PROMOTING MEASURES TO ENABLE FISH MIGRATION IN THE DANUBE RIVER BASIN

Interreg
EUROPEAN UNION
Danube Transnational Programme

DANUBE REGION strategy
Water Quality

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Acknowledgement: Project co-funded by European Union funds (ERDF) with the financial contribution of partner states and institutions. This brochure was prepared by the EUSDR PA4 from the project DTP PAC2-PA04 (Acronym: PA04 Water Quality).

We are also grateful to Gertrud Haidvogl, Thomas Hein and Karl Schwaiger for their helpful comments on the final version of this brochure.

2021 | prepared by: Gábor Guti

CONTENT

1. EXECUTIVE SUMMARY AND KEY MESSAGES

BACKGROUND

The EUSDR Water quality priority area – relevance of the topic of migratory fishes

The Water Quality Priority Area (PA4) is one of the eleven priority areas of the EU Strategy for the Danube Region (EUSDR) with the main objective of executing integrated river basin management measures in the Danube Region in line with the EU Water Framework Directive and with the International Danube River Basin Management Plan (DRBMP) in order to protect human health and freshwater ecosystems.

The EUSDR PA4 puts a strong emphasis on the protection of water resources and one of the the seven targeted actions aims to promote measures to enable fish migration in the Danube River Basin. "Water quality" priority area aims to promote measures towards reducing knowledge deficits and to

- raise broad public awareness and political commitment for the Danube sturgeons as flagship species for the Danube River Basin and for the ecosystems and biodiversity of the Danube River basin as a whole,
- foster sturgeon conservation activities including protection of habitats, restoration of fish migration routes and ex-situ conservation measures,
- close knowledge gaps concerning monitoring of pressures and planning of measures for fish migration.

In line with the above goals, the current brochure, developed within the framework of the DTP-PAC2 PA04 (PA04 Water Quality) project, aims to give an overview on the topic of migratory fish, to introduce the issue of migratory fish, by also outlining the challenges and possible solutions, best practices available today.

MAIN CHALLENGES AND PROBLEMS THAT MIGRATORY FISH SPECIES ARE FACING

Why migratory fishes and their preservation is important to us?

Freshwater biodiversity is of outstanding global importance. One third of all vertebrate species occur in freshwater, although surface freshwater habitats contain only about 0.01% of the world's water. The rivers and their ecosystems constitute valuable natural resources in economic and social terms, and their conservation and management are critical to the interests of all human society and governments. The exploitation of rivers is seen by many as a tool for economic development, but economic forecasts often rule out or underestimate the loss of ecosystem services and the costs of reducing the associated environmental risks. ***Fluvial ecosystems have suffered the most intense intervention*** of all ecosystems over the past century of human history, with severe negative consequences on fish biodiversity.

Migratory fish, especially sturgeons are particularly sensitive to environmental changes due to their extended longitudinal migration range and long-lasting reproductive cycles, therefore their native populations can be considered one of ***the best indicators for the integrity*** of the ecological corridors and fluvial habitats in the Danube River system. The wide-ranging migratory species, whose habitat requirements include many other species, can also be considered as umbrella species. Analysis of complex habitat needs of an umbrella species can help to determine the most suitable locations for restoration and protection to maintain viable breeding populations for several species.

As it will be introduced in the following chapters, there is a big variety of migratory fish species in the Danube River Basin. Despite their diverse appearance, danger can arise from human activities (such as fishery, hydropower utilisation, water storage, flood protection, navigation or even waste and sewage treatment), as a result of which the migratory fish population will become extinct in the coming decades. A long-term decrease in population size can result in a loss of genetic diversity and higher risk of extinction.

Destruction and fragmentation of fluvial habitats are the leading causes of down-trending population dynamics of migratory fish. Without adequate connectivity, river ecosystems cannot function properly, and without well-functioning ecosystems, the diversity of their biological components and ecosystem services are at risk. Restoring and ***managing ecological corridors*** within river systems are the central issues for improving and securing migratory fish populations. The loss of ecological connectivity is most often a consequence of policy and management decisions. While the focus is on fish migration, conservation aquaculture should be considered as well to emphasize the need for immediate actions to allow the time to restore the migration corridors. These measures have to be coordinated and synchronized properly.

What kind of solutions exist and how governance should facilitate the process to preserve and ***restore viable populations*** of migratory fish species in the Danube River Basin? The brochure outlines and answers these questions and introduces the best practices towards preserving healthy populations.

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2. SETTING THE SCENE

Introduction to migratory fish species of the Danube River Basin

The Danube River flows 2,780 km from its source in the Black Forest Mountains of Germany to its delta-like estuary at the Black Sea. Its vast drainage of 801,463 km^2 includes some 300 tributaries and a variety of natural conditions (ICPDR 2004). Primarily as a result of its historic connection to the Ponto-Caspian region, the Danube River system harbours the richest fish fauna of any European river. Diverse habitats created by the river and its tributaries host a unique mix of species with about 100 fish species (Balon et al. 1986, Holčik et al. 1989).

Most of the fishes in the Danube depend on connectivity between upstream and downstream river reaches, or between river channels and floodplain habitats. Periodic migration through a particular area of the river systems often plays an essential role in the life history of fluvial fish. Migratory behaviour is an adaptation by using movement to exploit a changing and spatially extensive environment. The habitats and resources that maximize growth, survival and reproductive success during different life history phases are typically separated in time and space (Gross et al. 1988). Benefits from migratory movements may come in the forms of access to resources, strategic positioning of gametes in locations that offer advantageous conditions for the developing embryos and offspring, or refuge from predators and adverse environmental conditions. Potential costs of migration include the energy expenditure associated with moving, predation risk, erroneous navigation, etc.

Seasonal migration up or down rivers involves a cyclic alternating movement by individuals between at least two, but more often three habitats (feeding, breeding and survival). The main types of seasonal migrations of fluvial fish are:

- *Spawning migration:* Adult fish move toward spawning grounds, usually against the current.
- *Feeding (post-spawning) migration:* Adult fish leave the breeding grounds, spread and return to their main feeding habitat.
- *Refuge-seeking migration:* Fish move from their feeding ground to a survival habitat when unfavourable conditions approach, as low temperature during winter period and extremely low or high water conditions. It can range from a few meters to hundred or more kilometres.
- *Downstream and feeding migration of juveniles:* Fish in their early development (eggs, larvae, juveniles) usually leave the spawning grounds, drift passively with the current or move actively to nursery areas where they grow before joining the adult stock at their feeding grounds.

Migratory patterns of fluvial fish are variable. Some species travel regularly over long distances and inhabit both marine and freshwater. Migratory behaviour of river fish can be divided into the following categories (Northcote 1998, Kroes at al. 2006):

- *Diadromy:* Migration across a transition zone between fresh and marine water. Adaptations to conditions of different habitats are precise, particularly with regard to the salinity of the water.
- *Anadromy:* Fish live in the sea and migrate to freshwater to breed.
- *Catadromy:* Fish spend most of their lives in freshwater, then migrate to the sea to breed.
- *Amphidromy:* Fish migrate from freshwater to the seas, or vice versa, but not for the purpose of breeding.
- *Potamodromy:* Migrations occur wholly within a river system.

The migratory behaviour of fish is controlled by a complex interaction between internal and external factors. External factors are abiotic conditions such as water temperature, changes of light level, river discharge, water quality, etc.

Main internal factors include physiological condition, sex-related hormonal changes, stress and other endogenous factors, as ability of homing navigation to the natal site during spawning migration. In general, internal factors are highly influenced by external factors (Pavlov 1989, Lucas and Baras 2001, Schmutz and Mielach 2013).

Sense of flow by lateral line organ, and sense of temperature and smell are relevant for the direction of migration within the river system. Swimming orientation during migration is mostly determined by the highest current velocity. For upstream movement, fish swim within or parallel to the main flow, whereby each species and size classes prefer a certain range of flow velocity within water flow along their migratory corridor.

Migration distances vary widely between or within populations of a single species. The typical long-distance migratory species frequently move only for short river sections, and vice versa the short-distance migrators can move over longer reaches. General movements of fishes of the Danube can be described by the following categories of migration distance (Waidbacher and Haidvogl 1989, Schmutz and Mielach 2013):

- *long distance* – migration of more than 300 km in one direction within a year
- *medium distance* – migration between 30 and 300 km in one direction within a year
- *short distance* – local migration of less than 30 km

In the river system of the Danube, long-distance migrations are only undertaken by diadromous species, which enter form the Black Sea, such as anadromous sturgeons (Acipenseridae) and clupeids (Clupeidae). Self-sustaining population of the catadromous European eel (*Anguilla anguilla*) does not occur in the Danube, however stocked individuals migrate downstream, but their reproduction is unlikely. Sturgeons migrate the longest distance within the Danube. For example, beluga sturgeon (*Huso huso*) historically undertook migrations of more than 2500 km in one direction (Fitzinger and Heckel 1835, Waidbacher and Haidvogl 1989). Two other anadromous species of the Danube sturgeons, the Russian sturgeon (*Acipenser gueldenstaedtii*) and stellate sturgeon (*Acipenser stellatus*) have similar migratory behaviour. Out of three clupeids occurring here, two species, the Pontic shad (*Alosa immaculata*) and the Black Sea shad (*Alosa tanaica*) migrate over long distance.

