ISSN 2070-1292

danube news

Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

donau aktuell

Tributaries of the Danube II: Drava/Mura – protected river corridor threatened by hydropower

Editorial

Dear Reader

Besides the extended floodplains in the Sava-Krka, the Lower Drava and Mura Rivers feature a large free-flowing river-floodplain system, particularly in connection with the Danube and its remaining floodplains such as Kopački Rit and Gemenc. Floodplains in large lowland rivers are the most beautiful stretches of riverine landscapes and without doubt the most functional parts of aquatic ecosystems. They provide outstanding ecosystem services and are hotspots of biodiversity. In most large rivers, adjacent floodplains were lost during the 19-20th century through major river regulation schemes (canalization) for navigation, flood protection and land use. In sharp contrast, mostly intact floodplains are present in the Lower Drava, and they are used in a rather sustainable way by the local people. Apparently, these people can wisely implement and appreciate their natural and cultural heritage.

Figure 1. *Canalization of the Stara Drava in Croatia between Varazdin and the Slovenian border in 2007. Aerial photos Spot I, II, III (27.6.2007). Credit: WWF Austria*

Lowland floodplains are impacted by many hydropower plants installed in the upper parts of the Drava and Mura Rivers that significantly change the hydrological regime and minimize sediment transport. A consequence is an incision of the riverbed downstream and reduced erosion power, both leading to a slow but continuous disconnection and drying out of the floodplains. For the non-expert visitor of today, neither these functional changes nor the relation to hydropower can be readily seen. Hence, this issue of Danube News may help increase public awareness of what we are going to lose in the long term if society and policy make erroneous short-term decisions.

The Mura and Drava River system is a fine example of non-spectacular but typical upstream-downstream effects on hydromorphological alterations. It addresses a major problem occurring in River Basin Management prescribed by the EU Water Framework Directive (WFD) and implemented for the Danube River Basin by the International Commission for the Protection of the Danube River (ICPDR). The solutions presented here are exemplary, as they provide transboundary cooperation to link individual protected areas into a larger functional network of floodplains to allow optimal longitudinal and lateral connectivity, and open migration corridors. Such solutions are clearly more sustainable than constructing river regulations *(Figure 1)* and new hydropower plants in the basin as promoted by the EU Danube Strategy. In this context, the political controversy of conflicting public interests between existing protected areas (such as Natura2000 sites, National and Regional Parks, Nature and Ornithological Reserves) and developing large Future Infrastructure Projects should be stressed. The status of protection urgently needs more political support and an improved implementation as demonstrated by the WWF Petition with over 20 000 signatures against the destruction of Danube Wetlands of Kopački Rit, handed over to the Croatian Minister of Environmental and Nature Protection Mirela Holy on the World Water Day 2012.

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Overview of the Drava River Basin

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Riverine state borders

If river courses form state borders in Central Europe today, they are mostly defined as the middle of the river, and the channels are stabilized by concrete and embankments. The important dynamics in river morphology and the steady transport of sediments have been lost. In earlier times the river was used as the borderline at a given date (Schneider-Jacoby 1996). While the border stayed constant, the unregulated river changed its course and, after several decades or even centuries, flows now from one country into the other and vice versa. The border is marked by the old riverbed and visible in the countryside as wet depression, oxbow or old river branch.

The best example of this historic phenomenon is the Mura-Drava-Danube corridor between Austria, Slovenia, Croatia, Hungary and Serbia, and the most interesting part is the Croatian-Hungarian border area, about 180 km long (Schneider-Jacoby 2001). The borderline is very likely one thousand years old and was even preserved during the Austrian-Hungarian Empire. Then, during the times of the Iron Curtain most of the floodplain – a broad corridor for wildlife up to five km wide – was not accessible for people due the wide variation of the borderline and the river, and the natural dynamics formed one of the most diverse river stretches in Europe (Schneider-Jacoby 1996). This historic border, which causes still dispute between Croatia, Slovenia and Serbia, is the basis for the great importance of the Drava River Basin for biodiversity protection in Europe and a historic artifact, which has to be preserved by modern nature and landscape management, e.g. through a transboundary protected area (Schneider-Jacoby 2001).

Characteristics of the Drava Basin

The Drava Basin is connecting the Alps with the Danube River in west-east direction. Beside the main river, the Mura is following the same direction, giving the riverine system the shape of a long Y from the mountains to the Pannonian Plain. The name is similar in all bordering countries (Dráva / HU, Drau / A, Drava / I / SI / HR / RS). Its source is in Italy near Dobbiaco/Toblach at 1450 m a.s.l. The length is 719 km and the basin encompasses 40 087 km^2. Mean discharge is 622 m^3/s at the mouth of the river in the Nature Park Kopački Rit (Croatia), bordering with Serbia. About one tenth of the overall water in the Danube is originating from the Drava, the fourth largest and longest Danube tributary (Trockner et al. 2009).

More than 350 km of free-flowing river from Austria (Spielfeld, Bad Radkersburg, Radenci) down to the Danube (Osijek, Apatin, Baja) remained at the Drava and its tributary Mura, while upstream 27 dams were built on the Drava and 15 on the Mura *(Figure 1).* The great value of the lower course of both rivers and the adjacent Danube wetlands becomes clear by looking at the distribution of the White-tailed Eagle in the Danube Basin *(Figure 2;* Schneider-Jacoby et al. 2003): Here large floodplains, large alluvial forests, many oxbows and a diverse riverine landscape have survived.

In September 2008, environmental protection and hydraulic engineering experts from the bordering countries met in Maribor (Slovenia) for an intense exchange of experiences. The result of the symposium was the signing of the Drava Declaration by the state representatives of the ICPDR. The declaration promoted the Drava River as a model for the implementation of EU Directives, ecological connectivity for migrating fish and the use as a cross-border area for recreation (www.life-drava.at). The conference was based on two EU Life-Projects: The first project "restoration of the wetland and riparian area on the Upper Drau River"

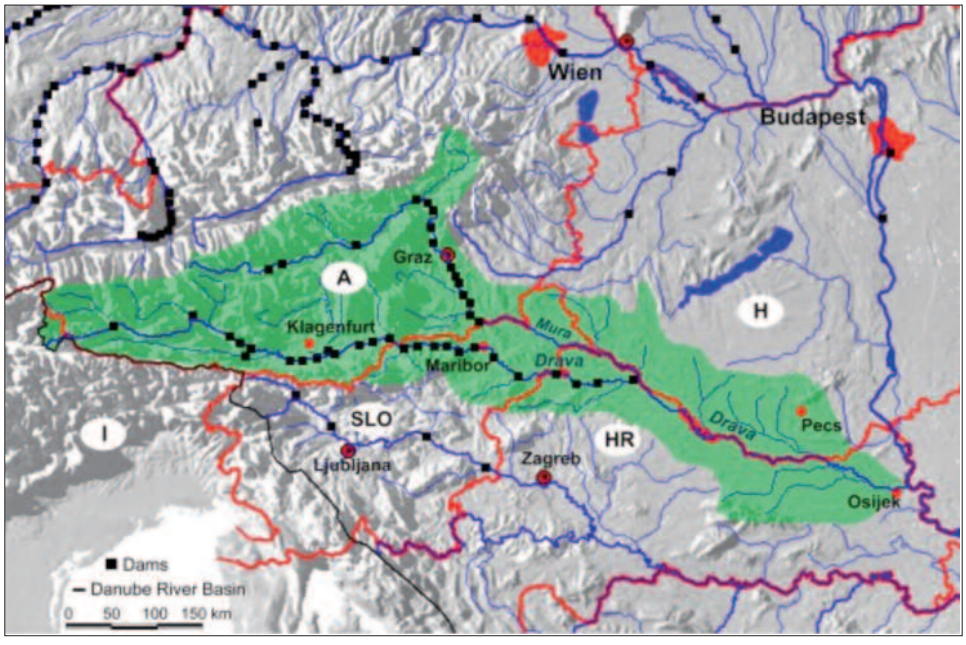

Figure 1. The Drava-Mura Basin and existing hydropower dams (Credit: Schwarz/FLUVIUS)

