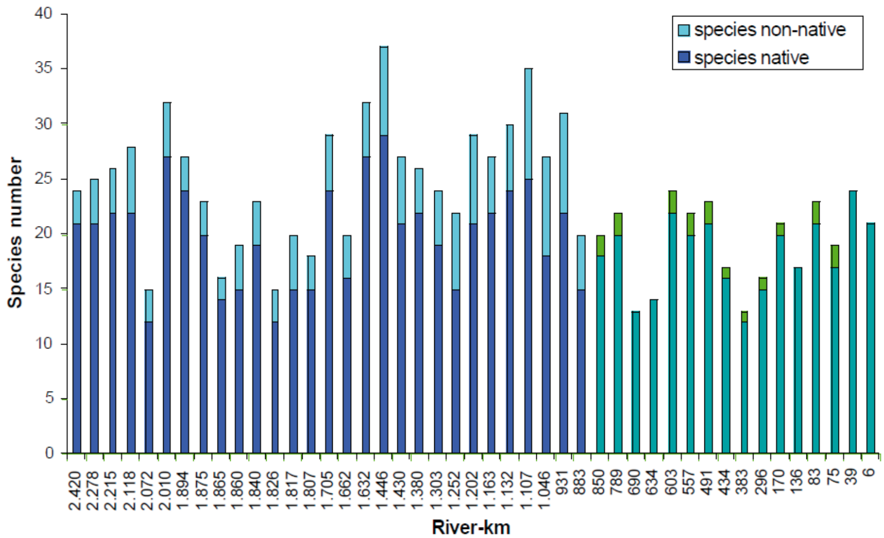

Fig. 4: Native and non-native fish species at different sampling sites investigated during Joint Danube Survey 2 (JDS 2, ICPDR 2008)

danubicus, *Romanogobio antipai*), one was endemic in subalpine lakes (*Salmo schiffermuelleri*) and one occurred in coastal lakes close to the delta (*Gasterosteus creonobiontus*, Kottelat & Freyhof 2007). The proportion of non-native species is particularly high in the Upper Danube (approximately 20 %). Figure 4 shows the proportion of non-native fish species found during JDS 2 in the 45 different sampling sites. Table 1 provides the summary for the four Danube sections (ICPDR 2008, Sommerwerk et al. 2009).

Tab. 1: Native and non-native fish species in the different sections of the Danube (data from Sommerwerk et al. 2009)

	Upper D	Middle D	Lower D	Delta
Native	59	72	70	70
Non-native	13	12	7	4

LONG-TERM DEVELOPMENT OF THE DANUBE LANDSCAPES

The environmental state and biodiversity of the Danube have never been stable and will never be stable in the future. They are the result of past, present and future human activities and environmental conditions, namely climate change. Emission of nutrients and especially hazardous substances have increased in particular in the 20th century. Morphological alterations and effects of land use changes can be traced back centuries and partly even millennia. The temporal development of the environment and biodiversity shall be highlighted here by some examples related to hydromorphology, the effects of land use change and overexploitation of fish. These examples demonstrate the long-term influence of humans on the riverine environment but also the dependence of the type and timing of these influences on societal requirements and circumstances.

- **River channelization and floodplain loss** are among the first larger measures of river engineering. For centuries human efforts were mainly aimed at supporting and improving navigation. In the 19th century new technologies and knowledge about river channelization together with new transport means and societal demand for resources triggered for instance most of the activities in the Upper Danube. Sometimes flood protection was an initial target, mainly in large urban agglomerations. Among the earliest exceptions where flood protection and land reclamation were the main target is the systematic Tisza regulation, which started in the 1840s. While these floodplains had supported the local population with its traditional fishing and agricultural management techniques for centuries, they were now suitable for intense grain cultivation.

Tab. 2: Floodplain loss along the four different parts of the Danube (data from Sommerwerk et al. 2009)

River stretch	Morphological floodplain [km²]	Recent floodplain [km²]	Loss
Upper Danube	1 762	95	95 %
Middle Danube	8 161	2 002	75 %
Lower Danube	7 862	2 200	72 %
Delta	5 402	3 799	30 %
Total	23 187	8 096	65 %

