lifelineMDD

# Living Sediment

Interreg
EUROPEAN UNION
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lifelineMDD

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# Content

Mura-Drava confluence

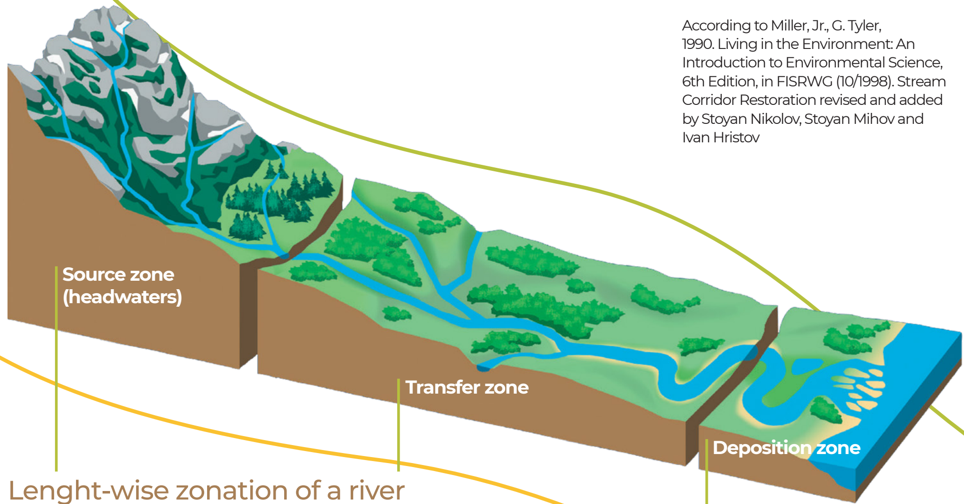
# Introduction

Rivers are complex, dynamic systems existing in a delicate equilibrium maintaining a balance between water flow and sediment transport. Under naturally dynamic hydrologic conditions, a river's balance in terms of dimension, profile, and pattern is enabled through the processes of erosion and deposition.

River birds that breed on so-called pioneer habitats such as gravel and sand bars, and on steep eroded banks need healthy river dynamics and active sediment erosion, transport and deposition processes in order to feed and breed. This gives them the role of so-called indicator species for healthy rivers, alongside fish and other aquatic animals such as larval stages of insects. All of these species react quickly to structural changes and provide good and quick indication of impacts on their habitats, whether positive, or negative.

When dynamic river processes are disrupted, not only does it affect wildlife and the nature that surrounds them, but the original state of the rivers changes significantly and their functions become disrupted. This consequently affects the life of local communities, in terms of availability of quality drinking water, the impact on flood defence but also on the agricultural activities that the population is engaged in. Exploitation of sediments outside the riverbed often involves a change in agricultural land, which endangers the existence of local communities that are traditionally connected to agricultural activity. In addition, activities that depend on a healthy river landscape (e.g. angling, tourism, recreation) are often endangering their own basis. In the end, we should not forget that rivers are deeply woven in the culture and tradition of the communities of people living next to them. Drastic changes in these areas are also significantly affecting the cultural identity of the communities living there. The aim of the **Living sediment** publication is to explain the importance of sediment for maintaining river dynamics and preserving habitats for different species. The publication also tackles threats and offers possible measures for restoring river dynamics and habitats.

According to Miller, Jr., G. Tyler, 1990. Living in the Environment: An Introduction to Environmental Science, 6th Edition, in FISRWG (10/1998). Stream Corridor Restoration revised and added by Stoyan Nikolov, Stoyan Mihov and Ivan Hristov




Lenght-wise zonation of a river

Steep slope and fast velocity. Large size sediments are formed and carried downstream.

Lower altitude, slower velocity and wider riverbed. Erosion and deposition processes are in equilibrium in the sediment transfer zone.

Very low slope, slow velocity, large bends (meanders) are formed and the river splits into branches. Most of the sediment deposits, including the finest drifts, are deposited in this zone.