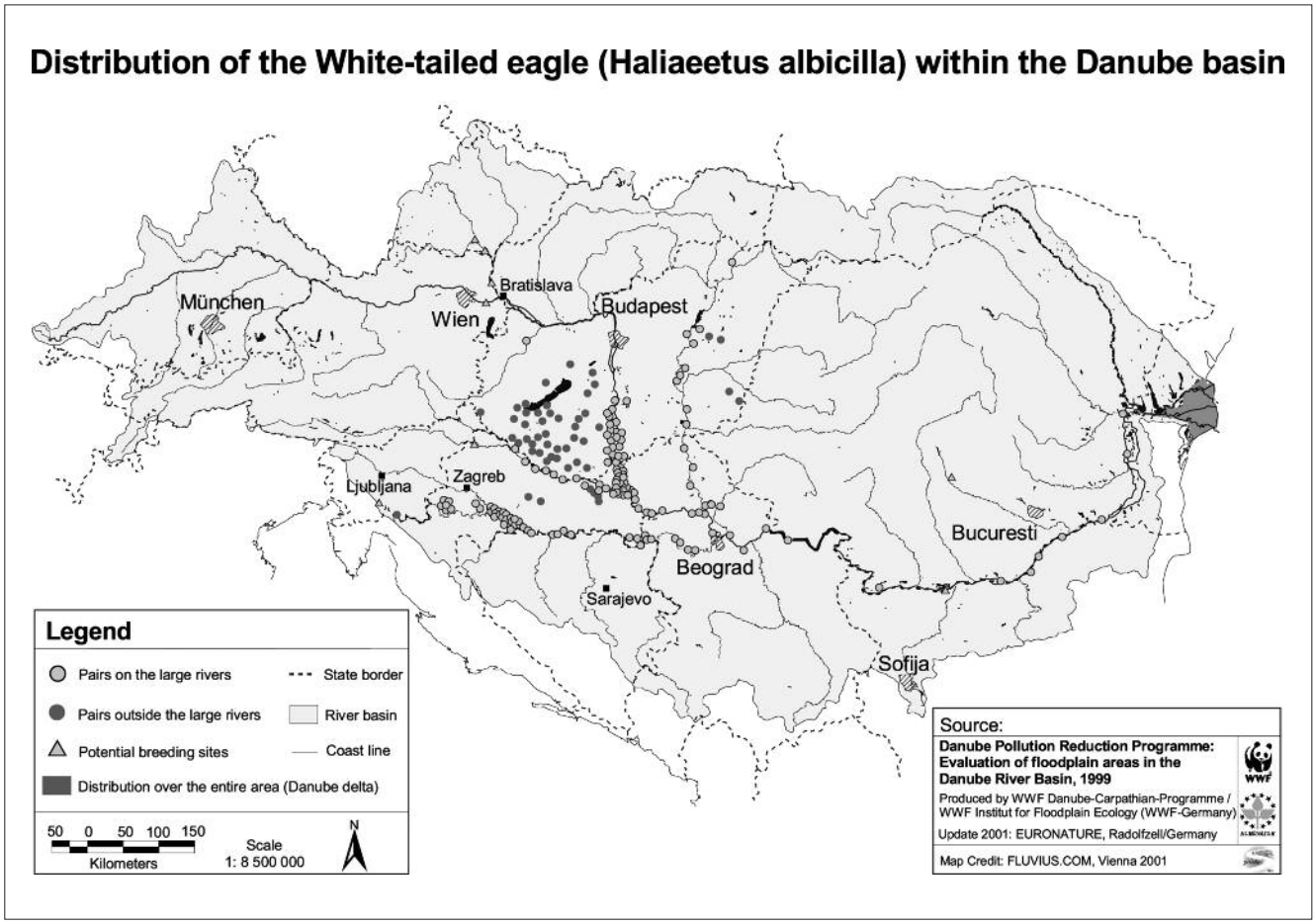

Figure 2. Distribution of the White-tailed Eagle within the Danube River Basin. Note the concentration along the Danube-Drava-Mura river system (Credit: WWF/EuroNatur prepared by FLUVIUS)

(1999–2003) was an incentive follow-up project prepared under the title "Life vein Upper Drau River". During the EU LIFE-aid Programme from 2006 until 2011, three major river widenings were carried out along a total length of approximately five km.

Nevertheless, building of new dams at the Mura (http://rettetdiemur.at/) and strong impacts by embankment and river canalization continued at the Lower Drava (see article by Schwarz). Restoration in the Upper Drava and canalization at the well protected Lower Drava are indicators for the huge loss of public money in Croatia and the difference between political declarations of Croatian Waters (Drava Declaration) and the old-fashioned and destructive water management practices.

Special features of the Lower Mura and Drava

It is evident that the rivers maintain self-revitalization processes of lateral erosion and shift even though they are impacted by hydrological and sedimentological deficits in the upper courses *(Figure 3 Left;* Schwarz 2007). This could be approved by comparing selected reference sites with the historical situation. The Rivers Mura and Drava form a unique corridor right down to the floodplains of the Danube through five countries and a European Lifeline, which needs transboundary protection (Schneider-Jacoby & Reeder 1999). These wonderful riverine landscapes are threatened by river regulation for navigation *(Figure 3 Right).*

There are numerous indicators for the unique value of the Lower Drava and Mura along the border corridor between Croatia and Hungary. Recent studies on caddisflies (Trichoptera) report up to 85 species and prove that in *"the undisturbed reaches of the Drava one of the most diverse caddisfly communities of central Europe can be found"* (Uherkovich 2008). The best indicator for the unique river stretch is *Platyphylax frauenfeldi,* which has *"its global ultimate existing population living in the river systems of Drava and Mura"* (Uherkovich 2008). The "Biodiversity studies along the Drava River" edited by Jenö Purger, Pecs, provide many other good examples for the uniqueness of Lower Drava such as the diverse gallery forests (Kevey et al. 2008), including seven different associations with natural succession and dynamics, as well as the highly diverse fish fauna with 64 species including 22 from the EU FFH Directive (Sallai & Kontos 2008).

Scenario planning as a warning system

In 1998 the future of the Drava River was the topic of the third Drava conference in Zagreb. Three potential development scenarios were described concerning the protection and development of the unique border stretch between Croatia and Hungary (Schneider-Jacoby 1998):

Figure 3. The Drava as it looks today (Left), and hopefully not tomorrow (Right). River regulation for navigation transforms the natural river bends with related ecological functions into a sterile canal disconnecting the adjacent floodplains (Credit: WWF Austria)

I. No cooperation and no common policy between the neighbouring states concerning the ecological and cultural value of the river and the riverine landscape, as practiced in 1998.

II. Building of hydropower dams as planned by Croatia (Programme for Physical Planning 1999 in Croatia) and international conflicts caused by controversial development aims.

III. Protection and restoration of the ecosystem as planned by Austria, Slovenia, Croatia (e.g. Schneider-Jacoby 1998; Radovic 1999), Hungary and Serbia on regional and national level.

Until recently, the first scenario had the largest impact on the river, which *"will lead to an erosion of the river bed and degradation of alluvial wetlands accompanied by decrease of groundwater. … No joint development of the border region means also a loss of funding possibilities for the region."* The impacts as described in the article by Schwarz are a result of the lack of political will to preserve the river. Most important was, that the second scenario, the building of hydropower dams could be stopped by a continuous presence of NGO activities (see article by Schneider-Jacoby & Mohl). The huge benefits for the regional development, which can be gained by the preservation and marketing of the unique riverine corridor are still not visible, as the transboundary cooperation in nature protection and tourism development has started only quite recently. However, it seems that the third scenario can be realized.

Conclusions

The Drava-Mura corridor is one of the greenest and best-preserved parts of the European Green Belt (Reeder et al. 2006) and has a great potential to become the driver of the regional development. The knowledge of the natural values is one of the important basics to promote the area as a special site in Europe and to develop tourism. The unique selling point is the intact riverine corridor through five countries along the Lower Drava and Mura including the Danube wetlands at the confluence. Monitoring is important to preserve these values and to detect ecological changes as early as possible. Beside the bilateral and multilateral cooperation along the river, the border region is a key area in the European Green Belt, an initiative which gave positive input to the conservation and development goals in Croatia for the Drava-Mura eco-corridor. Hopefully now with the EU accession of Croatia the impacts will decrease and the protection goals for this riverine ecosystem become reality not only for the Lower Drava, but also for the whole basin as stated in the Drava Declaration.

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Mura-Drava-Danube:
Five countries – three rivers – one Biosphere Reserve

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The protection of biodiversity of the three transboundary rivers needs a different solution to that applied to other ecosystems. Most important is the creation of a chain of connected protected areas along the river to secure the free flow of water, sediment transport and migration of animals, such as otter and fish. The protection of a riverine landscape in five countries is a long process. The vision created in Kaposvar 1993 on the first Alpe-Adria – EuroNatur Drava Conference to form a Biosphere Reserve unifying all protected areas along the riverine ecosystem is near to become reality. It is helpful to look back and to use this case of preparing the Mura-Drava-Danube Transboundary Biosphere Reserve (MDD-TBR) as a road map for the preservation of other similar ecosystems.