Sterlet is a potamodromous sturgeon that migrates over medium distance
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Danube salmon is a medium-distance migratory species in mountainous and sub-mountainous reaches of rivers
Photo: Wikimedia

Migration over medium distance for spawning and foraging is a characteristic of many potamodromous species on the whole length of the Danube. These fishes migrate a considerable, more than a 30 km distance, either within the main riverbed or to major tributaries. Some of them, such as Danube salmon (*Hucho hucho*), require mountainous conditions in running tributaries for spawning and during their early life stages. Other potamodromous species reproduce in relatively fast-flowing sub-mountainous sections of the main riverbed on stony or gravelly substrate. Most of them, such as barbel (*Barbus barbus*) and nase (*Chondrostoma nasus*) find spawning grounds and nurseries in the inshore zone, and some other species, such as sterlet (*Acipenser ruthenus*), prefer the deep medial zone for reproduction. After the spawning period, these fishes usually swim back into their feeding areas, usually downstream in the riverbed, however some of them, such as asp (*Leuciscus aspius*) also move into connected backwaters with low-flow conditions.

Short-distance migration is a characteristic of several limnophilic and eurytopic species of the Danube fish fauna, with a preference of flooded or submerged vegetation as spawning ground, which is accomplished by utilising various backwaters and side channel habitats through the lateral connectivity between river and floodplain. These habitats additionally function as refuges during flood events (Schiemer and Waidbacher 1992, Waidbacher and Haidvogl 1989).

As shown in the overview above, a variation in fish migratory behaviours manifests at different hierarchical levels and at different spatiotemporal scales, and can be of genetic or environmental origin. ***The habitat conditions of migratory fish depend significantly on the integrity of the river's geomorphological processes. The spatial extent and connectivity of key habitats are crucial to the viability of fish populations and the resilience of the Danube river ecosystem.***

3. IMPACTS OF HUMAN ACTIVITIES ON FISH MIGRATION

Freshwater biodiversity is of outstanding global importance. One third of all vertebrate species occur in freshwater (Dudgeon et al. 2006), although surface freshwater habitats contain only about 0.01% of the world's water and cover only about 0.8% of the Earth's surface (Gleick 1996). The rivers and their ecosystems constitute valuable natural resources in economic and social terms and their conservation and management are critical to the interests of all humans and governments. Fluvial ecosystems have suffered the most intense intervention of all ecosystems over the past century of human history, with severe negative consequences on fish biodiversity (WWF 2020). Identifying the causal links between human activities and environmental changes of the Danube River ecosystems and understanding their cumulative impacts on fish migration is an essential prerequisite for effective management of migratory fish populations.

The DPSIR Principle (Driving Forces - Pressures - State - Impacts - Responses) (EEA 1999) is an effective tool for overviewing the cause-and-effect relationships in complex environmental issues. This approach is suitable for analysing the problems of fish migration in a socio-economic context. According to this assessment, social and economic developments, as *Driving forces* may cause *Pressures* on the environment and, as a consequence, the *State of the environment* changes and, finally a number of cause-and-effect chains of alterations can exert *Impacts* on fish populations in different ways and their cumulative effects may also occur.

The following economic driving forces and pressures are relevant to the migratory fish in the Danube River system:

FISHERY

Historically, ***river fishery*** was the earliest human activity, which affected fish populations in the Danube. Migratory fish were particularly vulnerable to traditional fishing, because the activity was interested in increasing the efficiency of catch methods. Fishermen were familiar with the behaviour of fish, they knew the time and route of migration. They utilized their knowledge in development of fishing gears, consequently they were able to remove large quantities of fish via interruption of the longitudinal and lateral migratory corridors by special fish traps.

Since prehistoric times, people living along the Danube had exploited certain anadromous fishes during their migrations. Sturgeons are highly vulnerable to fishing due to their large body size, slow sexual maturation and long spawning migration. Overfishing of populations resulted in a significant decline of sturgeon catches in the Upper and Middle Danube in the Post-Medieval times. The intensity of the former sturgeon fishery in the Middle Danube can be estimated from historical documents such as one of Marsigli's maps, which indicates 6 sturgeon fishing sites along a 70 km long Danube stretch at Budapest downstream at the end the 17th century (Guti 2014). The magnitude of former catches of sturgeon fishery can be assessed from some archival records. For example, 77 specimens of beluga were caught in a single day at one of the fishing sites near the tributary of the Váh River in 1553 (Unger 1931), while the annual catch included 27 tonnes of beluga in a 55 km long Danube section at Paks (r.km 1530–1475) in 1746 (Solymos 1987).

The cumulative effect of a number of sturgeon traps may have been significant on migrating fish. Assuming that there was one trap along the Danube for every 40 km long section, migrating fish had to pass through about 50 traps until they reached the upper section of the Middle Danube. There is no information on the proportion of fish catch, however, assuming that an average of 1% of individuals migrating to spawning ground were caught at each fishing site, the size of the population would be reduced by 40% compared to their initial abundance. If fishing was more efficient and 2% of migrating individuals were removed at the sites, the size of population

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would be reduced by 74%. This is the reason why the decline in anadromous sturgeon catches started earlier in the Upper and Middle Danube. Former metapopulations of sturgeons consisted of several subpopulations using separate spawning grounds at different distances from the sea. Individuals of each subpopulation were navigated by their homing behaviour to their own spawning ground. The length of the migratory route was significantly longer to the Upper and Middle Danube, and individuals migrating over longer distances had to overcome more fish traps until they reached their spawning grounds, therefore the risk of their fishery mortality (referring to proportion of individuals which are removed from the population by fishing) was significantly higher.

Regular sturgeon fishing had already ceased in the upper section of the Middle Danube in the middle of the 19th century (Khin 1957), and only 33 beluga catches were recorded in Hungary during the 20th century (Guti 2008). The three or four orders of magnitude decrease of sturgeon catches over five hundred years indicate the collapse of the Middle Danube subpopulations before the beginning of extensive river regulations (Guti 2014). Abundance and reproductive success of the Lower Danube sub-populations began to decline later, in the second half of the 20th century (Bacalbaşa-Dobrovici 1997, Navodaru et al. 1999). Nowadays, legal sturgeon fishing has ceased along the Danube, but poaching and incidental by-catch of juveniles remain a problem.

HYDROPOWER UTILIZATION AND WATER STORAGE

By fragmenting free-flowing rivers, hydropower dams have played a key role in the 84% global decline in freshwater species populations since 1970 (WWF 2020). The construction of ***dams and weirs*** is one of the main environmental pressures on the Danube ecosystems. Dams and reservoirs have been built in nearly all mountainous areas of the Danube Basin


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and in some lowland regions. The Iron Gate Dams I and II, the Gabčíkovo river barrage system and a series of 49 hydropower plants in Austria and Germany represent significant migration barriers for the fish in the Danube. In terms of longitudinal river continuity, the DRBMP Update 2015 highlights that for the Danube River itself, 83 barriers were identified, out of which 32 barriers are passable for fish by 2015 (ICPDR 2015).

Transverse blocking of the river channel interrupts its longitudinal connectivity and it may obstruct the free migration of fish both upstream and downstream. As migration is essential for the breeding of fluvial fish, this constraint may cause complete absence of several species in river stretches where they were once abundant. The ***dammed river section*** becomes a trap for sediment, therefore suspended sediment and bedload transport is significantly affected, which are critical for maintaining geomorphological processes and habitat developments downstream of the dam. Another serious change in the state of the river ecosystem is the transformation upstream of the dam from a free-flowing river to a slowly flowing impounded sector. Alterations in temperature, chemical composition, dissolved oxygen levels and the physical properties of the dammed watercourse are often unsuitable for fluvial species that evolved with the river system. Deterioration of the river habitats results in changes in the dominance of fish species and the abundance of their food organisms. The disappearance of rheophilic species, especially anadromous species is a usual tendency.

The dammed river section itself also forms a barrier to the migration of juvenile fish which are reluctant to move downstream via large standing water mass, particularly if it is thermally stratified. If fish penetrate the reservoir, they are physically impeded in their downstream migration by the dam, and at hydropower dams suffer high mortality if they pass through the turbines (Cowx and Welcomme 1998).

The flow dynamics in the river section which is out of the effect of hydropower dams are mostly influenced longitudinally by other ***in-stream structures*** (e.g. weirs, wingdams etc.) and laterally by branch closures. Concerning the longitudinal river continuity, out of a total of 1262 obstacles, 747 were identified on the Danube River and 515 on its major selected tributaries (National Administration Romanian Waters 2018).