Natural gravel bank on the river Drava



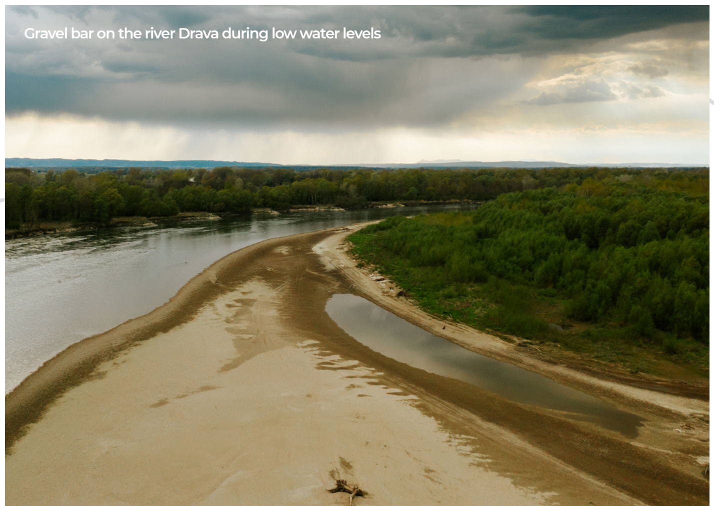
## Sediment types, origin and importance

River sediment is a solid material that is transported or deposited in rivers. Sediment is mostly created by the erosive work of rivers, i.e. by washing away soil, rock fragments and organic and inorganic material. Sediments are an integral part of the hydrological system and cannot be observed separately.

There are a number of ways to classify sediments, and some of the most common distinctions are based on the sediment texture, the sediment composition, and the sediment's origin.

Sediment texture can be examined through several variables - one example is grain size. Sediments are classified by particle size, ranging from the finest clays (<0.002 mm) to the largest boulders. Among other things, the grain size of sediments reflects the conditions under which it was deposited.


Dried side branch of the river Drava


Gravel bar on the river Drava during low water levels

| SEDIMENT TYPE | |
| --- | --- |
| BOULDER<br><br>COBBLE | A type of sediment that is characterized by larger particle size. One type is **boulder**, a water-washed or river-run surface stone of granite and sandstone, worn over the eons by wind, sand and rain. It varies in size (from large to smaller boulder). Another type, cobble, is a clast of rock commonly used as a building material, usually for covering road surfaces. |
| GRAVEL | A rock fragment which is rounded or elliptical in shape; due to erosion effects these rock fragments get naturally tumbled with flowing river water from mountains towards planes, making their surface smooth. |
| SAND | A finer sediment, composed of finely divided rock and mineral particles |
| SILT | A fine-grained soil that does not include clay minerals tends to have larger particle sizes than clays. |
| CLAY | A type of fine-grained natural soil material containing clay minerals. |

The exact nature of sediment is dependent on its location, and the geology of that location. **Glacial-type sediment** is common in mountain ranges, while low-lying rivers are more prone to collect **soil-based sediment**. In high-flow waterways, sediment transport will include local gravel, pebbles and small rocks. Harder rocks are less likely to become sediment, while soft rocks erode quicker and are easily carried away by flowing water. The physical make-up of transported sediment is strongly influenced by the geology of the surrounding environment and this, in its turn, influences further factors, such as the vegetation that occurs along a river's pioneer habitats. Sediment transport is often responsible for intermixing these geologic features by carrying mineral particles far away from their origin.

Many ecosystems benefit from sediment transport and deposition. Sediment is necessary for the development of aquatic ecosystems through the creation of benthic - at the bottom of the river - and riparian habitats - directly along the river, spawning areas, and nutrient replenishment. They help form the groundwater aquifer and improve water quality through surface and subsurface exchanges, i.e. natural filtering processes.

Sediments and their main grain sizes are one of the main factors determining the morphological river type (see our publication *Living waters*). High gradients tend to lead to the formation of


Sediment movement pattern visible on the Danube sand bar during low water levels

braided/anabranching stretches in the case of bedload surplus, while straight river types are present in the case of comparable gradient conditions and bedload deficiency. At low gradients and dominance of fine sand and silt, meandering rivers or river sections are formed. At constant gradient, meandering sections tend to form at low discharges, but braided sections at high discharges.