Conception Phase: What has to be protected?

The first initiatives in the different countries started in the early 1980s. People of the Mura region ("Pomurje") in Slovenia protested against seven dams planned in their river; they stressed the importance of the use and non-use values of the Mura River for the local people (Smej & Žabot 1994). In 1989, the newly formed Hungarian regional NGOs started to fight against the big dam near Djurdjevac which was planned by Hungary and former Yugoslavia *(Figure 1).* In 1991, the Hungarian Parliament changed its policy on the Drava River project and decided to create the Danube-Drava National Park. In Austria, EuroNatur prepared a feasibility study for the development of the "Border Mura – the only free-flowing part of the lowland Mura in Austria". In Croatia, local NGOs such as the Ecological Society from Djurdjevac organised exhibitions and lectures and started a campaign "Living Drava". From the beginning, the typical Croatian naive painting which originated on the Drava was a part of this regional protest against the transformation of the natural landscape of the "Podravina" by a new hydropower dam at Novo Virje. Since 2000 the "Drava League" promotes the establishment of a transboundary biosphere reserve with WWF as the international leading organisation in cooperation with EuroNatur.

The main value of the Drava-Mura region is its high biodiversity. First evaluations reported that more than 70 pairs of White-tailed Eagles, 110 Black Storks and 400 Ferruginous Ducks bred along the rivers. More than 50 fish species and 54 dragonfly species had been registered in the early 1990s (Schneider-Jacoby 1994, 1996). Many of the species were indicators of a natural river course, including the Little Tern *(Sterna albifrons),* an excellent bioindicator for highly endangered natural rivers throughout Europe (Mohl 2001), which was used as the flagship species for the preservation (http://www.sterna-albifrons.net).

The old towns along the Drava and Mura from Graz and Bad Radkersburg to Osijek and Baja as well as from Ptuj and Varazdin to Pecs are well preserved and offer a unique view of the history of the defence of Central Europe against the invasion of the Osmanian Empire over several centuries. The Drava-Mura region was part of the military border, and towns like Varazdin have a long, fascinating history. Today also the small settlements are a part of the cultural heritage because they have preserved their charm and not been modernised. The region is famous for its large number of thermal spas but there is no infrastructure to connect health tourism with nature (Schneider-Jacoby & Reeder 1999).

Promotion and formulation

The first step to promote transboundary protection of the river ecosystem after the national protests against dams was the formation of a working group in 1992. It was clear that a good alternative for the regional development had to be found that was strong enough to compete with the dam projects. The German Ministry for the Environment supported EuroNatur with a grant to prepare a draft plan for the protection of the Drava-Mura region. NGOs from the four countries met for the first time and information on protected

Figure 1. Meeting of the representatives of the "Somogy" Provincial Association for Nature Conservation (Somogy PANC) and EuroNatur on May 2, 1990, at the European Green Belt and famous high bank of Visvzar in the Danube Drava National Park

areas and ecological values was gathered. A series of Drava-Mura conferences beginning in 1993 were important steps towards promoting ecological value and international co-operation. They were organised by EuroNatur and the appropriate local NGO. More than 150 people from the whole region and from international organisations such as UNESCO, Europarc and IUCN participated regularly.

Most important for successful project development was the vision which could be shared by all partners and which was strong enough to be accepted also by politicians. During the first Drava Conference in Kaposvar 1993, the idea of a Transboundary Biosphere Reserve (TBR) arose. It seemed that only international status for the region and a framework combining the cluster of different protected areas could encourage the development of transboundary cooperation. The region was considered as of high ecological and cultural importance for Europe.

In 1996, after the first collection of basic materials on biological diversity, protected areas and tourist infrastructure, the proposal was discussed in the thermal spa of Radenci again and an initial set of background material was sent to UNESCO. As a result, the countries were invited to apply for the nomination of the Drava-Mura region as a TBR (Schaaf in Schneider-Jacoby & Reeder 1999). A clear concept for transboundary cooperation was found and a transboundary protected area was created. From 1997–1999, the Dutch PIN-Matra Programme has supported the project. To prepare the establishment of the transboundary cooperation, a working group of GOs and NGOs with up to 40 people from five countries met to exchange the latest information on protected areas and to discuss the zoning.

The last conference followed in Zagreb in 1998 and was characterized by the conflict between the water management sector in favour of creating more dams and the foresters and NGOs promoting preservation and transboundary cooperation in protected area management (see overview-article by Schneider-Jacoby).

As a basis for the implementation process and for planning the transboundary area, EuroNatur and Dornier Satellite Systems have produced a satellite map 1:50 000 for the whole European Lifeline Drava-Mura and updated the GIS of the existing protected areas. The project was supported by the EU and the Centre for Earth Observation (Schneider-Jacoby & Reeder 1999). At the same time, with support of Euronatur and WWF a counterproposal to the planned hydropower dam at Novo Virje on the Drava was developed aiming at preserving and restoring this river section as a first concept leading to the future ecological management of the transboundary area (Mohl & Schwarz 2008)

Tourism development based on natural values

Using the biosphere concepts would have the following advantages in the tourism planning and development (Schneider-Jacoby 2002): One MDD-TBR shared by five countries would be unique world-wide. The BR concept respects national approaches and promotes sustainable use. And it is a very modern instrument for regional development and transboundary cooperation. The UNESCO encouraged this project already in 1997 *"as a means to foster peace between national states through mutual understanding and collaboration"* (Schaaf in Schneider-Jacoby & Reeder 1999).

Concerning tourism development a joint strategy is needed with a

(1) Core Zone as a very sensitive, strictly protected zone: *"Tourism on the river",*
(2) Buffer Zone, where the landscape is protected and managed: *"Tourism by the river",* and
(3) Transition zone, open to a regional sustainable development: *"Tourism along the river".*

Tourism on the river has to be in view of the sensitivity of the zone strictly regulated to protect rare plants and allow retreat of animals. It means that only few public or licensed visitor boats should be allowed to travel along the river in the border zone to maintain the impression of a virgin scenic riverine landscape as the international unique selling point of the region. Good practice are solar boats or traditional wooden rowing boats. At the Drava – in contrary to the Danube with its cruisers – the river cannot be developed as the main tourist axis. Water mass tourism on the Drava would attract people, but they would bring very little benefits to local people. At the same time the ecological and scenic value of the region would be destroyed or heavily impacted.

Tourism by the river means that the villages along the Drava can keep their identity. Various examples can already be encountered on the Danube such as the hunting museum in Szekszárd or the visitor centre of the Nature Park Kopački Rit in Kopacevo. Important is a *"Place at the river"* for each village and town as an entrance to the virgin river landscape. Therefore, zones for angling, swimming and nature observation have to be defined. The specific situation and local attractions should be used to find individual solutions for each village. Local people would be awarded by such an approach, they would consider themselves as a part of the park system and would feel recognized. The villages would profit economically as visitors would stay overnight and eat in the local restaurants. But most important such an ecological tourism concept would allow that the secret life of the river has space to endure.

The inrush of guests would be guided by the *Tourism along the river* programme. This has to create

- common means for public transport and international trails for hiking and biking (compare www.donau-info.org)
- a joint presentation for the unique cultural and natural heritage of the region
- a marketing platform for the regional specialities as for example wine

– an integrated concept for all regional attractions e.g. fish farms, parks, museums and festivals.

The aim of the joint programme has to be, for example, a bicycle trail from the Alps to the Danube, which will take guests at least one week or more to spend their holiday in the region. But also regions of Northern Croatia such as the Baranja, Podravina and Medimurje could be involved to profit from experience and visitors of the destinations in the neighbouring countries.