FLOOD PROTECTION

River engineering works concerning mainly flood protection are responsible for disconnection of former floodplains. Flood events can be hazardous for society, but are also a very important ecological factors for riverine ecosystems. Alteration of the frequency and duration of floods and the loss of active floodplains due to flood defence measures are significant pressures to fluvial ecosystems on the basin-wide level (ICPDR 2009). At the Danube River Basin level, 7807 km of dykes were identified on the Danube River and 2254 km on the tributaries (National Administration Romanian Waters 2018).

Flood control structures impact severely on lateral hydrological connectivity between river and floodplains, resulting in obstacles for many fish species migrating towards their preferred feeding, spawning or nursery sites. Loss of inshore habitats in large areas and isolation of floodplain waters may cause enormous decline of macroinvertebrate fish food production and disappearance of obligate floodplain spawners and may reduce populations of opportunistic spawning species.

NAVIGATION

Historically, the Danube and its major tributaries have formed important trade routes across Europe. Navigation can contribute to making transport more environmentally sustainable,


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particularly where it can act as a substitute for road transport, but facilitation of navigation has radically changed physical and ecological characteristics of the river ecosystems, while pollution from ships and boats is also a significant problem. For the purpose of navigation, long ***river sections have been narrowed, channelized and disconnected from floodplains***. These interventions have led to increased bed shear stresses, limited sediment supply and loss of instream structures, especially the disappearance of considerable gravel bars, which provide suitable spawning grounds for migratory fish species. In addition to geomorphological impacts, ship traffic also affects fish. On the one hand, ***waves induced by ships*** have damaging impacts on fish populations, which particularly destroy juvenile fish assemblages and populations of fish food organisms along shallow inshore habitats (Wolter and Arlinghaus 2003, Kucera-Hirzinger et al. 2008, Krouzecky et al. 2013). On the other hand, ***underwater ship noise*** conditions are a major source of stress for Danube fish resulting in a relatively acute stress response and cortisol secretions increase. High levels of cortisol secretion may have detrimental effects on growth, sexual maturation and reproduction in fish (Wysocki et al. 2006).

CONSERVATION STATUS OF THE MIGRATORY STURGEONS IN THE DANUBE RIVER BASIN

The conservation status can be described by the IUCN Red List categories, which express the degree of their endangerment (http://www.iucnredlist.org). In the Danube River Basin, out of the 6 sturgeon species historically present the Atlantic sturgeon (*Acipenser sturio*) became extinct in the 20th century. Another species, the ship sturgeon (*Acipenser nudiventris*) is already functionally extinct. Less than ten individuals were observed in the Danube and its tributaries in the last fifty years and the last specimen was caught in the Hungarian section of the Danube in 2009, which died in a hatchery.

All of the last remaining sturgeon populations are in a bad condition and their conservation status is becoming more and more critical. The Russian sturgeon (*Acipenser gueldenstaedtii*) is very rare, critically endangered, only single captures were reported annually in the Lower Danube and there was no evidence for its natural reproduction in the last decade. The Stellate sturgeon (*Acipenser stellatus*) is critically endangered, its occurrence is restricted to the Lower Danube and it is extinct in the Middle Danube. Natural reproduction exist only in a few places, and its small population decreases year by year. The Sterlet (*Acipenser ruthenus*) is the most widely distributed sturgeon species in the Danube, but it will be up-listed from vulnerable to endangered in the IUCN Red List because its populations are declining fast. Only single individuals of the beluga sturgeon (*Huso huso*) have been observed in the Danube during the last decades, it is extinct in the Middle and Upper Danube. The reproduction of a small wild population is restricted to short sections of the Lower Danube.

Declines in population size can result in a loss of genetic diversity and higher risk of extinction. Small populations are more likely to experience the loss of diversity over time by random chance, which is called genetic drift. Further possible outcome from reduced gene pool is a reduction in fitness of population by inbreeding depression. Higher genetic diversity in a larger population provides a better adaptive capacity to environmental alterations and stochastic events.

In very small populations, demographic stochasticity decreases the population growth rate, which increases the risk of population extinction. This demographic process may vary depending on the Alle effects (Kramer et al. 2009). The Allee effects have several mechanisms. One of the most common process is the mate limitation, when population decline can be caused by limits in the likelihood of individuals gaining access to the opposite sex or stochastic shortage in one sex. A strong Allee effect results in a critical population density below which per capita population growth rate is negative and this process leads to the extinction of the population. The influence of Alle effect may be strong in case of sturgeon populations since female sturgeons spawn only two or three times per decade, thus additionally limiting the encounters of mature fish when population size is small.

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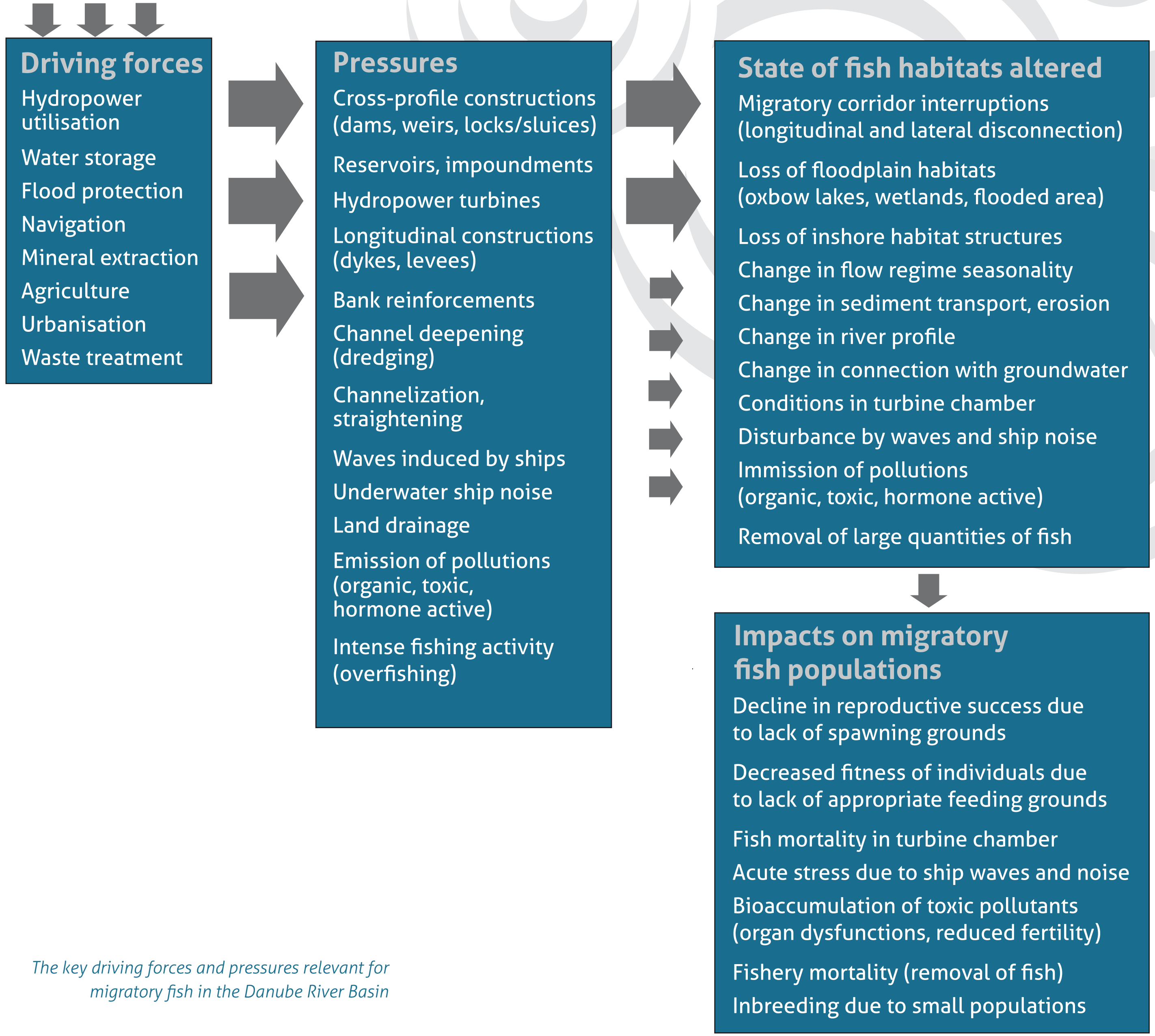
WASTE AND SEWAGE TREATMENT

The degree of industrial development and amount of ***pollution caused by the industrial sector*** varies among the countries. Almost all industrial sectors are producing pollution. Over the past three decades, the closure of many heavily polluting industrial activities in the Middle and Lower Danube countries has contributed to a decrease in organic pollution. A preliminary analysis on industrial and food industrial sources of organic pollution identifies a total number of 173 facilities emitting directly into the DRBD and 189 facilities with indirect emissions to water through urban sewers. Pollution caused by hazardous substances can seriously damage riverine ecology. Sources of hazardous substances are: industrial effluents, storm water overflow, ***pesticides and other chemicals applied in agriculture*** as well as discharges from mining operations and accidental pollution. In recent years, ***endocrine substances and pharmaceuticals*** have been increasingly analysed in effluents from wastewater treatment plants or water intakes (ICPDR 2009). Migratory fish populations can be impacted by toxic and hormonally active substances accumulated in the river sediments and trophic network. Sublethal effects of pollutants lead to decline of reproduction potential or change of behaviour, but only limited information is available about these impacts. Sturgeons are sensitive to toxic pollutants accumulated in the sediments due to their benthic feeding habits and longevity, which increases bioaccumulation in their tissues and may lead to organ dysfunctions, especially affecting the gonads and reducing fertility (Poleksic et al. 2010, Jarić et al. 2011).