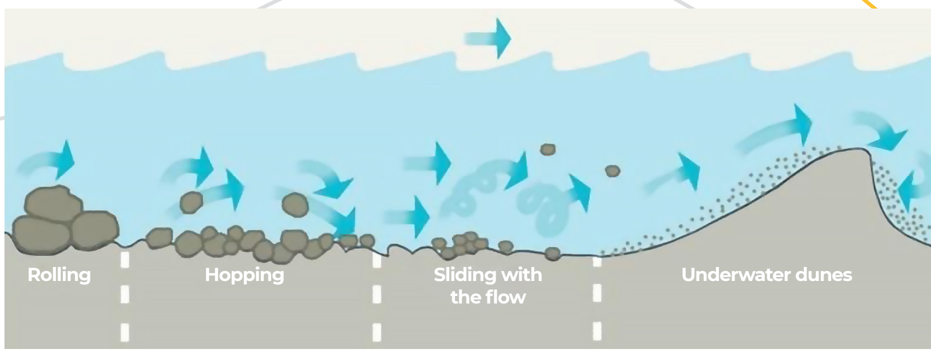
A change in one of the parameters can lead to the formation of a different morphological type or corresponding transitional situations. Sediments also play a critical role in the habitat composition. The faunistic composition is a consequence also of the sediments. This means that an alteration of the sediment dynamic and sediment composition will also lead to a shift in the community composition.

Sediment is needed to give some force to the river and make side erosion possible in the first place. Downwards erosion does take place due to the force of the water and without sediments there is no deposition, causing riverbed erosion. This in its turn leads to lowering of the water table, which is connected to the riverbed and groundwater level. Agriculture is affected through these processes due to the drought effect: groundwater levels connected to the riverbed also decline, which causes water scarcity or intensifies it during prolonged droughts.

According to Dunne, Thomas; Leopold, Luna B., 1978. Water in Environmental Planning, W. H. Freeman and Company in FISRWG (10/1998).

Stream Corridor Restoration, revised and added by Stoyan Nikolov, Stoyan Mihov and Ivan Hristov

## Forms of sediment movement



Sediment extraction from the riverbed

## Factors influencing the change in sediment composition

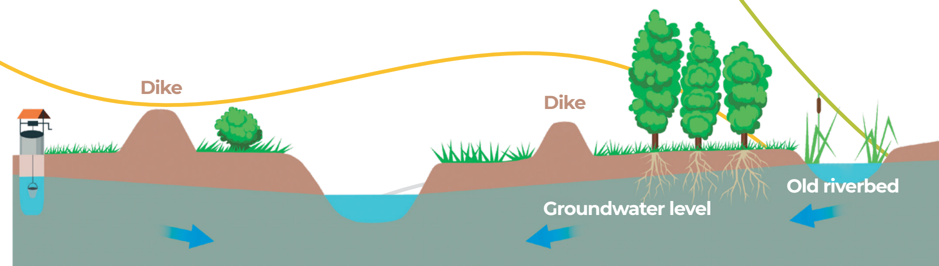
There are numerous factors that affect sediment composition, but we can group them around three main cause groups: gravel and sand extraction, channelization and sediment retention in the catchment.

### Gravel and sand extraction

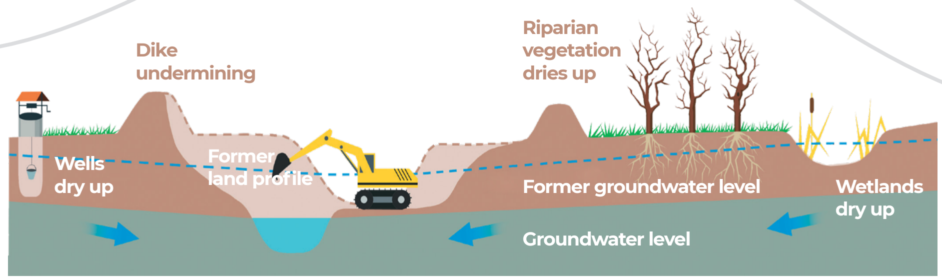
Natural sediment transport as one of the key elements of dynamic riverine systems is seriously endangered by gravel and sand extraction. It speeds up the erosion process of both the banks and the river bottom, and it has a huge impact on biodiversity. This can lead to a disruption of riverine processes and a reduced connectivity with the floodplain. Specialised species such as larval stages of insects are particularly affected through or may even be eradicated by the extraction of bottom sediments. Without sufficient sediment supply from upstream, dynamic processes in the river are significantly reduced. Stretches with a lack of sediment input tend to undergo a gradual destabilization of morphodynamic processes and incision of the riverbed and consequently a change from a multi- to a uniform channel system.