Government commitment

In 1997, Croatia, Hungary and Slovenia signed a letter of support for the PIN-Matra Project Drava-Mura to prepare the TBR. In 1999, a cooperation between the two leading protected areas Danube-Drava National Park (HU) and the Nature Park Kopački Rit (HR) started. In 2005, in a meeting between the Croatian Ministry of Culture and WWF, Croatia committed itself to support the development of a transboundary Biosphere Reserve jointly together with Hungary in the frame of the new intergovernmental cooperation agreement on environmental issues between both countries (Mohl in Schneider-Jacoby & Reeder 1999). Subsequently, coordinators on both sides were appointed and a Croatian-Hungarian TBR proposal was prepared (Bojić & Érdi 2008). In September 2009, a declaration was signed by Croatia and Hungary to jointly nominate the TBR at UNESCO. Hungary executed the plan in 2009; Croatia followed in 2011 *(Figure 2).*

In March 2011, in the Hungarian town of Gödöllö, near Budapest, in an act of great environmental leadership and transboundary cooperation, the Ministers responsible for environmental and nature conservation of Austria, Croatia, Hungary, Serbia and Slovenia with support of WWF signed a joint declaration to establish the reserve. The joint declaration was founded in the bilateral agreement between Croatia and Hungary from 2009. A transboundary UNESCO Biosphere Reserve will combine the cluster of more than ten single protected areas of the Mura-Drava-Danube region *(Figure 3)* and jointly manage the shared river ecosystem in a sustainable manner, encouraging economic impetus and development in the region. The Biosphere Reserve concept defines about 260 000 hectares of core and buffer zones and another roughly 540 000 hectares of transition zones (Mohl et al. 2012). The first meeting of the coordination board for the establishment of the MDD-TBR was held on 28 October 2011 in Budapest and backed-up by an international working group. This informal stakeholder meeting with more than 50 participants from all five countries was initiated by WWF and the NGOs working group. On that occasion WWF proposed a roadmap for the final establishment of the five country Biosphere Reserve (MDD-TBR) to be declared by UNESCO in 2013 including also the riverine areas in Austria, Serbia and Slovenia.

Figure 2. Signing ceremony of the five-country MDD-TBR in 2011

Conserving the „Amazon of Europe"

The NGO Drava working group and three conferences held in Kaposvar 1993, Radenci 1996 and Zagreb 1998 played an important role during the conception, promotion and formulation phases. The common vision of creating a Biosphere Reserve has proved to be a good basis for the work in the past 20 years. Grants from the German and Dutch governments, many private donations and recently the MAVA Foundation and the Asamer Holding helped the NGOs to establish a transboundary platform which is now supporting the GOs in implementing the MDD-TBR. Since 2000 the coordination shifted

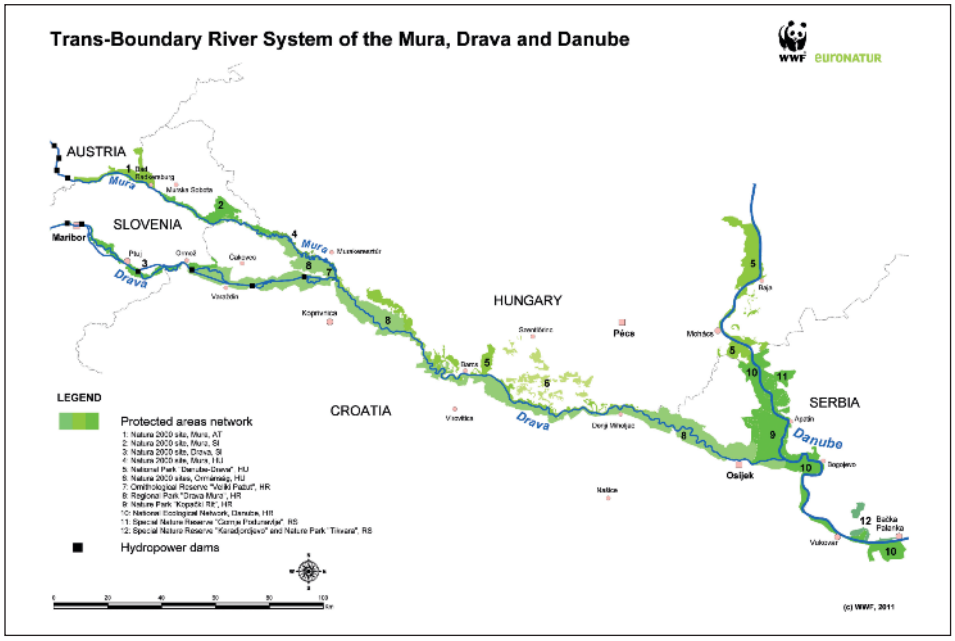


Figure 3. Map of MDD-TBR showing the European Green Belt and the five-country Biosphere Reserve

Figure 4. Protest at the Danube against unsustainable water management

from EuroNatur to WWF. The goal of the project is to support stakeholder meetings and to include a wide network of NGOs, but also protected area managers and local stakeholders in the MDD-TBR preparation.

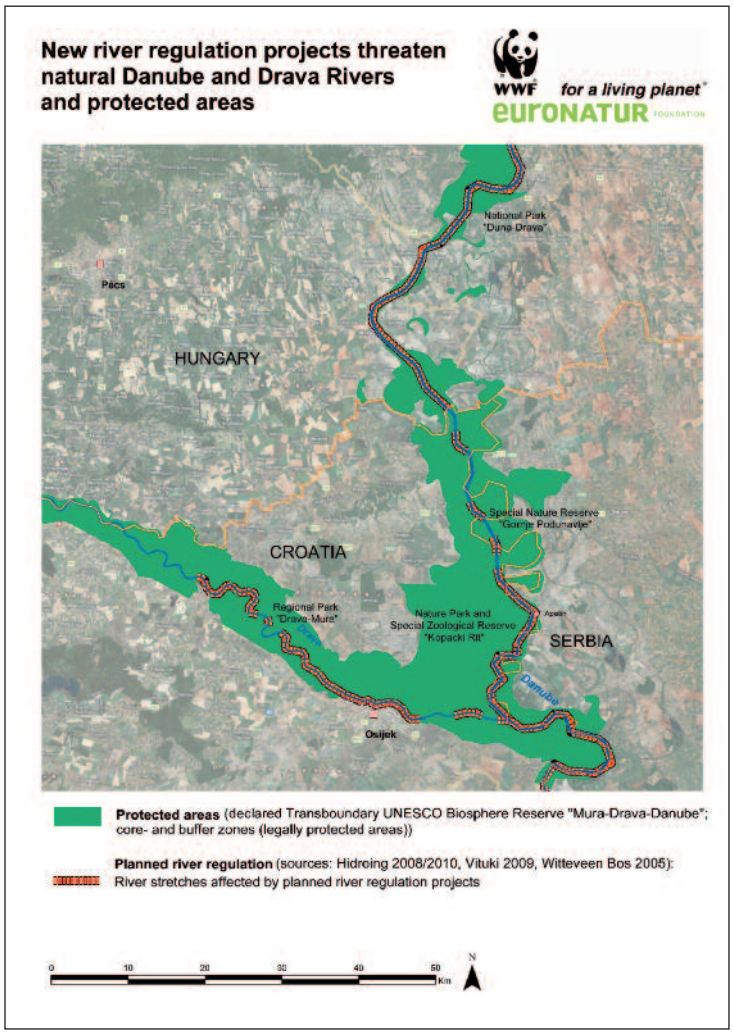
A key of success of creating national and international awareness and support for transboundary protection was always the fight by WWF, EuroNatur and local NGOs against nature-destructive projects especially along the Croatian-Hungarian Drava *(Figure 4).* These included new hydropower dams and outdated water management projects such as river regulation and gravel/sand extraction. Thus, over the last 12 years major deterioration of the river landscape has been prevented and better protection achieved.

In recent years major milestones have already been achieved. These include the establishment of a coherent protected area network across the five countries, halt of major destructive hydropower dam and regulation projects, the joint agreement on the establishment of the reserve as well as the start of the declaration of the reserve. However, there is still a lot to do (Mohl et al. 2012), as the river management has to change and huge impacting projects such as the regulation of the Mura confluence, canalization of different parts of the Drava and Danube inside the core zone of the TBR are still planned *(Figure 5).*

The goals of the NGO works are (see website: www.amazon-of-europe.com):

- Transform the customary river management into a modern and ecologic one (according to the EU Water Framework Directive)
- Stop river channelling and any further removal of gravel and sand from the rivers
- Restore degraded river stretches
  - Stop high peak mode operation of the Drava dam at Donja Dubrava
  - Halt any further construction plans of hydropower dams in the TBR area.

Figure 5. New river regulation projects threaten natural Danube and Drava Rivers and protected areas



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Hydromorphological assessment and situation of floodplains in the Drava Basin

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Introduction

The comprehensive characterization of riparian (river-floodplain) ecosystems by hydromorphological assessments and floodplain inventories is an important contribution to the long-term conservation and management of entire river basins and river corridors under various European Directives, namely the FFH (Flora Fauna Habitat), the WFD (Water Framework) and FD (Flood) Directives. Hydromorphological assessments help to evaluate physical changes of the riparian ecosystems (the deviation from the reference conditions), being also an important indicator for ecological status under the WFD. Floodplain inventories allow a longitudinal view of types and losses of these highly endangered habitats, and can be used to manage and restore floodplains.