The key driving forces and pressures relevant for migratory fish in the Danube River Basin

4. POLICY AND LEGISLATION

INTERNATIONAL CONVENTIONS

The importance of ecological connectivity is increasingly recognized in policy, and most global and regional legal instruments for biodiversity conservation have objectives that require the restoration of fragmented ecological corridors. There are a number of major global conventions that have been signed by multiple countries around the world in order to protect migratory fish either directly, or indirectly.

The ***Convention on Biological Diversity*** (CBD 1992) obliged a significant part of the countries to take actions, including monitoring the state of diversity. It required that CBD Parties prepare a national biodiversity strategy and they must also integrate the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans and policies. The CBD includes provisions for in-situ conservation of biological diversity to rehabilitate and restore degraded ecosystems and promote the recovery of threatened species. Contrary to the target set in 1992, the slowdown in biodiversity loss by 2010 has clearly lagged behind (Homeyer et al. 2011). Maintaining connectivity as a core conservation objective can be found in the ***Aichi Biodiversity Targets of the CBD***. Aichi Target 6 has relevance for sturgeons since it indicates that all fish stocks are managed and harvested sustainably, legally and applying ecosystem-based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species. Aichi Target 11 states that by 2020, the planet's area under protection will be increased and the conservation areas should be well-connected using corridors and ecological networks to allow connectivity and the application of the ecosystem approach.

The ***Convention on the Conservation of Migratory Species of Wild Animals*** (Bonn Convention 1979) is a worldwide treaty currently with over 120 member states and one of the key global agreements designed specifically to facilitate management and conservation of transboundary migratory species. It addresses the protection of migrating wild animal species (defined in appendices I and II), while Section 2 recognises the importance of migrating fish species and requires appropriate measures to be taken to protect them. All European sturgeon species were listed under Appendix II (migratory species which have an unfavourable conservation status) in 1999, but *Acipenser sturio* was uplisted to Appendix I (migratory species in danger of extinction.)

The ***Convention on International Trade in Endangered Species of Wild Fauna and Flora*** or Washington Convention (CITES 1973) is an international agreement between governments, aimed to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species. The species covered by CITES are listed in three Appendices, according to the degree of protection they need. All sturgeon species were listed on Appendix II (species not necessarily threatened with extinction) in 1998, with the exception of *Acipenser sturio*, which is on Appendix I (species threatened with extinction). The EU implements CITES and provides additional measures for the conservation of species in trade through the European Union Wildlife Trade Regulations.

The ***Convention on Wetlands of International Importance especially as Waterfowl Habitat*** (Ramsar Convention 1971) is an intergovernmental treaty concerned about the increasing loss and degradation of wetland habitat for migratory water birds. It has relevance to migratory fish, because selected wetlands are described in the handbooks on Wetland Policy, which also include coastal habitats of the littoral zone populated by anadromous migratory fish.

REGIONAL REGULATIONS, INCLUDING EU LEGISLATION (EUROPEAN COMMUNITY LAWS)

The ***Convention on the Conservation of European Wildlife and Natural Habitats*** (Bern Convention 1979) aims for the conservation of wild plant and animal species and the habitats on which they depend. The Convention was first implemented through Council Directive 79/409/EEC (on the Conservation of Wild Birds, known as the EC Birds Directive) and then in 1992 through Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna, known as the ***EC Habitats Directive*** (Habitats Directive 1992). Under both directives, 'Natura 2000' sites have been established to reverse the loss of biodiversity in Europe. Framework of both directives is one of the main pillars of the EU's system of wildlife and nature conservation, which led to the setting up of a network of protected areas across the EU, along with *Special Areas of Conservation*, which together with the existing *Special Protection Areas*, became the so-called Natura 2000 network established to protect species and habitats (listed in Appendixes I, II, III, and IV of the Directive). Several migratory fish species living in the Danube River system are listed in the Annexes.

THE CONCEPT OF ECOLOGICAL CORRIDORS

Destruction and fragmentation of habitats are the leading causes of decline of migratory fish populations in the Danube, therefore managing and restoring ecological connectivity within river systems are the central issues for promoting fish migration. The loss of ecological connectivity is most often a consequence of policy and management decisions made by the development of navigation, energy and agriculture sectors. Without adequate connectivity, river ecosystems cannot function properly, and without well-functioning ecosystems, their biological components and ecosystem services are at risk.

The ecological connectivity of habitats has both physical and functional components (Hilty et al. 2020). The physical connectivity is a measure of habitat permeability based on structural features, arrangements of habitat patches and disturbances presumed to be important for organisms to move through their environment. It identifies areas through which a variety of species may be able to move. The functional connectivity is a description of how effective the movement of individuals or populations between the core habitats is. Observation and evaluation of target fish movements can be used for the estimation of effectiveness.

Regarding the connectivity of habitats, it is proposed to adopt a connectivity definition, termed "ecological corridor", to denote areas within ecological networks that specifically indicate ecological connectivity, and incidentally may also contribute directly to biodiversity conservation. The ecological corridor is a clearly defined geographical space that is managed over the long term to maintain or restore effective ecological connectivity. Fluvial ecological corridors are critical conservation areas designated to ensure that river ecosystems are functioning properly. The ecological corridor encompasses more than the river channel as a migration route for aquatic organisms. It also includes different types of habitat, its inherent habitat use and hence also "habitat-using"-fish populations, as well as all processes and exchanges such as information (e.g. behavioural, genetic), turnovers (e.g. energy, biomass, bedload) necessary for the ecological functioning of the system to support viable populations of native fish and migratory species in particular (Haidvogl et al. 2021).

Legislation and planning instruments have been increasingly supported for sustainable protection and management of water resources due to growing human pressures and environmental threats. The ***Water Framework Directive*** (WFD) (EC 2000) is a substantial legislation relevant to ecological conditions and to the well-being of migratory fish in the Danube River Basin. It provides the necessary framework for a sustainable water management and implies a management of waters with the aim of achieving good ecological status for all ground and surface waters in the EU. It intends to ensure preservation of aquatic ecosystems and the areas directly dependent on these ecosystems from further deterioration. In order to achieve the objectives set, ecological monitoring programs have been developed and applied, as well as River Basin Management Plans and associated Programmes of Measures for each of the river basins were implemented.

The ***Marine Strategy Framework Directive*** (EC 2011) aims to achieve 'Good Environmental Status' of the EU's marine waters by 2020 and to protect the resource while maintaining marine-related economic and social activities that depend on the marine environment. This also focuses on protecting fish, including migratory fish that spend part of their lifecycle in a marine environment.

The ***EU Strategy for the Danube Region*** (EUSDR 2010) seeks to create synergies and coordination between existing policies and initiatives taking place across the Danube Region and aims to promote the sustainable development in the macro-region and to protect natural areas, landscapes and cultural values. It focuses on twelve priority areas and two of them specifically mention the problems of fish migration.

One action of PA4 is specifically focusing on migratory fishes including three targets:

- *"Raise broad public awareness and political commitment for the Danube sturgeons as flagship species for the Danube River Basin and for the ecosystems and biodiversity of the Danube River Basin as a whole*
- *Foster sturgeon conservation activities including protection of habitats, restoration of fish migration routes and ex-situ conservation measures*
- *Close knowledge gaps concerning monitoring of pressures and planning of measures for fish migration in coordination with PA 6 (Action 3)"*

One of the actions of the Priority Area 6 (PA 6, Preserve biodiversity, landscapes and the quality of air and soils) is targeted to the Danube sturgeons:

- *Action 3: "In particular, sturgeons play an important ecological role as indicators of healthy ecosystems. The Danube River Basin preserves some of the most important wild sturgeon populations and functional habitats in the world today. Implementation of the Danube-related measures from the Pan-European action plan for sturgeon conservation will contribute to their protection and protection of other freshwater species and their habitats."*

The ***European Green Deal*** is a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral in 2050. It has goals extending to many different sectors, including construction, biodiversity, energy, transport and food. A comprehensive and long-term strategy to protect the European Union's biodiversity will be developed in 2021 (2030 EU Biodiversity Strategy). It aims to put Europe's biodiversity on a path to recovery by 2030 and highlights among other things the need to restore free flowing rivers and to address barriers preventing the passage of migrating fish.