### Impact of barriers

Sediment transport interruptions disturb the dynamic balance between transport and sediment deposition which causes rapid hydraulic changes. Lack of sediments leads to increased river depths, increased erosion of





the river bottom and a gradual riverbed incision. Barriers play a major role in this regard as they prevent the natural transport of sediments. Combined with bank protection that prohibits side erosion and lateral introduction of sediments, it becomes impossible to compensate for sediment deficits from upstream.

### Channelization

River channelization is a common problem for sediment disruption. Channelization refers to a host of different strategies of river engineering. Fundamentally, a relocated channel replaces a natural section of a river with an artificial channel, which is often shorter and steeper than the natural one - it has different bed and bank material, has no floodplain, and cuts across tributaries. Channelization affects every aspect of river geomorphology and ecology. Some of the direct consequences of channelization include loss of the river's connectivity with the floodplain, changes in water quality, and loss of aquatic habitats. Moreover, since natural erosion of banks is prevented, the river erodes the riverbed which leads to additional incision and change in sediment composition.


Grey heron (*Ardea cinerea*)

## Key bird species - indicators of river dynamics

There is one group of living beings that need a dynamic river with a healthy sediment balance more than any other. Birds that nest, or also feed and rest in highly dynamic habitats of riverine ecosystems, such as steep banks, gravel and sand bars, are highly threatened mainly due to the habitat loss connected to the transformations rivers have been subjected to over the past few centuries, and even more during the recent past.

This is also the case in the UNESCO 5-country Biosphere Reserve Mura-Drava-Danube. Whereas the three rivers' sections flowing through that area are still mostly free-flowing, even here heavy interference with their courses has had a tremendously negative impact on the distribution and the population sizes of river birds.


Common tern (*Sterna hirundo*)


Little tern (*Sternula albifrons*)


Common kingfisher (*Alcedo atthis*)

Seven bird species are considered so-called *indicator species* that show the level of naturalness of river ecosystems. The common and little tern (*Sterna hirundo* and *Sternula albifrons*), common sandpiper (*Actitis hypoleucos*), little ringed plover (*Charadrius dubius*), kingfisher (*Alcedo atthis*), sand martin (*Riparia riparia*), and bee-eater (*Merops apiaster*) react quickly to structural changes and provide good and quick indication of impacts on their habitats, whether positive (e.g. restoration actions) or negative (e.g. river regulation). Finally, the birds are easy to recognize, to identify and to monitor.

The common and little tern, common sandpiper and little ringed plover are all gravel and sand bank breeders. Like many other gravel or sandbank breeders, loss of suitable nesting sites is often caused by habitat destruction (river regulation, gravel and sand extraction, new hydropower development) or human disturbance. Especially during the breeding season, the **common and little tern** are particularly vulnerable to human disturbance at breeding sites. Hydropeaking can be problematic for their nests and chicks. This is a fast and partially extreme flooding caused by the operation of hydropower plants and repeated in small intervals (sometimes several times a day), making adaptation of any species to such conditions impossible. Heavy floods can also emerge due to long snow melting periods or quick floods after heavy 2-3 days rainflow on the upper catchment.


Little ringed plover (*Charadrius dubius*)


Sand martin (*Riparia riparia*)

This could also influence nesting since water can take away nests. Little terns are under the biggest threat of disappearing from the TBR MDD area since they only nest on natural gravel bars.