The Drava Basin as largest alpine west-east tributary of the Danube is strongly influenced by hydropower use in the upper and middle river reach causing changes in the hydrological regime (multi-annual flow peaks) and an interruption of sediment transport (nearly all gravel is trapped in the chain of upstream dams). Sediment dredging and river regulation impact the lower river courses as well. In addition, dikes for flood protection disconnect in total about 77 % of the potential floodplains, which is slightly less than in most alpine and pre-alpine rivers in Germany and Austria (loss of 80–85 %).

However, the still rather dynamic hydromorphological conditions downstream of the modified stretches on Drava and Mura together with a still moderate level of river regulation over decades preserved several river reaches with the typical sequence of riffles and pools, building gravel and sand bars, dynamic banks and in the lower river courses large meanders with steep banks and point bars as well as some remaining extensive floodplain forests *(Figures 1 and 2).*

Methodology, CEN standards

Among various national approaches for small and medium sized rivers only the two CEN standards (CEN 2004 and 2010) offer a guidance framework for hydromorphological assessments in Europe. The individual parameters are subdivided into three main groups: the channel, banks/riparian zone and floodplain. The standard allows a sampling site oriented survey (on detailed profiles a data based inventory e.g. according to the British River Habitat Survey RHS) or a continuous inventory such as widespread in Germany, Austria or France. There is also space to adapted surveys concerning the length of surveyed river reaches, and individual assessment can be made for left and right channel, bank and floodplain features. The standard finally proposes a five class evaluation system according to the WFD, visualized e.g. in color-ribbon maps (compare *Figures 3 and 4).*

Unfortunately, current methods are not well intercalibrated, tested and applied as many freshwater assessment methods, e.g. for the biological quality elements under the WFD. As a cross-discipline of fluvial morphology (geography), freshwater ecology, and river engineering and management, hydromorphology should consider a wide range of parameters. The monitoring interval should be every six years (compared to annual monitoring for biological quality elements such as fish and macrophytes according to the WFD). However, the single hydromorphological parameters required officially

Figures 1 and 2. Two photos from the most intact Lower Drava reaches. Top: downstream of Legrad/Őrtilos (Mura confluence). Bottom: near Barcs (Credit: Arno Mohl, WWF)

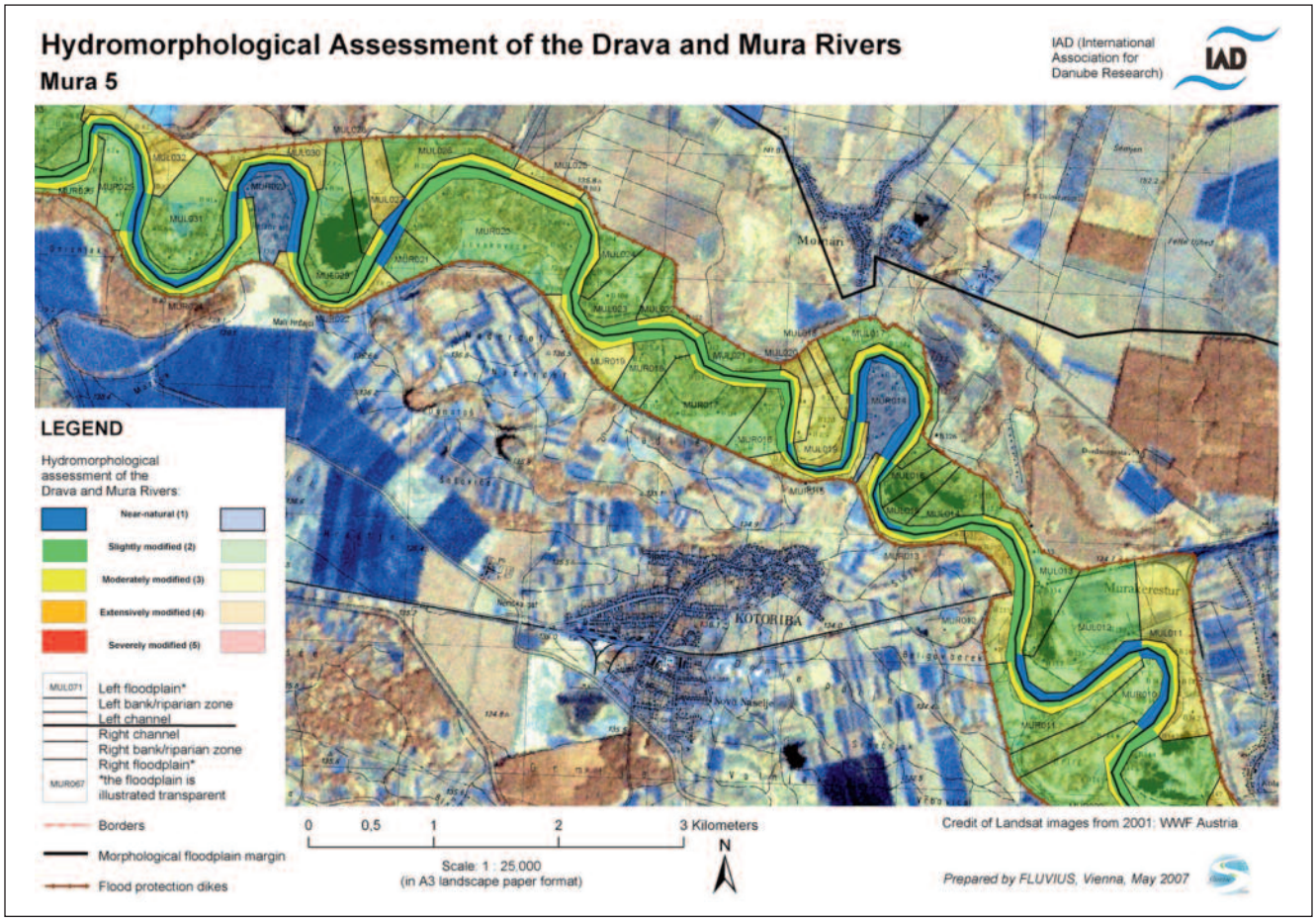


Figure 3. Detail sample map of the Drava-Mura survey 2005

under the WFD are different highlighting (1) the hydrological regime and river continuity, (2) the morphological conditions, and (3) the riparian zone (meaning "banks"). The floodplain is not considered as such.

Still problematic are the assessments of catchment indicators, such as a better consideration of sediment transport interruption, vertical exchange with the groundwater bodies (colmation of the river bed) and the scaling of large rivers. Most of the available assessments provide a good snap-shot for the current situation of a river stretch. Of course, this situation is the result of previous changements (e.g. dam construction), but the further development is not well represented in the assessment. An example is the permanent but slow channel incision with all its consequences (e.g. lowering of water tables with decreasing ecosystem health and missing rejuvenation of the very dynamic river-floodplain habitats). If most of the "reference" habitats and parameters are evident in reasonable size and quality the scoring will be high, even very high, which is also important to define "best available" or "reference stretches" and to compare rivers in Western Europe with rivers in Central-Eastern Europe or the Mediterranean area. However, factors such as the long-lasting channel incision and the changed hydrological regime (e.g. suppression of smaller flood events due to storage in reservoirs or hydropeaking) lead definitively to a lower score and, hence, a worse rating.

Finally, the linkage and correlation of the ecological status under the WFD and hydromorphological assessments must be strengthened. In this context, the "radiation effect and stepping stone concept" (German Council for Land Stewardship) should be considered, stating that hydromorphologically more intact reaches can have a positive influence on degraded reaches further downstream. The concept works also in the other direction, meaning that dam chains influence downstream intact reaches. These concepts are crucial for integrative River Basin Management Plans under the WFD to respect the conservation/restoration of river corridors and whole catchments.

Assessment of Mura and Drava

In 2005, a Mura-Drava survey (in total 306 rkm) was carried out as IAD pilot study on hydromorphology (Schwarz 2007), unique in its covered river length and detail for the Danube Basin. For the first time, "reference conditions" in form of river section types were defined. The method was applied and modified for large rivers. The Drava was subdivided into about 160 river segments, each independently for the right and left bank, and with a different length varying between 200 m and 5.3 km. About 500 individual river reaches were evaluated all together for the right and left river channels, banks/riparian zones and floodplains for the Mura and Drava Rivers. Each data set comprises about 40 single parameters. Based on the database and GIS application de-

tailed hydromorphological evaluation maps can be prepared *(Figure 3).*

Based on the highly detailed survey for the Lower Mura and Drava and additional data (mostly from national inventories as far as available in 2005 and own field surveys in all countries) an overview map was compiled showing the generalized hydromorphological status for the entire rivers *(Figure 4).* More than 500 km (40 %) are slightly modified or near natural *(Table 1).*

In Austria, the Upper Drava from Spittal to Oberdrauburg and a longer reach of the Upper Mura between Leoben and Murau – hosting the most important Danube salmon *(Hucho hucho)* population in Austria – were classified in the second class (the first class can be found only in the uppermost headwaters of the Mura and in some tributaries, e.g. Upper Isel River).