NATIONAL LEVEL REGULATIONS

At national level, a variety of policies, laws, administrative authorities, regulations and management plans also require the conservation of connectivity to achieve their objectives (Lausche et al. 2013). Government policies and plans such as National Sustainable Development Strategies and National Biodiversity Strategies guide overall development. Practically, all national legal systems also have specific laws relevant to ecological corridors that deal with nature and biodiversity conservation. Conservation and sustainable resource use laws are the first level for this purpose. These include protected areas laws, general biodiversity or species conservation laws, and resource-specific laws such as those relating to sustainable utilisation or protection of fish populations, water resources or other elements of river ecosystem. These instruments normally involve direct regulation and should give attention to connectivity conservation to meet their objectives effectively. Supportive laws may extend to fishery and water quality controls.

Major substantive areas of law beyond traditional conservation instruments are also important. These include laws and policies on the water-use planning, the development of navigation infrastructure and hydropower utilisation or the project-focused environmental assessments.

Economic instruments are another suite of available tools that may reinforce direct regulation or serve as an alternative approach to support connectivity conservation. These instruments may encourage certain responsibility that could include actions of rights-holders and owners of any dam or other obstruction to migration to achieve additional specific ecological corridor objectives. Such instruments include positive incentives (e.g. technical assistance, subsidies and reduced tax liability) or negative incentives (e.g. tax increases) (Lausche et al. 2013, Hilty et al. 2020).

NECESSARY GOVERNANCE ARRANGEMENTS

Governance arrangements play a decisive role in the decline and recovery of conditions for migratory fish populations, which are effective indicators of ecological status of rivers in the evaluation system of the EU Water Framework Directive. ***The Strategy for ecological corridor conservation and restoration*** of the MEASURES project (Haidvogl et al. 2021) provides a good overview of the necessary management measures in the Danube catchment. Their main findings in this regard are:

The responsibility for the protection of migratory fish in the Danube lies with several authorities, so it is important to clarify the sharing of their responsibilities. Maintaining the connectivity of rivers and the ecological status of habitats is the responsibility of the national authorities coordinating river basin management. However, the Danube is one of the most international rivers, so the ecological corridors in the riverbed cross national borders and therefore cannot be managed by national measures alone. The ICPDR is the competent authority for transboundary water management in the Danube Basin, with sufficient powers to authorize the Danube States to take measures to maintain and restore such corridors.

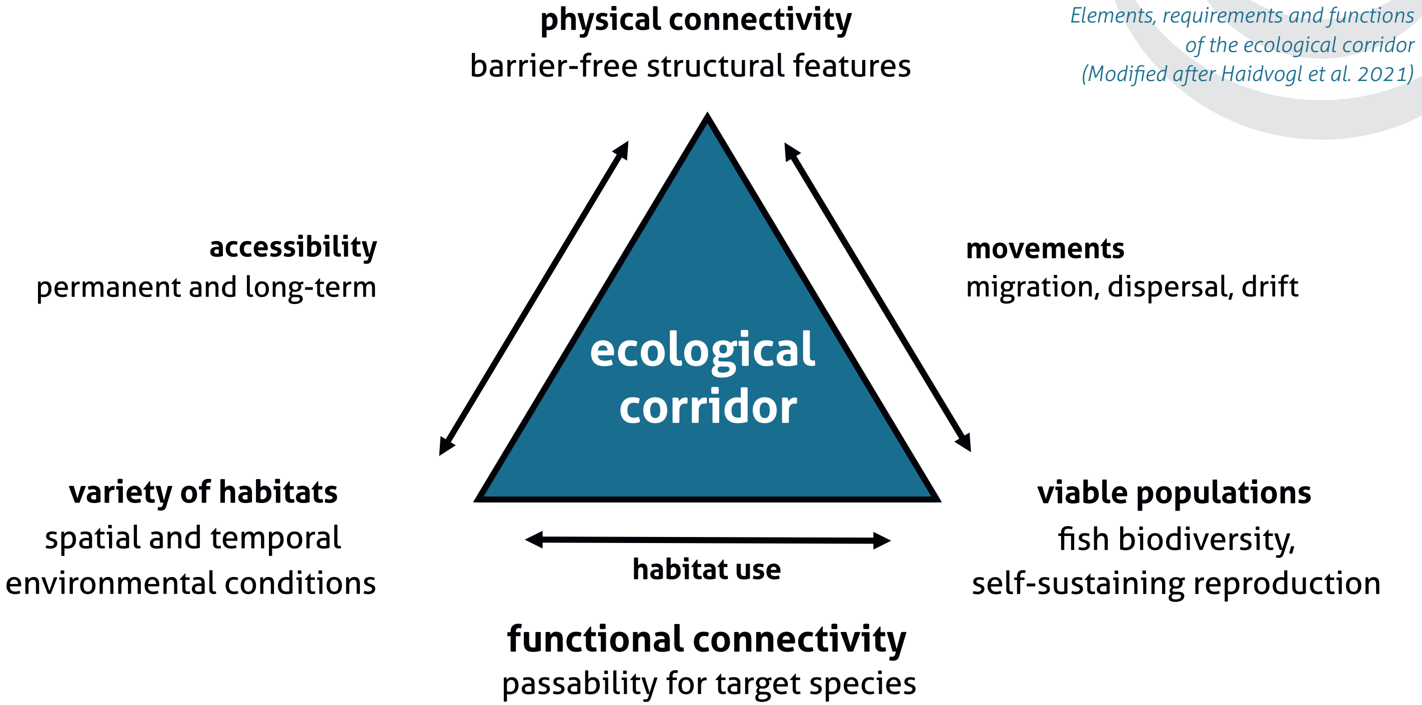
Water management and nature conservation are important pillars for the protection of migratory fish, but the competent authorities of the latter have so far played a minor role in efforts to restore the threatened migratory fish populations in the Danube basin, in spite of the obligation arising from the adoption of the Pan-European Action Plan for Sturgeons. This highlights the need for the Danube Basin States to clarify the role and responsibilities of national authorities for water management and nature conservation.

There are no legal obligations to reinforce threatened migratory fish populations by conservation stocking actions and operating conservation hatcheries, and there are no clearly defined responsible authorities to order these. In view of the objectives to be achieved, it is proposed that the nature conservation authorities of the Danube States take responsibility for such activities, together with the fisheries authorities where appropriate.

In addition to water management, pressures from a number of other sectors affect the population dynamics of migratory fish species in the Danube, so it must be ensured that policies and their implementation effectively promote the recovery and conservation of migratory fish. The EU, the ICPDR and the EUSDR (PA 4 and 6) should play a leading role in developing this support (especially in sectors with cross-border implications such as energy, climate and inland waterway transport) for implementation by the competent national authorities.

Fishery pressure has a significant impact on some threatened populations, especially sturgeons. Despite bans on sturgeon fishing, poaching remains a problem, so enforcement of fishing bans must be effective. This is the responsibility of the national fisheries authorities.

Risk levels for anadromous species in the Danube basin is also affected by changes in migration routes and marine habitats. Very little information is currently available on these routes and habitats. The EU, the competent national authorities for sea fisheries, the Black Sea Commission and the FAO-GFCM should develop this issue in order to contribute to the recovery and conservation of sturgeon populations.



Elements, requirements and functions of the ecological corridor (Modified after Haidvogl et al. 2021)

5. GOOD PRACTICES TOWARDS LONG-TERM PRESERVATION OF MIGRATORY FISH

STRATEGIES AND ACTION PLANS FOR THE PROTECTION OF MIGRATORY FISH IN THE DANUBE RIVER SYSTEM

The decline of the sturgeon populations in the Danube reinforced the urgent need for enhanced basin-wide cooperation and actions for the protection of endangered migratory fish and several conservation plans have been worked out with the aim of raising awareness of the serious situation since the beginning of the 21th century. In 2005, a ***Sturgeon Action Plan*** (Bloesch et al. 2006) prepared by experts and stakeholders was adopted by the Standing Committee of the Bern Convention in the frame of the Council of Europe. The conservation of sturgeon populations is a highlighted effort in the EU Strategy for the Danube Region, which has facilitated the establishment of the Danube Sturgeon Task Force (DSTF). The DSTF was established at the initiative of governmental and non-governmental organizations, research institutes and universities from the Danube Region in 2012 with the support of the EUDSR PA 6. It aims to coordinate and foster the conservation and revival of native sturgeons in the Danube River Basin and the adjacent Black Sea by promoting the implementation of the ***Programme "Sturgeon 2020"*** (Sandu et al. 2013). The program describes a number of measures and recommendations for sturgeon conservation, such as the restoration of lost and altered habitats, the prevention of further habitat degradation, the enabling of fish migration, the improvement of water quality etc. The implementation of the Program "Sturgeon 2020" requires applied projects and measures, which are developed by making best use of existing funding instruments as well as EU and national legislation.

