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Editorial

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Dear Reader,

We are pleased to announce that the International Association for Danube Research (IAD) and the Floodplain Institute Neuburg (Catholic University of Eichstätt-Ingolstadt) will organize the 43th IAD conference focused on "Rivers and Floodplains in the Anthropocene – Upcoming Challenges in the Danube River Basin" from June 9-11, 2021. Due to the corona pandemic, the event will take place in a virtual format, allowing us to exchange ideas and research results in a safe way. With this opportunity, we invite all IAD members to participate in the General Assembly meeting and elect the new IAD president, the person who will coordinate our activities for the next six years. Please check the conference homepage iad2020.ku.de for the latest updates.

This issue of Danube News presents an overview of the role of hydropower plants and their ecological impacts, the threats posed by new development plans and the lessons learned from the past years.

Long considered as a "clean" energy source due to their low emission of greenhouse gases, hydropower plants proved to have a highly negative impact on river systems. For decades these impacts were not properly prevented/mitigated, and hence, the costs of hydropower energy remained low and attractive to consumers. However, the real price was paid by the aquatic communities, numerous species being brought near extinction, such as the migratory freshwater fish. Without subsidies and with real environmental costs included, the hydroenergy will not remain as attractive anymore as other renewables, such as wind, solar, geothermal, wave energy, become increasingly affordable.

The EU Green Deal, aiming to protect, conserve and enhance EU's natural capital, the EU Biodiversity 2030 Strategy goal to restore 25,000 km of EU rivers to the free-flowing state, the Water Framework Directive, aiming to achieve good ecological status/potential by 2027, and the Habitats Directive, supporting among others habitat restoration for endangered species, provide a key legal frame for river restoration in the EU. In this context, instead of constructing new hydropower dams and altering new river sections, the focus should be shifted to restoration and where feasible dam removal, while refurbishing and upgrading of existent plants must strictly ensure full compliance with the environmental legislation.

We hope that our articles will contribute to raise awareness on the numerous environmental challenges posed by hydropower dams and solutions to mitigate their impacts. Enjoy reading!

Hydropower balancing between global climate change and regional water protection

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Hydropower has been a human use for a long time. In many countries, it is a major pillar of electrical production. The consumption of energy is continuously increasing in parallel with population growth as well as quantitative and qualitative demands. In the emerging debate about global climate change and "sustainable" development, hydropower has gained increasing attendance. On the one hand, it is almost free of greenhouse gases (mainly CO_2, but some hydropower plants emit CH_4). On the other hand, it causes significant and often irreversible damage to freshwater ecosystems. Therefore, the advantages and disadvantages of hydropower plants must be balanced. This article provides a general overview and develops recommendations to mitigate impacts from hydropower.

Short Abstract of Hydropower History

Hydropower to operate machines (bucket wheels) was started some 5000 years ago in China and later used by all major ancient cultures (e.g., Mesopotamia, Greeks, Romans). At the end of the 18th century, when the industrial revolution began, hundreds of thousands of water mills were in operation. In 1880, the first hydropower plant was put into operation in England, followed in 1896 by the first large hydropower plant in the USA (de.wikipedia.org/wiki/Wasserkraft, visited 17.9.2020). A hydropower boom started after World War II due to economic and technical developments. Today, hydropower is classified as "old" renewable energy, in contrast to "new" renewable energy such as solar and wind.

The actual Energy Debate and Strategy

The newly launched global energy debate is dominated by two issues: First, the ever increasing human population demands more production of energy and electricity. In particular, the general quantitative demand is complemented by a qualitative demand, basically triggered by increasing welfare, mobility and globalization. Second, ongoing global climate change requires a drastic limitation of greenhouse gases, mainly CO_2 and CH_4; hence, decarbonization is on the political agenda, especially the substitution of oil products (Sustainable Development Goals UN 2015; Paris Agreement 2015). Every country has developed its own strategy, usually based on securing energy supply, particularly in winter. While the application of "sustainability" is indispensable, some still rely on oil and gas, and some on nuclear power and hydropower. New renewable energies have emerged and gained importance, mostly wind and solar energy. The strategy chosen is highly dependent on economic considerations as well as the share of basic and peak energy. The costs of production, the dynamics of the energy market, the price of electricity, and the gross national product all play a crucial role. Today, electricity is bought and sold within minutes on a floating market similar to a stock exchange. In addition, and in the debate about "sustainability", we need to consider decentralized versus centralized systems (Wilderer & Grambow 2016): The latter require substantial, costly transport and storage capacities.