In Slovenia, the Drava is entirely used for hydropower production. Some very short free-flowing stretches just downstream of dams and the residual former channel remain. The long residual water stretches (also in Croatia) host partially still interesting riparian structures, but are totally altered by their hydrological regime (less than 10 % of discharge can be estimated). The Mura in Slovenia is characterized as entirely free-flowing river with strongly increasing hydromorphological intactness downstream, reaching the highest values in the border triangle with HR and HU.

Class after CEN	Stretches length	Portion of total length
1) Near-natural (blue)	108 km	9 %
2) Slightly modified (green)	400 km	31 %.
3) Moderately modified (yellow)	278 km	23 %
4) Extensively modified (orange)	132 km	11 %
5) Severely modified (red)	315 km	26 %

Table 1. Overall evaluation result corresponding to the map in Figure 4 (1233 km assessed river stretches: Drava 750 km, Mura 483 km)

In Hungary, the Mura meander bends further downstream are mostly fixed by bank reinforcements, but river-floodplain features appear frequently. The Hungarian Drava banks are located mostly in the National Park or other protected areas and are moderately regulated (only the city of Barcs is extensively modified and 15 rkm further downstream only third class situations were found). The rigth banks *(see Figures 1 and 2)* belong to the first class.

In Croatia, among the transboundary stretches with HU, in particular the Lower Drava still hosts several outstanding

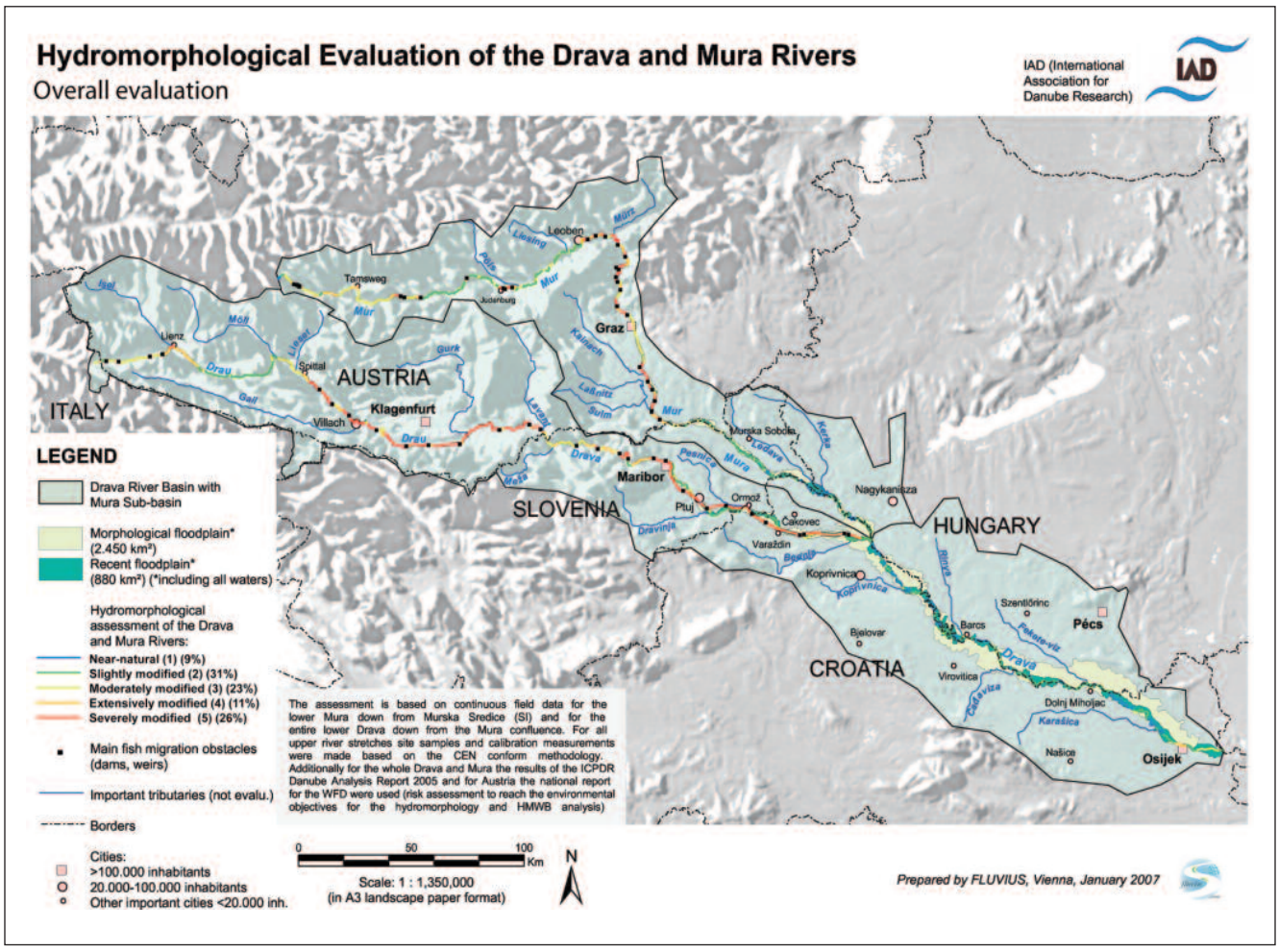


Figure 4. Five-class overall evaluation of the Mura and Drava (based on data from 2000–2005) and distribution of floodplains

meanders in the first class and long stretches in the second class. Only the city of Osijek as well as the 18 rkm to the confluence into the Danube belong to the fourth and third category, respectively. Where rivers have space the lateral shift and erosion of bedload material is significant: on the Croatian side upstream of the Repaš bridge and near Ferdinandovac (Novo Virje) two several 100 m long steep banks with erosion rates of some 10 m per year were observed during the last years. Both were altered in the meantime by bank revetments and groynes reflecting side-flows and fresh rip-rap (protection of infrastructure and gas production wells in the vicinity). The Lower Drava (rkm 30–70) is a unique example of self-initiating meanders and reduced channel incision: the river length increased significantly since the total rectification under the K&K monarchy around 1915 due to the abandonned maintenance.

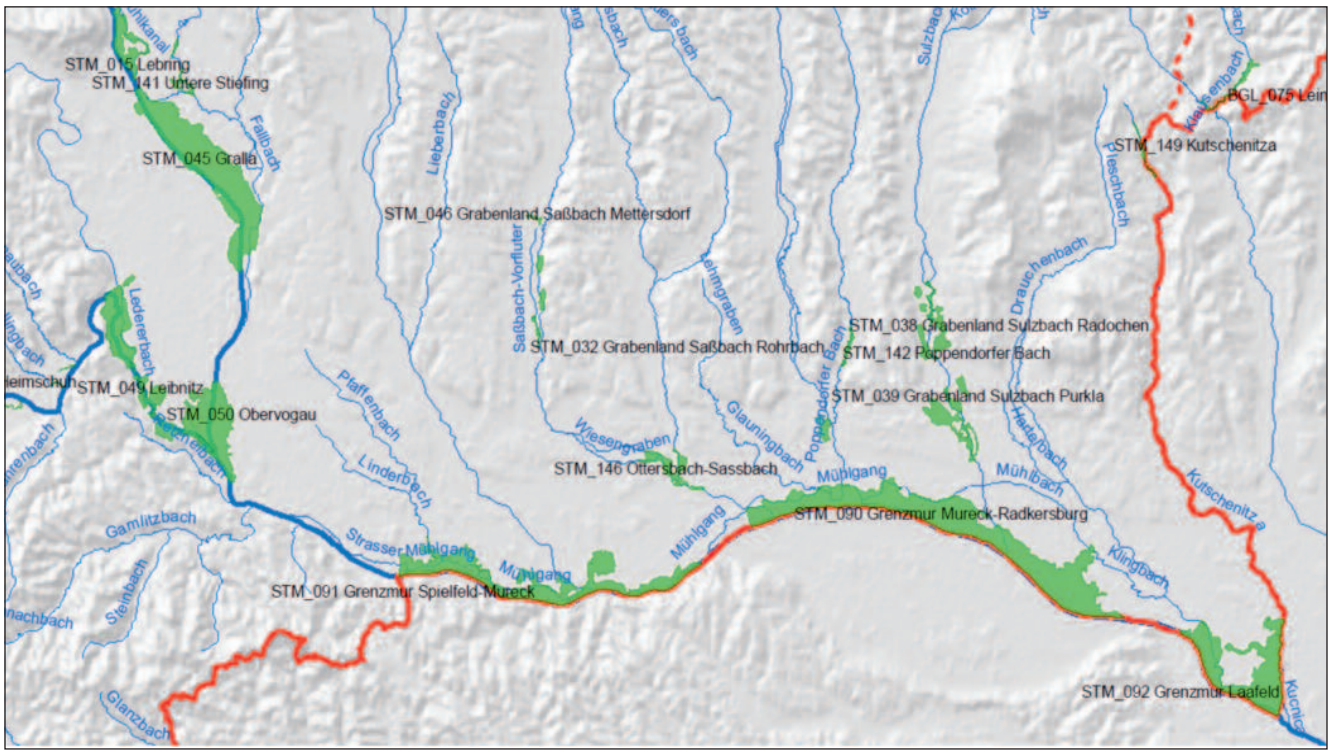
What is the situation today, about 6 years after this first survey? Since 2005 nearly 2 % deteriorated from class 3 and 2 to class 5 (two new hydropower plants south of Graz are under construction, another is currently planned in the free-flowing reach in the city of Graz); another more than 3 % decreased from class 2 to class 3 or even 4 due to river regulation (rip-rap, groynes) on lower river courses. In contrast, only about 2 % shifted from class 3 to class 2 including the restoration measures on the Upper Drava and the border Mura and the construction of fish by-passes to improve fish migration for some dams in Austria. The latter are only local measures – often covering only some 100 m – and the monitoring results proving the function are still missing.