The ***WWF Network Sturgeon Strategy*** (WWF 2017) aims to foster cooperation with important strategic regional and international partners in sturgeon conservation. It outlines a common global strategy which, increases conservation impact of WWF's conservation work through sharing knowledge and experience, resources and cooperative transboundary work streams. The main strategic objectives of the initiative include the protection and restoration of key habitats and the provision of fish migration.

The International Commission for the Protection of the Danube River (ICPDR) is leading efforts to bring stakeholders together to protect the sturgeons. As the administrating platform for the Danube River Basin Management Plan – which includes issues of sturgeons – the ICPDR coordinates works on the river continuity to meet the requirements of the EU's Water Framework Directive (WFD). The ICPDR has long realised the importance of fish migration and endorses sturgeons native to the Danube as its flagship species. This commitment was emphasized at the occasion of the Danube Ministerial Conference in 2016, where the ICPDR adopted sturgeons as a flagship species. The ICPDR works closely on this matter with their partners in the PA 4 and PA 6 of the EUSDR and aims to contribute to the survival and recovery of sturgeons in the Danube River Basin. Its ***Sturgeon Strategy*** (ICPDR 2018) highlights the challenges currently faced.

The World Sturgeon Conservation Society (WSCS) and the WWF International developed the ***Pan-European Sturgeon Action Plan*** (Friedrich et al. 2018). It covers 8 European sturgeon species – 7 of which are listed as critically endangered on the IUCN Red List of Threatened Species. Several experts have found that the conservation status of all sturgeon species in Europe has become highly critical without showing signs of recovery, indicating that the previous action has not been successful. Four main reasons for the insufficient implementation of existing action plans are mentioned: lack of simplicity, lack of coordination and clear responsibility, lack of public and political awareness and lack of resources. The new, continent-wide, multi-species action plan sets the framework to conserve the last surviving sturgeon populations, protect and restore their habitats and migration routes, urgently end their illegal fishing and by-catch and reintroduce the species to a number of rivers. It is intended to serve as a guiding framework for a better coordination and pooling of resources among national states.

The ***MEASURES*** project published a new ***Strategy for Danube Ecological Corridor conservation and restoration***, which built on project findings to outline how migratory fish habitats can be restored and reconnected through the Danube basin. The MEASURES Strategy is designed to help supporting and improving environmental management plans and legislation at different scales throughout the basin, providing suggestions for specific conservation and restoration activities. The strategy paper draws attention to the fact that governance arrangements play a major role in the degradation and rehabilitation of conditions for migratory fish populations. The Danube migratory fish populations are subject to the requirement of good ecological status of the EU's Water Framework Directive. Migration corridors and the state of habitats are therefore part of river basin management responsibilities of the competent national authorities. However, important responsibilities with respect to migratory fish species conservation may also lie with other authorities and it is therefore important to clarify the distribution of responsibilities.


Photo: Interreg-Danube

TECHNICAL MEASURES FOR THE RESTORATION OF ECOLOGICAL CORRIDORS IN RIVER SYSTEMS

The negative impacts of man-made barriers such as dams and weirs on migratory fishes have been known for centuries. ***The best way to re-establish longitudinal connectivity of rivers is the removal of barriers (dams, weirs and other obstacles) of fish migration.*** This option is becoming more and more available when barriers have ceased serving their initial purpose, when licences have expired, when retrofitting with fish passage facilities is economically not viable, where the dam owners no longer have an interest in the structure, or where ecological aspects are put above economic considerations. ***Removal of dams or other obstacles may restore the pre-damming condition of the river after a long period.*** However, there may be problems as usually reservoirs accumulate a significant amount of silty sediment and its downstream transport can alter the hydro-morphological characteristics of a long river section after the dam removal. This pressure may be unfavourable for certain river habitats.

When ***restoration of longitudinal connectivity*** of rivers by removal of barriers is not feasible, ***mitigation measures*** have to be sought. Mitigation seeks to offset the impacts of an ongoing use of the aquatic resource that is judged to have a greater social and economic value than the conservation or restoration of habitats and biodiversity. Furthermore, in many cases, historical changes of river systems are functionally irreversible for ecological, social and economic reasons. In such circumstances, efforts should be made to reduce the impact of pressures through a range of interventions, making the best possible use of the modified system. Such an intervention could be the construction of a route for fish that passes through the interruption of the ecological corridor.

The first written reports of rough ***fish passes*** date to 17th-century France, where bundles of branches were used to create steps in steep channels, allowing fish to bypass obstructions. Today, the majority of fish passages follow a similar basic concept, providing a route for fish to swim around the barrier through a series of gaps or slots that control the flow velocity. The design of instream structures that provide appropriate conditions for fish passage requires special knowledge of fish ecology and the swimming ability of different migratory species to overcome various hydraulic and morphological conditions and involves a multidisciplinary approach based on close collaboration between engineers and biologists (Williams et al. 2012; Schmutz and Mielach 2013, Link and Habit 2014). Efforts to increase the efficiency of fish passages have resulted in various technological solutions, which were often developed using empirical methods, i.e. based on feedback from experience; therefore fish passage facilities must be systematically evaluated. The most significant progress in fish passage technology has been made in countries which systematically assessed the effectiveness of the passes and in which there was a duty to provide monitoring results (Larinier 2001). In the early 2000s, the EU WFD added legal background to efforts to improve fish passage facilities at dams and other obstacles in Europe.

The mitigation of fragmentation of ecological corridors includes improvement of both longitudinal and lateral connectivity. Two aspects of longitudinal migration in the main channel are important: active upstream and downstream migration of adult fish or juveniles, and downstream movements of eggs, larvae or juveniles either through active migration or drift. Improving lateral connections provide access for adult and juvenile fish to a variety of floodplain habitats that are essential for several species.

Improvement of longitudinal connectivity for upstream migration

Several types of fish passes have been used worldwide (Pavlov 1989, Clay 1995, Cowx and Welcomme 1998, Jungwirth et al. 1998, Thorncraft and Harris 2000, Larinier 2001, FAO/DVWK 2002, Larinier and Welcomme 2003, Schmutz and Mielach 2013, Brink et al. 2018). Choosing the best practical option does not always mean adopting a low impact engineering approach. Best practical environmental option means selecting the approach that addresses the problem or need while minimising harmful environmental impacts as practically as possible (SEPA 2008).

The selection of the appropriate fish pass type requires an assessment of the local conditions, the parameters of the barrier, the height differences between upstream and downstream, and the available space for construction. Where height difference is small and there is enough space for construction, nature-like types of fish passages are usually preferred. Where height difference is large and there is enough space, nature-like and technical types or combinations thereof are possible. Where height difference is large and there is less space, technical solutions are more appropriate (Schmutz and Mielach 2013). Where height difference is very large, alternative solutions, like fish lifts and fish locks are suitable.

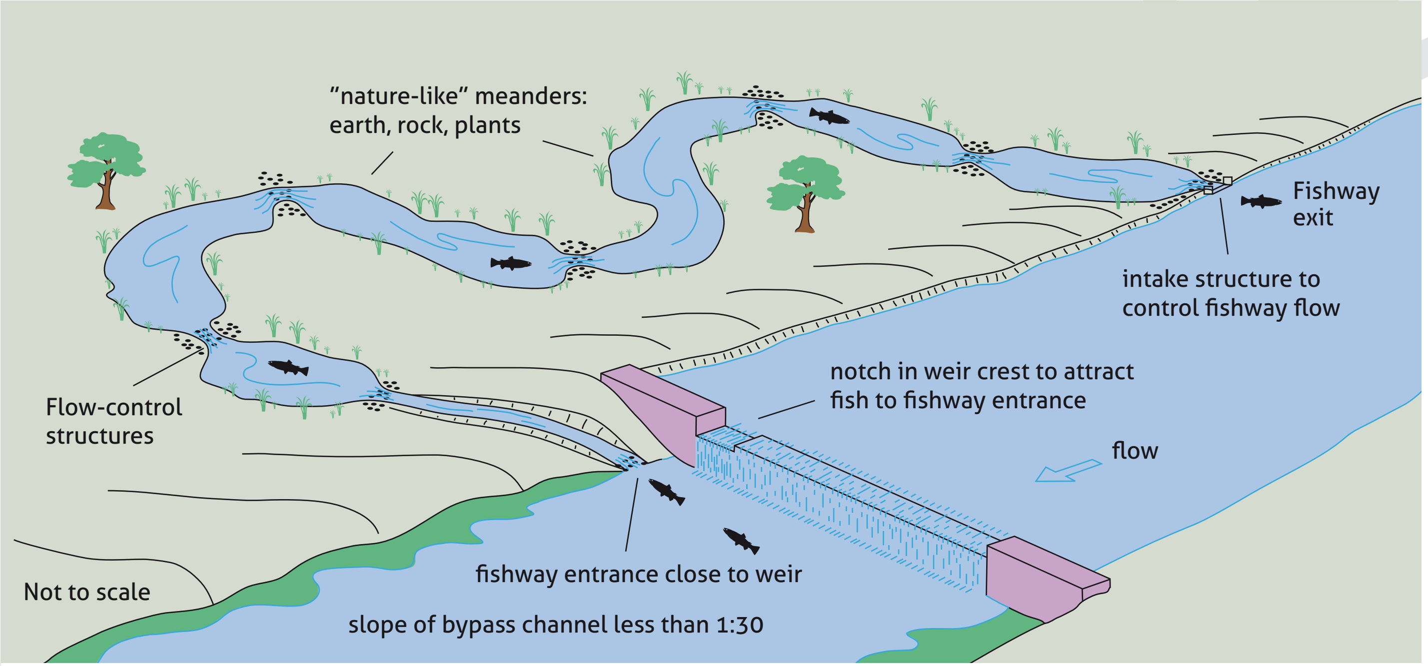
Nature-like types of fish passages are thoroughly engineered structures mimicking natural structures where natural materials such as boulders are used to create slopes. According to their location, nature-like fish passes can be divided into full bed width facilities (i.e. bottom sill or underwater weir), partial bed width facilities (rock ramps) and facilities running along the riverbank (bypass channels).