Also, the **common sandpiper** breeds at the Mura and Drava rivers. The species' distribution is restricted to dynamic and natural, more or less free-flowing sections, with islands and near-natural river banks. High breeding densities can be found at the Drava upstream of the town of Barcs, Hungary. Further downstream, natural breeding sites are restricted to a few places due to the high percentage of the artificial river bank protection. The **little ringed plover** needs bare or sparsely vegetated gravel or sand bars, laying its disguised eggs on blank sediments. It is mainly threatened by the degradation and loss of its preferred habitats, e.g. because of river regulation, new hydropower plants, or sediment extraction. Locally, the threat posed by recreational activities can be another main factor for the decrease of the breeding population.

**Sand martin, common kingfisher** and **European bee-eater** are all steep bank breeders, therefore they are indicator species for an active lateral erosion of rivers.

**Common kingfishers** do not breed in colonies, therefore they also tolerate nesting in a smaller and partially overgrown sandy or silty steep wall. The most significant threats to this species are harsh winter conditions. Chemical and biological river pollution, as well as channelization of streams, vegetation clearing and also overgrowing of the steep wall with invasive species (e.g. Japanese knotweed) later in the season were found to be additional threats.

The **sand martin** breeds in colonies and needs bigger steep natural river banks to burrow its nests. Periodical erosion of the bank is crucial as birds prefer to have new nesting holes every year. Loss of breeding sites due to human activities, including river regulation, is the most important threat to this species. The use of pesticides can lead to a loss of prey species (insects).


Common sandpiper (*Actitis hypoleucos*)

The main threats to the **European bee-eater** are the loss of breeding habitats along rivers due to river regulation and the decrease of not only wasp and bee populations but insect populations in general due to numerous complex reasons, alongside widespread pesticide use. Additionally, large numbers are shot and killed during migration in the Mediterranean Region. They get shot by beekeepers due to "stealing and eating their bees", or they deliberately destroy nests on light plateaus to prevent them from settling there.


European bee-eater (*Merops apiaster*)

Aerial view of hidden groynes on the Drava, a less restrictive form of bank protection

Example of an embankment

## Habitat and species endangerment factors

Anthropogenic disturbance has significantly accelerated the endangerment factors of habitats and the species that inhabit them in the TBR MDD area. It often refers to inadequate river management and adapting the river structure for human needs. Some of the most present factors are building different types of infrastructure for bank protection, straightening of the river course, cutting of meanders and cutting of side channels, gravel and sand extraction, construction of dams, and others.

One of the most negative anthropogenic impacts is **river straightening and the construction of embankments** in the mid and lower streams of rivers. The main purposes of these actions were to provide more agricultural and construction land for developing the economy, and to protect against flooding. These activities in many cases did not solve, but intensify the problems. The main consequence of river "straightening" by building dykes and cutting off meanders from the rivers is that the river becomes shorter and steeper. The new river is narrower due to the artificial embankments and the active floodplain also narrows due to the dykes built on its banks. All of this results in higher flow velocity and higher water levels during floods. The faster flow itself results in intensified erosion of both the river banks and bottom. The river banks are protected by embankments, so limited erosion appears on them. But the river starts "eating" its own bed and digs into the ground until it reaches harder bedrock. The uniform flow velocity and lack of space for the river causes all riverbed structures to disappear and the river no longer works as a friendly habitat for any species.

Embankment structure

Another, even more serious problem related to riverbed incision is the **lowering of groundwater levels**. The problem is particularly increased when these processes are combined with gravel extraction. The river and neighbouring groundwater

Abandoned ship for sediment extraction

are interconnected bodies, and the drop of water levels in the river could lead to a parallel decrease in the groundwater level because the river acts as a draining channel. The lowering of groundwater levels further results in withering of riparian trees and a general drainage of adjacent farmland; wells run dry and boreholes dry up.