This list of "active" (positive and negative) changes contrasts with the ongoing negative channel incision. The quick assessments of steep banks and sediment bars show a further slight decline allowing an estimation of a future reduction of class 1 (very high status) and class 2 (high status) sites by 2–3 %, shifting to moderately altered reaches (class 3). All together a negative shift of 2–3 % through all classes can be expected. Main reasons are the slight but long-lasting effects of the dam chain upstream (alteration of hydrological regime, interruption of sediment transport), but mainly the construction of new dams in Austria, the intensified activity to protect river banks (particularly in Croatia), and the still ongoing gravel and sand extraction (also by Hungarian companies). The intensive observations since the mid 1990s, including characteristic bird's observations (see article by Schwarz et al.) support the hypothesis of this unfavourable development. In late 2011, first tentative local measures to reopen a couple of side channels on the Hungarian side could be started for large-scale restoration higly needed and realistic in the Biosphere Reserve (see articles by Schneider-Jacoby).

Upstream-downstream effects and climate change

The impact of hydropower plants is considerable, in particular on the bedload of rivers and altered hydrological regime. Strong regulation works, e.g. along the Austrian and uppermost Slovenian Mura prevent any lateral movement and sediment supply to the system. Therefore, the incision of channels further downstream is still the most serious problem of the river system. Downstream of the dam chain completed in 1989, the incision is more than three cm per year summing up to about two m over the past seven decades. Due to intensive sediment extraction along the entire Lower Drava this incision rate remains significant even

Figure 5. Example for the mapping of floodplain objects in Austria



downstream of Dolnji Miholjac in the meandering lower course.

Further analysis shows the hydrological alterations due to hydropeaking (daily water oscillation, e.g. downstream of the last Croatian dam Dubrava about 1.8 m, which is reduced to about 30 cm, mostly by flow retention in side-channels on the stretch downwards to Barcs (120 km). This hydropeaking causes colmation, i.e. closure of the interstitial on gravel beds by fine sediments, which destroys habitats of benthos and fish species. There is no local solution available, although "hydrological alterations" are significant pressures under the WFD.

Without any doubt, climate change will have a strong impact on the whole ecosystem: Temperature already increased by 1–2 °C over the past 30 years in the Lower Drava and the Danube. Since the discharge of the Danube is greatly affected by the Alpine tributaries featuring a glacial regime with high flow in summer (Huss 2011), the dramatic glacier melt through global warming let us expect a drastic decrease of mean discharge until 2100. A decline of precipitation and discharges in the southeastern Austrian catchements by 2–3 % on average is already evident (GLOWA 2010). The conclusion must be to stop any further degradation of the river systems to enhance the resilience against these upcoming changes.

Floodplains and ecosystem services

By exploring historical, geological, geomorphological and pedological maps of the region, the overall morphological floodplain size (including all riparian water bodies) was estimated to about 2809 km² (Schwarz 2010). This is about 7 % of the total catchment area. The extent of active floodplains in the Drava and Mura including all natural as well as artificial water bodies in the main stream (especially the large barrages in Carinthia and Croatia) amounts to 652 km². The active floodplain was extracted mostly by up-to-date topographical maps showing all flood protection dikes and impounded stretches of the rivers. After the subtraction of the impounded reaches and reservoirs in the main stream with mostly untypical standing water (e.g. HEE Dubrava with 16 km², Völkermarkter Stausee 10.5 km²) the remaining area is about 550 km². The still existing floodplains of the Austrian Mura downstream of Graz are strongly, and with the new two dams entirely modified through a chain of hydropower plants. The main channel is monotonous and without lateral connections. Other impacted river stretches occur in parts of the middle course of the Drava in Slovenia and Croatia where the old river beds receive only about 5–10 % of the discharge resulting in a permanent decrease of near-natural floodplains. All together these heavily modified floodplains can be estimated to about 200 km². Thus, only about 350 km² of near-natural floodplains remain mostly in small patches.

For the entire Drava and Mura Rivers the overall loss of floodplains amounts to about 77 %. From the remaining 23 % most of floodplains suffer from considerable bed incision (locally up to 4 m), hydrographical alterations (flood retention of 1–5 year floods in the existing reservoirs and in the mountainous headwater reaches, damping the natural flood dynamics, or hydropeaking), and forest cultivation (large hybrid poplar forests along the Lower Drava). Finally, it must be stated that only very few larger floodplain areas remain under near-natural ecological conditions along the Drava and Mura (estimated 8000 ha), showing highly dynamic pioneer stands, wet softwood areas and scattered regularly flooded hardwood stands.

Despite of the overall loss, the local distribution and ecological potential of floodplains is different. Especially the Lower Drava hosts still large potentially flooded forests (mostly hybrid poplar plantations). The most important and significant exception is the Kopački Rit which still hosts some 2500 ha natural softwood stands and large flooded grass areas and shallow muddy floodplain lakes and channels. With a moderate incision of about 0.9 m or 1 cm/year (data from 1920–2010) the Kopački Rit reach of the Danube still provides rather intact inundation dynamics (in comparison, the nearby 80 km long Danube stretch in the Gemenc Beda National Park in HU eroded for some 1.7 m in the same period). However, this degradation may be intensified by new low water regulation works for navigation in the Danube. The already strongly modified, straightened and dredged Lower Drava course (from Osijek to the confluence) cannot contribute to stabilize the incision.

Since 2011, the "Austrian Floodplain Inventory" (Lazowski et al. 2011) describes in detail about 209 objects in the Drava-Mura Basin with a total size of 13 293 ha (including all tributaries). A floodplain typology comparable to that required by the WFD (freshwater typology of rivers) will support the further management and development of floodplains. To stipulate those activities a floodplain campaign is foreseen for the next years in Austria *(Figure 5).* Ecosystem services are more and more quantified for floodplains, specific areas and topics: e.g. if the hydropower project Novo Virje (project title nowadays changed into Molve 1 and Molve 2) would be realized, the potential loss of the Slawonian oak forest at Repaš by changing the groundwater situation after construction was calculated to some 4500 ha by the Croatian forestry.

Not calculated so far are services for nutrient reduction, self-purification, flood mitigation and groundwater supply, all services extremely valuable under the WFD, FD and FFH and highly dependent on functioning ecosystems. The importance of the river corridors for many endangered species is well documented e.g. by the Duna-Drava Nationalpark. In Hungary, with intensive land use for agricultural production, the river corridors and floodplains are the most significant areas of the Natura2000 network. Presently, flood protection measures are discussed as most of the flood defenses in all riparian Lower Danube countries are more than 30 years old. While the capacity of the main channel slightly increases due to incision and dredging, the floodplain itself is subject of

further aggradation and, hence, losing its important function of flood retention. This leads to dangerous situations in case of major floods. Studies on potential restoration areas in floodplains strongly indicate their importance for flood mitigation (Schwarz 2010).