Apart from a complete presentation of the various technical fish passes, two commonly used types should be mentioned. The pool-and-weir type passes are among the oldest types of fish passes. They are suitable for maintaining the possibility of migration at dams for strong swimming species, some bottom-oriented and small fish. The Denil type passes have the advantage that they can be used on relatively steep slopes and thus require limited space.

Several alternative solutions have been used for enabling passage of fish upstream. These include large mechanisms like fish locks and fish lifts, the advantage of which is that they can operate over considerable differences in height and can thus accommodate the needs of high dams (20–60 m or more when using lift). Both fish lifts and locks are usually operated at intervals, and locks especially may not be open continuously. Their capacity to move large quantities of fish at once is limited, however the fish lift's capacity is much greater, but its operative cost is also higher. Fish locks may facilitate downstream migration depending on local conditions. In some cases, fish are captured and transported around the dam by truck for release either upstream or downstream (Clay 1995, FAO Fisheries Department 2008).

The surmountability of most of the fish passes is usually incomplete, and accumulation of migratory fish is often observed below obstacles (Pavlov 1989, Noonan et al. 2012). The cumulative effect of a series of limited efficiency fish passes may be very significant (e.g. if a fish pass operates at an efficiency of 20% for a target species, then the migrating

Conceptual layout of a bypass fishway



stock of fish ascending through a second similar facility would be reduced to 4% of its initial number). In view of the rapid reduction in the abundance of upstream migrants, it is important to consider whether the number of individuals required for successful spawning will arrive to the potential spawning grounds. The importance of monitoring is particularly apparent in the case of rivers where multiple facilities operate to support fish migration (Armstrong et al. 2010, Jones, and O'Connor 2017). Long-term monitoring of fish migration provides information about the effectiveness of facilities providing connectivity and function of ecological corridors.

Improvement of longitudinal connectivity for downstream migration

Safe downstream passage of fish needs to be considered carefully as mortality resulting from passage through hydraulic turbines can be significant. Experience shows that problems associated with downstream migration can be a major threat to diadromous fish and for species with larger body sizes (FAO Fisheries Department 2008). Downstream fish passage technologies are much less advanced than those for upstream passage and represent a range of issues that require further research. The development of effective facilities for downstream migration is much more difficult. A large number of systems exist to prevent fish from being entrained into water intakes but they are by no means as effective as bypasses. They may take the form of physical barriers, which physically exclude fish from turbine intakes, or behavioural barriers that attract or repel fish by means of applying stimuli to elicit behavioural responses. Bypasses for downstream passage can be complemented with such systems. The design of effective facilities for assisting the downstream passage of fish must, of course, take into account the swimming ability and behaviour of the target species and the physical and hydraulic conditions at the water intake (Larinier and Welcomme 2003).

Improvement of lateral connectivity for migration between river and floodplain

In lowland rivers, fish populations depend much more on smooth and durable overflows that gently inundate the floodplains. Floodplains usually consist of a large expanse of flat land that is flooded seasonally. The regular connection of the floodplain is necessary for fishes to access the plain for reproduction and foraging. The importance of seasonal connectivity is indicated by the close correlation between the extent and duration of the flooding and the expected fish yield in the following years.

It is beneficial to have floods every year, but even if not every year, at least so often that all species can reproduce during their lifetime. Floods are particularly favourable for river fish, when water level rises and falls relatively slowly and the course of the flood is smooth, without repeated peaks. In this case the fish eggs adhering to the submerged riparian vegetation are not endangered by dehydration. Extreme flood events that result in significant wash-out of fish and drift of fry are unfavourable.

Because of the dynamics of lowland floodplain rivers, there is an overproduction of juvenile fish in years of good flooding to compensate for the mortalities during the dry season. There is often so much overproduction that in lowland reaches the river does not need to be restored or rehabilitated in its entirety but that selected sections only should suffice to maintain functioning and sustainable populations (FAO Fisheries Department 2008).

Disconnection of lateral connectivity between the river and the floodplain occurs when the plain is physically separated from the channels by dykes or when the channel becomes so deeply incised that water levels do not pass on the border of the riverbed under normal discharge regimes. The easiest method for reconnection is the local removal of flood protection dyke to allow water to flow to the plain. As some floodplains are very extensive and may overlap with agricultural areas or buildings, new dykes may have to be constructed at the border of the restored area. If the channels have become so incised as not to permit water to overbank, adjustments of level in the main channel may be made using bottom sill that directs the water laterally over certain flows. Alternatively, localized restorations have taken place by scraping the topsoil from the floodplain to lower areas so that they can be flooded.

Another aspect of restoration is the reconnection of isolated wetlands and backwaters in the floodplain. This can be done by opening a connecting channel from the river. Connected canals have a tendency to silt up, therefore periodic dredging may be necessary.

SECURE AND SUPPORT POPULATIONS OF MIGRATORY FISH BY EX-SITU MEASURES

The importance of ex-situ measures or conservation aquaculture should also be emphasized in order to take immediate action to allow time for improvement of migration corridors and restore key habitats for migratory fish. Population abundance below a certain level will not allow for recovery on its own and lead to extinction with high probability. Such populations need protection in the wild, but also supportive programmes for rebuilding population structure by releasing genetically suitable individuals. The ex-situ activities provide controlled propagation in specialized facilities for production fish that are able to survive and reproduce under natural conditions. The ex-situ measures are closely linked to other conservation activities such as habitat protection and restoration, as well as restoring continuity at migration barriers.

Photo: wikimedia

ONGOING PROJECTS

For the implementation of strategies and action plans for the protection of migratory fish, applied projects and measures are required, which are developed by using existing funding instruments. Several projects have been accomplished or are currently ongoing to facilitate fish migration along the Danube. Among the major ones, the We Pass and the MEASURES projects are noteworthy examples.

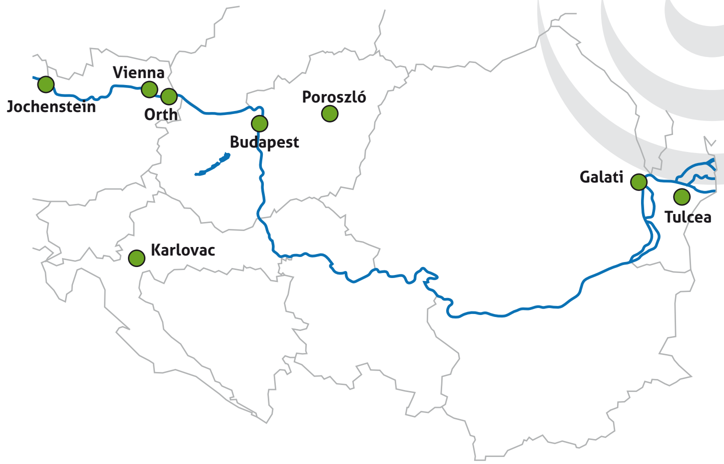
The ***"We Pass" project*** (We Pass project) is an initiative aiming to facilitate fish migration by preservation and reestablishment of migration routes of endangered fish species in the Danube River and its tributaries, specifically at the Iron Gates. The ICPDR coordinates and implements the activities jointly with the Danube Delta National Institute for Research and Development, Jaroslav Černi Institute, CDM Smith, OAK Consultants, and the Norwegian Institute for Nature Research. The project is supported by the European Commission. Its first phase, from 2011 to 2016, facilitated dialogue between the ICPDR, relevant stakeholders, and the European Commission, represented by DG REGIO and DG ENV. The second phase consists of the elaboration of a feasibility study that includes an assessment of the present situation by analysis of hydrological, hydraulic, geotechnical and hydropower plants operational data, as well as monitoring fish behaviour (sturgeons, shads, barbel, nase, etc.) at the Iron Gate dams by the installation of telemetry system and preparation of 3D CAD models as basis for future fish passage design. The third and fourth phases regard technical design (planned for 2021–2023), and implementation (2024 and onwards), respectively. The results will feed into an action plan ultimately allowing fish migration through both hydropower dams. The project also aims to raise awareness of the problem of biodiversity loss and habitat loss, as well as the need for ambitious fish conservation measures. The completion of the whole study still requires significant additional financial means.