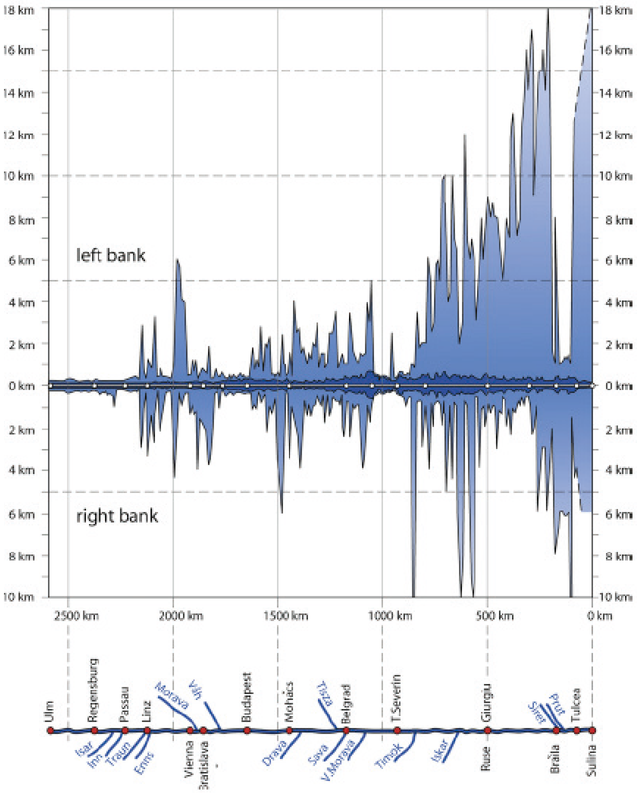

Fig. 5: Width of the floodplains inundated during higher floods along the Danube (Lászlóffy 1967 and Sommerwerk et al. 2009)

This allowed excess production for export, e.g. to Austria via the newly developed steam ships (see Pinke 2014).

Before the erection of flood protection dikes the inundated floodplains along the Danube extended up to 10 kilometers in many sections of the upper and middle Danube and up to 25 kilometers in the lower Danube and in the Delta region (see fig. 5). Since the 19th century most of the Danube floodplains were reclaimed for agriculture, partly also for urban land use. By the 21st century on average 65 % of the initial area of roughly 23,000 km^2 were lost, most of them in the Upper section with a value of 95 % (tab. 2). This resulted in habitat and biodiversity loss but also in severe socio-economic risks because of the immense values which were established in the floodplains in particular in the last decades. In a medium-sized Austrian town situated on the Traisen, a tributary of the Danube, the potential damage in case of inundation increased from about 0,12 Mio. € in 1870 to approximately 15 Mio. € in 1960 and 28 Mio. € in 1980. Since the 1990s the buildings here are protected from a 100-year return flood, but a dam failure may result in a loss of 32 Mio € (Eberstaller et al 2004).

Only in the 1920s hydropower production and connectivity interruption started to affect the ecological status of the Danube. The German Kachlet dam built close to the border to Austria was the first hydropower plant of the Danube built in 1927. Plans for hydropower production on the Danube existed in Austria already in 1918, but they were only implemented after WW II. Nowadays, Austria produces 60 % of its electricity from hydropower, which one might take as a logic consequence of the alpine environment. But this was not at all the case. In fact, despite hydropower plants were erected since the late 19th century, the large scale and politically supported campaigns started only after the collapse of the Austro-Hungarian Empire. The coal resources in Silesia and Moravia were no longer available for the succession state and alternatives to coal had to be found. Socio-political decisions on which resources to use have always been a consequence of the access and availability of resources.

Hydropower dams interrupt the longitudinal connection of rivers in both directions. Downstream they block for instance bed load transport, upstream the migration of various aquatic animals. This is the case for diadromous fish species migrating from the Black Sea to the Danube for spawning. In particular sturgeons cannot pass the Iron Gate since the erection of the first dam in 1972. However, the main threat to sturgeons has been overexploitation for many centuries.

The fate of Danube sturgeons and their decline over the centuries demonstrate the close connection of people living along a rivers course. In the Middle Ages the diadromous Danube sturgeons migrated from the Black Sea up to the German Danube and the large tributaries enabling sturgeon fishery on a regular basis in Austria. In the 16th century sturgeon fishery was intensified in Hungary. Sturgeons were caught with large nets e.g. in the region of Komarom. This caused in Austria a decline of sturgeons and the collapse of the sturgeon fishery. As late 18th and early 19th century data from the Viennese fish market show, sturgeons were still brought to Vienna in considerable quantities from the Hungarian Danube. The delivery declined however, and in the 1880s only few fish were imported. This was not due to the Viennese starting to dislike sturgeons. In fact, it was the result of an intensification of sturgeon fishery in the Lower Danube and a subsequent decline of fish in the Hungarian Danube (see fig. 6; Balon 1968, Haidvogl et al. 2014).

A final example demonstrates the long-term interaction of people and the Danube over millennia, in particular the consequences of **land use change in the catchment**. An investigation of sediment cores revealed the spatial and temporal development of the Danube delta. The formation of different parts was the result of different storage rates throughout time. These rates amounted until about 3,500 bp to roughly 20 Megatons per year, increased for the following 1500 years to 30 Mt per year and to 50 Mt per year until about 300 years ago and to 65 Mt per year in the last three centuries. Climate change