A mechanism often used for altering river streams is **cutting of meanders** for agriculture and navigation purposes. Although used more often in the past, even today there are attempts to manage and change the river flow, as can be seen in numerous examples on the Danube River (e.g. in Hungary, the Danube was shortened by cutting-of meanders from 472 km to 417 km). River meanders have been removed to repurpose the floodplain for development or providing flood protection. However, human modification of rivers too often leads to unintended consequences on river flows, sediment transport, riverbank stability, and freshwater habitats, making river meander loss a significant public concern. Cutting of meanders can reduce the length of the river and reduce local flooding regimes and sediment deposition patterns on the floodplain. When a meander is abandoned, the channel's slope increases, thereby increasing flow velocity and the river's ability to carry sediment. For flood protection and land reclamation purposes, side channels have also been disconnected from the main river course, severely impacting the river's morphology and ecology, including the floodplains. In addition, straight stretches mostly develop few morphologic structures, such as cut banks and slip-off banks, scours, and gravel bars.

This leads to further disconnection of the side channels from the riverbed, even during floods. As a consequence, the vegetation of gallery forests, wetlands, and meadows along the side channel changes: as the groundwater table drops together with the riverbed incision, water-loving plants are replaced by more dryness-resistant plant species, softwood gallery forests are gradually replaced by hardwood forests. The modification of habitat conditions can cause a risk of spreading invasive alien



Urban development on the river banks constrains natural river dynamics

species. The landscape changes and so do the habitats, becoming less suitable for previously resident animal and plant species; thus the shift in riverbed characteristics has long-reaching consequences far beyond the riverbed. Compared to the pre-1815 state of the rivers in the TBR MDD the number of gravel and sand bars dropped from 1,053 (4,148 ha) to 491 (711 ha), which corresponds to a size reduction of 83%.

Disturbance and increasing pressure from **nature tourism, angling and water sports** is another endangerment factor. With a lack of clear visitor guidance, aligned with nature protection's goals, paired with the increasing interest in recreational activities by and on the river, pressure on the remaining few sand and gravel bars increases. Disturbance to birds surveying such bars suitable for nesting, or nesting and protecting their nests during mating season (April through July) may cause nest abandonment or, gradually, the overall extinction of the species.

As mentioned previously, **gravel and sand extraction** from the riverbed as well as from the banks leads to a loss of sediment and thus to habitat loss. Birds rely on gravel and sand banks for breeding and nesting, while fish species depend on the structures in the riverbed and on the river

River constrained by dikes and groynes

Dubrava Hydropower dam, the last one on the river Drava

bottom to reproduce or to forage for food. Without sufficient sediment supply from upstream, dynamic processes in the river are significantly reduced.

**Dam construction** is also one of the problems in the TBR MDD area. The upstream chain of hydropower dams interrupt sediment transport, which highly impacts the ecosystems downstream. Several of these impacts are relevant for river bird species. First, the reduction of sediment load leads to an increased erosion of the riverbed, resulting in riverbed incision and thus habitat loss for river bird species. Second, to reduce sedimentation in reservoirs, sediments are flushed, leading to unnaturally high concentrations of fine sediments in downstream riverine systems. This high amount of fine sediments covers gravel and sand-bars, leading to habitat degradation for species that depend on these bars or islands. Another extreme effect of hydropower in terms of how it affects fish, birds, but also other species downstream, is **hydropeaking**. For birds or even reptile species who prefer to nest on primary habitats such as gravel or sand bars, hydropeaking makes such surfaces uninhabitable: the area which is close enough to water but safe from such frequent increases in water level cannot be easily identified. If fluctuations are large enough, no gravel bars are left high enough to be spared from sudden flooding several times a day, and thus become unsuitable for nesting.

**Water abstractions for hydropower** can leave stretches below dams far below the ideal ecological demand. Dams also impact water quality by causing a temperature rise in the reservoir, leading to further decreased oxygen levels that has a great impact on the species looking for prey by the river, but also water organisms that inhabit the river.

**Flood protection dykes** are structural barriers that protect communities against costly effects of inundation. Still, this kind of infrastructure disconnects floodplains from the main river, and their water household becomes dependent on precipitation instead of cyclical level changes in the river itself. This leads to transformation or even loss of habitats for different bird species.