The ***MEASURES project*** (Managing and restoring aquatic EcologicAl corridors for migratory fiSh species in the danUbe RivEr baSin) (MEASURES project), is coordinated by the IHG/BOKU and financed by the EU's Danube Transnational Programme in 2018–2021. It involved 24 partners from 10 countries cooperating to secure threatened riverine fish species. The cooperation allowed major steps in gaining new knowledge on migratory fish in the Danube River Basin and transferring these insights into practice. The project created an "Infosystem Eco-Corridors", based on the establishment of a network of Danube stakeholders across 8 partner countries. This new MEASURES Information System (MIS) hosts online information on migratory fish and habitats in the Danube basin. It is linked to the Freshwater Information Platform and integrates the Danube Future Knowledge Base. Project researchers undertook field surveys to map potential sturgeon habitats (including geographical locations of spawning, nursery, feeding and wintering habitats for long and medium-migratory fish) along the Danube and its tributaries. This resulted in the Danube Migratory Fish Habitat Manual, which details key sturgeon habitats in the basin, and the methods used to map them. The project undertook a series of activities to strengthen populations of migratory fish populations in the Danube basin. These included conservation restocking programmes for Russian sturgeon and sterlet, alongside with the development of an eDNA sampling method to monitor their populations. Project researchers collected gene stocks of sturgeon populations from broodstock and ex-situ samples for future stocking, which is hoped to be undertaken through a follow-up project. The project published a new Strategy for Danube Ecological Corridor conservation and restoration, which built on project findings to outline how migratory fish habitats can be restored and reconnected through the Danube basin. The MEASURES Strategy is designed to help supporting and improving environmental management plans and legislation at different scales throughout the basin, providing suggestions for specific conservation and restoration activities.

RAISING PUBLIC AWARENESS

Today, there is a widespread and increasing focus on the promotion of partnerships, working to deliver environmental improvements and sustainable solutions for all stakeholders. Close cooperation between government agencies, water authorities, private and public sector entities is essential. Communicating with society about fish migration issues increases overall perceptions on the improvement of the status of the waters in the Danube River Basin. If the general public and decision makers do not understand that the free migration of fish is usually prevented at dams and weirs, then it is unlikely that the issues arise as significant and problematic.

There are various activities and platforms which can be used to facilitate and enhance engagement with relevant audiences. This may include international awareness days, visitor centres at fish passages, information programs, educational activities, etc. On a global scale, thousands of organisations have celebrated World Fish Migration Day every other year since 2014 to create awareness and attract public attention. In 2016, over 70 million people were engaged in this event (Brink et al. 2018). The Danube Day celebrates the Danube and the rivers that flow into it. It has become one of the largest river ceremonies in the world since 2004, with huge festivals, public meetings and educational events. Its coordination is carried out by the ICPDR on international level. Networking between existing visitor centres can also be used to explain interdependencies with respect to ecological issues, water quality, ecological corridors, fish migration, floods and low water, and the communities around the river and to increase awareness of all these issues. A global map of visitor centres throughout the world is currently being developed by the World Fish Migration Foundation (Brink et al. 2018) and a preliminary map indicates here several localities of existing visitor centres in the Danube River Basin.



Visitor centers presenting native migratory fish species in the Danube countries

Visitor centers presenting native migratory fish species in the Danube countries

Germany	
Jochenstein	Visitor center Jochenstein "Haus am Strom"
	https://www.hausamstrom.de/en/
Austria	
Vienna	Haus des Meeres (Aqua Terra Zoo)
	https://www.haus-des-meeres.at/en/Home.htm
Vienna	Zoo Schönbrunn
	https://www.zoovienna.at/en/
Vienna	LIFE Sterlet station on Danube Island
	https://life-sterlet.boku.ac.at/index.php/the-project.html
Orth an der Donau	National parc center "Donau Auen" Schloss Orth
	https://www.donauauen.at/en/visit/schlossorth-national-park-centre
Hungary	
Budapest	Tropicarium Budapest
	https://tropicarium.hu/en/hungarian-fauna/
Poroszló	Lake Tisza Ecocentre Poroszló
	http://www.tiszataviokocentrum.hu/en/guests/travel-information
Croatia	
Karlovac	AQUATIKA – freshwater aquarium Karlovac
	https://www.aquariumkarlovac.com/en/homepage/
Romania	
Galati	Natural Sciences Museum Complex
	https://www.dreamstime.com/garden-natural-sciences-museum-complex-galati-romania-image220720410
Tulcea	Visitors Center Danube Delta Aquarium
	https://www.slideshare.net/stelaspinoie/tulcea-acvariucentru-ecoturistc

6. LESSONS LEARNED AND MESSAGES TO STAKEHOLDERS

The decline of migratory fish populations in the Danube River Basin started centuries ago due to overfishing, and their vulnerability increased by the large river regulation schemes, hydropower utilization, pollution and shipping from the 19th century. The current environmental status of the Danube and its major tributaries is not satisfactory with respect to the requirements of the long- and medium-migratory fish species. The Iron Gate barrage system is one of the largest river engineering structures in Europe, built to provide cost-effective utilization of hydropower and to create safe navigation along the Iron Gate gorge. However, hydropower dams are also an obstacle for migratory fish such as the sturgeon, which block access to the Middle Danube and its large tributaries. A feasibility study on the possibilities of fish migration through the dam is currently being prepared.

Migratory fish are particularly affected by fragmentation and destruction of river habitats, as they are prevented from movements between their spawning grounds and other core habitats, which are essential for their long-term survival and recovery. Blocking migration routes with river control facilities is the leading cause of their down-trending population dynamics.

The functionality of ecological corridors is a fundamental conservation priority in a river system, which can be ensured by the following measures: 1) improving the physical connectivity by mitigation or the removal of migration barriers, 2) restoration or maintaining core habitats for fish and 3) enhancing or sustaining viable fish populations by supportive programmes for rebuilding population structure and restoring natural reproductive potential.

A variety of passage facilities can be installed at river barriers for the restoration of connectivity of fragmented rivers. Despite the cost of building these structures, there is not enough information about their functionality and overall success in restoring the ecological corridor. Surmountability of most of the fish passes is usually incomplete, and accumulation of migratory fish is often observed below obstacles. Tagging, mark-recapture, fish pass trap and telemetry tracking of fish movement are informative methods for assessing the overall effectiveness of fish passages.

Photo: wikimedia

Biological and engineering expertise is now available to build and operate fish passes, however more detailed biological information is needed about migratory behaviour of the Danube fish, above all sturgeons. The swimming ability of target fish species is various. Understanding of complex interacting factors of fish migration and proper knowledge of swimming performance is crucial for designing effective fish passage systems.


Photo: Shutterstock

The cumulative effect of a series of limited efficiency fish passes may be very significant. The importance of monitoring is particularly apparent in the case of rivers where multiple facilities operate to support fish migration. Long-term monitoring of fish migration provides information about the effectiveness of facilities providing connectivity and function of ecological corridors.

The mortality of fish migrating downward is confirmed by several surveys at hydropower plants. Migrating fishes are often not likely to be successful in overcoming the numerous obstructions in sufficient quantities to maintain populations unless mitigating measures are taken. A variety of downstream protection facilities have been used to guide fish away from turbine intakes and transport them to the tailrace downstream of the power station.

The conservation of migratory fish species and the enhancement of their populations require a long-term, well-funded program of fish pass developments and constructions, improvements to dam operation, and removal of barriers wherever possible in the Danube River Basin. Governments are obliged to comply with international agreements such as the CBD, CMS, CITES, Ramsar Convention, etc. and regional regulations such as the Habitats Directive, WFD, EUSDR, etc. These frameworks can therefore be used actively to promote the restoration of fluvial ecological corridors. The strategies and action plans for the conservation of migratory fish can be successfully implemented through strong international cooperation. Development of national organisations for research of fish migration would be also important for the success of extensive international cooperation.

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Gábor Guti is the author of the text of the brochure
while Zsófia Hutai provided grammar proofreading.

The brochure development was lead by the EUSDR PA4 HU Team and ICPDR
and coordinated by Diana Heilmann, advisor of the EU Strategy for the Danube Region
"Water quality" priority area Hungarian coordination.

MINISTRY OF
FOREIGN AFFAIRS AND TRADE
OF HUNGARY

This brochure was prepared by EUSDR Priority Area 4 and financed by the project
DTP-PAC2-PA4 (Acronym: PA 04 Water Quality). The lead partner of the project
is the Ministry of Foreign Affairs and Trade of Hungary.

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nor the Ministry of Foreign Affairs and Trade of Hungary are responsible for any use
that may be made of the information contains.

This project is supported by the Danube Transnational Programme funded under the
European Regional Development Fund with the contribution of partner states and institutions

More information about the EU Strategy for the Danube Region "Water quality" priority area:
https://www.waterquality.danube-region.eu/

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