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Impact on riverine breeding birds along the Lower Mura and Drava

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The observation of birds has a long tradition and is predestinated for ecological monitoring, in particular for specific habitats. Besides the ornithological wetland observation the monitoring of specific groups of „river birds" can be used as they are significant indicators for intact hydromorphological conditions. There are two groups, the open gravel and sand bar breeders, and the steep bank breeders. In the Lower Drava and Mura continuous monitoring data from 2005–2010 are available to compare the hydromorphological conditions during the past years.

Birds as riparian indicators

A unique database of riverine breeding bird species prepared by Stumberger (2005) and Grilica (2010) allows the indicative overall breeding development and the direct correlation of hydromorphological featurs and needed habitats.

Figure 1. *The Sand Martin, a typical inhabitant of steep natural river banks (Credit: H. Kretschmer/ 4nature)*

Figure 2. *The Little Tern is a typical breeder of undisturbed gravel bars, today occurring only in some pairs in the respective Drava reach (Credit: S. Steiger)*

A first group is composed of steep bank breeders such as Sand Martin *(Riparia riparia, Figure 1)*, Bee Eater *(Merops apiaster)* and King Fisher *(Alcedo atthis)* breeding in smaller and large colonies, typically distributed very densely along the lower courses of rivers. The largest colonies are built by Sand Martin reaching 100 to several 1000 pairs on one large steep bank along the main channel, followed by Bee Eater colonies with some 10–50 pairs. King Fishers do not need large steep banks and are distributed more scattered also along side-channels and oxbows. In particular, Sand Martin and King Fisher need the water bodies for feeding and are restricted to the rivers.

The second large group is given by gravel and sand bar breeders. Typical are the Little Ringed Plover *(Charadrius dubius),* the Common Sandpiper *(Actitis hypoleucos),* and the Little and Common Terns *(Sterna albifrons and Sterna hirundo, Figure 2).* The Little Tern has only a very scattered continental distribution (larger populations are living on the coast only) e.g. along the Lower Loire in France or the Middle Vistula in Poland. The Drava population is very small, but significant and highlighting the good conditions of the riparian habitats.

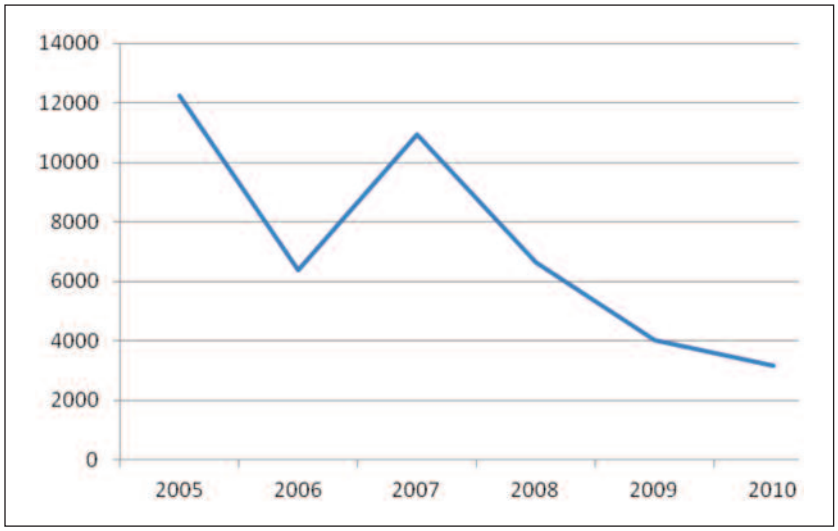

Figure 3. Breeding pairs of Sand Martin from 2005–2010 at the Lower Drava (0–255 rkm)

Significant decrease of riparian populations of Sand Martin

Based on estimations from the 1980s with some 30 000 breeding pairs, the number decreased from over 15 000 around 2000 to some 3000-4000 in recent times. The number of colonies between 2005-2010 varied between 17-39, showing the high variability and disturbance of the population. The size of most colonies decreased significantly *(Figure 3)*.

Among other factors, river regulation and the destruction of potential habitat sites are the most important causes for the decrease. The hydromorphological data show that natural steep banks were limited to some 21% in 2005 *(Figure 4A)*. As described in the article by Schwarz the deterioration (loss of natural banks) increased since 2005 by at least 2–3 %. Only a very few totally new steep banks were formed. Analyzing the availability of open gravel and sand bars in the historical scale *(Figure 4B)* the loss is even more significant (not even 10 % of originally available habitats remain). Since 1997 the situation slightly deteriorated and is dependant on hydrological events.

Conclusions

The usage of birds as indicators for the hydromorphological intactness of rivers strongly underlines the significant loss of riparian habitats over time. It seems that the correlation with selected species is much stronger than with some biological quality elements given by the EU Water Framework Directive. Hydromorphological assessments together with these bird indicator species can provide a high integration of structural intactness of main riparian habitats. Together with other indicator groups (fish, macrophytes/helophytes/plant pioneer species, macrozoobenthos, dragonflies, amphibia and beetles) riparian habitats can be assessed systematically. The negative trend should be carefully monitored and the realization of restoration measures, namely the removal of bank reinforcements and side-channel interruptions in conjunction with a stabilization of further channel incision should start soon.

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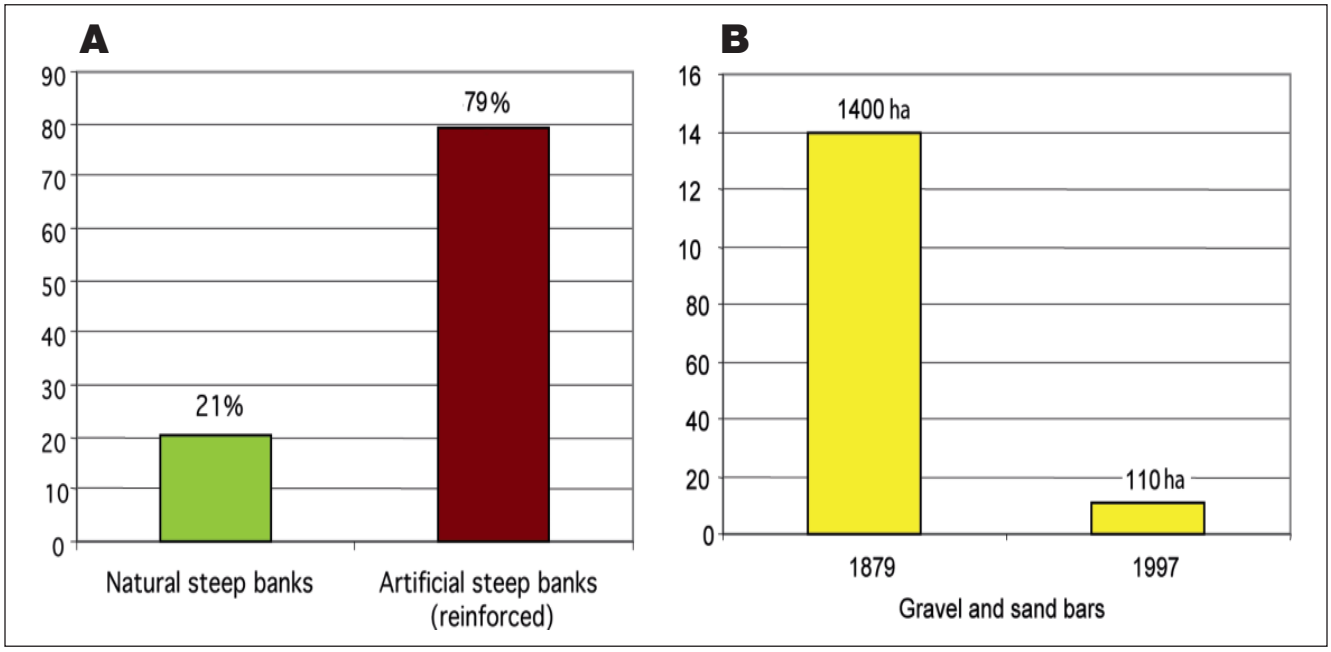

Figure 4. A. The status of steep banks in 2005 (Drava-Mura survey);
B. The reduction of sand banks/bars along a Drava stretch of about 45 km (Botovo-Ferdinandovac)

ISSN 2070-1292

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Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

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Hydrological catchment of the River Danube

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Layout:
Diener + Bachmann GmbH
Winterthurerstr. 58, 8006 Zürich
Tel. 0041 (0)44 440 11 50

Printing:
VDV Friedrich, A-4020 Linz, Austria