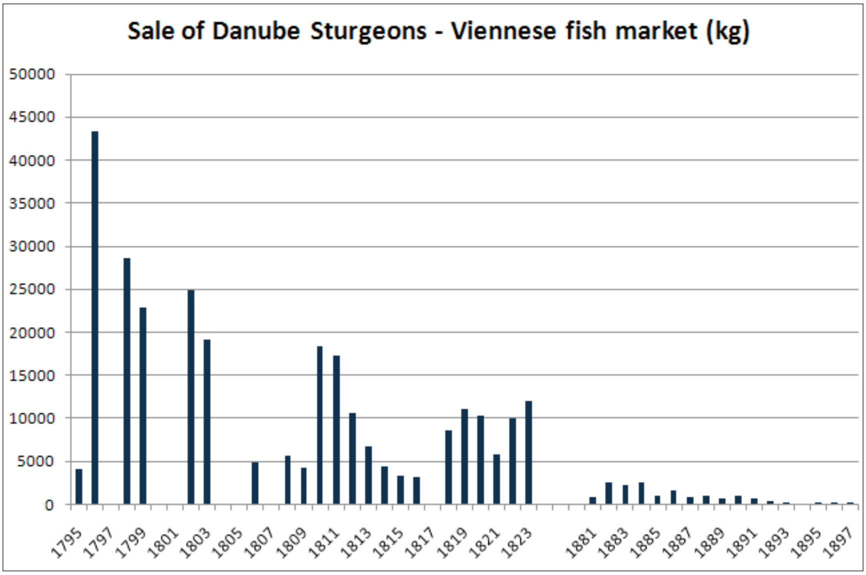

Fig. 6: Sturgeon sales at the Viennese fish market in the 19th century (Haidvogl et al. 2014)

and land use change have been tested as possible reasons for this increase in sediment storage rates. It appeared that – although changes in precipitation and discharge patterns had also an effect – the dominant factor was land use change, and particularly deforestation, which occurred first in the Upper catchment and in the last centuries also in the lower catchment. In the last decades the erection of large hydropower dams considerably decreased the effective bedload and sediment input (Giosan et al. 2012).

LONG-TERM DEVELOPMENT, BIODIVERSITY AND NATURAL HERITAGE

The Danube we see today is the result of the common and intertwined history of the riverine environment and the societies settling along the river. A large diversity of landscapes and ecosystems can be found which are however nowhere untouched nature but rather a hybrid of natural and cultural characteristics. Biodiversity changed and will change even in those areas which have been declared as natural heritage sites. Such areas exist in particular along the middle and the lower sections of the river. In total, about 1,000 protected areas are registered with a total area of approximately 150,000 km^2 (ICPDR 2009). Most of these protected areas have been declared under the EU-Fauna-Flora-Habitat-Directive or the EU-Birds-Directive and many of them are related to aquatic or semiaquatic habitats, animals or plants. The 17 national parks situated along the river corridor exchange and collaborate in the maintenance and protection requirements since 2007 in the Danube-parks initiative.

According to the definitions of Natural Heritage – as expressed for instance in the Convention of biodiversity – natural heritage refers to biodiversity. It includes, however, not only flora and fauna but also ecosystems as such, together with geological structures and formations. The different conventions and directives such as the Convention for Biodiversity, the World heritage convention, the European Fauna-Flora-Habitat-Directive or the European Bird-Directive have similar targets: they aim at protecting endangered species or preserving and restoring an assumed natural or native status of species and habitats. The latter is in particular true for the European Water Framework Directive (WFD), the main European legislation for aquatic systems. The WFD requires achieving a good ecological status which deviates only slightly from a natural reference state in the absence of human influence. Often the conditions of the 19th century are taken as a reference to define for instance native species or natural habitat conditions.

But is it possible to return to a previous state or to preserve an existing state? River systems are nowadays subject to fundamentally altered framework conditions. Dufour & Piegay (2009) argue in their recent publication that rivers follow trajectories. Dams alter the system on a long term scale for instance, because they changed the sediment transport and there are also parameters which develop progressively, such as climate change. This clearly prevents the recovery of a previous status. The distribution of species depends both on temperature conditions and precipitation and hydrology. These factors vary with climate. The occurrence of some fish species in the Salzach catchment, for instance, which is part of the Upper Danube, changed considerably in the last decades and is now out of the variability range of the last 200 years. It is likely that this will continue in the future (Pont et al. accepted).

In line with such research findings the European Commission stated in its report on the loss of biodiversity, that "Climate change has the potential, over a period of few decades, to undermine our efforts for the conservation and sustainable use of biodiversity." (European Commission 2006). As Rannow et al. (2014) recommend, this requires, among others, studies on the effects of climate change on a regional and local scale and the assessment of the sensitivity of both habitat and organisms to climate change. Any project for future sustainable development has to take this into account, not only in terms of species distribution and abundance but also in socio-economic terms.

From these considerations it is evident that the Danube and the DRB have a rich natural heritage and a large potential for conserving and improving it. Maintenance and conservation targets can support sustainable development in the fields of ecotourism or agriculture, but they must clearly take into account that ecosystems have changed over time and will continue to change in the future. It is indispensable to investigate the long-term trajectory of the Danube and the DRB to make successful plans for the future.

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