## Climate change

Climate change effects, such as more frequent and intense rain events, can increase e.g. soil erosion on agricultural areas close to rivers and result in greater amounts of sediment and nutrients being washed into rivers, lakes and streams. More frequent and intense rain periods can increase sediment loads from stormwater runoff. Higher water levels, and higher flow velocity can increase erosion and result in increased suspended sediment (turbidity) in water bodies as well as affect normal distribution of sediment along rivers. These climate impacts can challenge efforts to maintain water quality through effective erosion and sediment control management efforts.

Interruptions in the river corridor and habitat changes caused by dams (hydropower station, artificial lakes and other man-made structures)

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Aerial view of the Mura-Drava confluence with visible gravel bars and side branches

## Lack of transboundary cooperation and harmonisation

The UNESCO Biosphere Reserve Mura-Drava-Danube stretches across five different countries. Although administrative borders exist, nature does not know borders. However, since the Mura, Drava and Danube mark country borders in parts of their length within the biosphere reserve's area, political and practical cross-border cooperation and coordination is inevitable. Mainly due to political circumstances up until a recent past, but also due to their cultural and economic diversity, transnational exchange between these countries has been hampered for decades. Whereas the 5-country biosphere reserve is a major step towards cross-border cooperation and several instances and projects of joint effort across borders are known, there is still a lot of potential to improve cooperation. So far, a joint strategy for protection of species in the target area has not been put in place. A joint management structure for the biosphere reserve is still to be implemented (2022). Advances in protection measures are uneven across borders, which has led to measures conflicting in some situations. Nevertheless, over the past several decades intensive work has been done on joint solutions that contribute to the overall improvement of the state of nature in the biosphere reserve, and have a favorable impact on both wildlife and humans.

River Drava bottleneck with visible gravel bar and different types of river infrastructure

Sand bar on the river Danube

## Restoration measures as part of solutions

Dubrava hydropower dam reservoir

Rivers like Mura, Drava and Danube in the TBR MDD are naturally complex systems with many different habitats along a longitudinal and lateral gradient. Wetlands are one of those important habitats since they represent essential breeding sites for many bird and fish species. Many existing water engineering structures, such as protection dykes, are causing wetlands to eventually dry-up, losing to a large extent their critical ecosystem role. This pointed to existing problems in water management that require a different approach to river and habitat protection.

In the recent years of changing environmental perceptions, the understanding of natural river services together with the awareness that most of the endangerment factors are actually induced by human activity, triggered the first attempts to restore the natural state of rivers. **River restoration** in its broad sense means to return life, vitality and functioning to rivers. It describes the process of improving and regenerating the structures, habitats and processes of river ecosystems through different measures. River restoration in a transboundary river corridor needs an integrated approach to be effective, efficient, use synergies as much as possible and provide benefits not only locally but on a transboundary scale. The focus lies on measures for sediment mobilisation & improvement of the sediment balance.

The goal is to re-establish freshwater ecosystem functions and related physical, chemical, and biological characteristics. There is no universal recipe for river restoration and measures depend on many different factors such as hydromorphology of the rivers, biological quality and pressures. Restoration measures also depend on the goals and desired impact on the landscape. One example of restoration measures is the **removal of bank protections and widening of the riverbed**. This allows the river to naturally widen and shape its bed, which reduces the sediment transport capacity in the river. The removal of bank protections and increasing the lateral space available for the river helps to stabilise the bed levels, which have incised as a result of channelization. By removing bank protections we allow natural dynamics in the form of bank erosion, which always balances out in deposition. A new dynamic of steep natural banks and gravel bars creation is enabled, which also creates breeding habitats for birds. If there is enough space available for the river to form a new channel and to migrate within a corridor, there will always be bank erosion at varying locations, and always deposition somewhere else.

Restoring rivers and wetlands depends on cooperation between a broad range of different stakeholders, from local land owners and users, to authorities, government officials and other relevant stakeholder groups. In order to be efficient and effective, it is necessary to achieve a partnership among water, nature and forest management authorities, local anglers and hunters, but also nature conservation organizations, which will further contribute to river and wetland restoration for the benefit of nature and people. This cooperation will lead to promoting knowledge and raising awareness, but also to building trust and giving inspiration to future stakeholders to engage in such initiatives.


River Mura near confluence

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