Any energy strategy is in conflict with environmental protection, at the global as well as regional level. The basic question is whether humans, driven by economy and egotism, should ultimately destroy freshwater ecosystems as the basis of our lives (Boon et al. 2000). In particular, power plants using water are a focus in aquatic science, including nuclear power (thermal pollution through cooling systems) and hydropower (see below). Hydropower is in conflict between targets of global climate change mitigation and regional nature and water protection. In this context, it matters whether we deal with the construction of new plants or the refurbishment of existing plants. New concessions or permits require an Environmental Impact Assessment (EIA), including an analysis of the (near-) natural reference state of the river system affected upstream and downstream of the hydropower plant. They also require a deficit assessment by comparing the reference with the actual state and expected impacts, and a science based evaluation of the potential for mitigation or compensation. This procedure needs proper public participation. Ultimately, the quality of national environmental laws (the Water Framework Directive (WFD) in Europe) and the willingness of governments and authorities to implement laws deciding on sound solutions.

Recently, hydropower was positioned not only as producer of electricity, but also as multiple-use plants; e.g. for flood control and irrigation. For instance, climate change increases the dimension and frequency of flood events and can cause intensive droughts. Such trends increase the request of operators to value even small hydropower plants as an "overriding public interest". This complicates the political discussion because the conflict of interest is enlarged. In this context, natural floodplains should be conserved and restored.

Types of Hydropower Plants and Environmental Issues

The technology of hydropower plants is described in many textbooks (e.g. Hütte 2000). Nowadays, technical progress is mainly targeting the increase in production efficiency; e.g., modern turbines. With regard to installed capacity, we can distinguish between small hydropower (<10 MW), medium hydropower (10–100 MW) and large hydropower (>100 MW). Sometimes, other threshold values are used. For example, Hudek et al. (2020) classified hydropower plants with an installed capacity >10 MW as large, 1–10 MW as medium, <1 MW as small, and <0.1 MW as micro. It should be noted that a few large plants contribute to the majority of energy production, while many small plants provide a few percent (ICPDR 2013). Moreover, small hydropower plants, usually situated on small rivers or streams, have similar negative environmental impacts as those caused by large plants on large rivers; e.g., disruption of the river continuum. Therefore, small hydropower, promoted particularly by unsuitable subsidies in SEE countries in the Lower Danube region, cannot be used to combat climate change. Apart from hydropower size, general types include run-of-river (impoundment), diversion, and (pumped) storage plants *(fig. 1)*. The former are mostly in lowland regions, the latter mostly in steep mountain regions.

Hydropower: Pros and Cons in the Global and Regional Perspective (Danube River Basin)

From a global perspective, hydropower is almost CO_2-free except in the tropics and large lowland rivers where CH_4 is emitted from the sediment of reservoirs (Maeck et al.

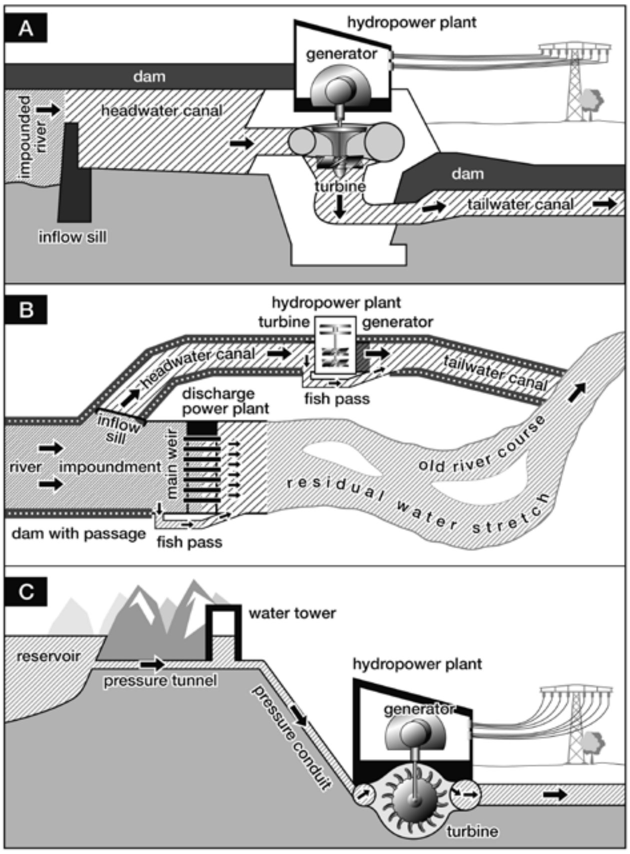

Figure 1: Technical schemes of various types of hydropower plants: (A) run-of-river plant, (B) diversion plant, (C) (pumped) storage plant. Credit: RAOnline EDU & Bayerische Landeskraftwerke, redrawn by Claudia Pietsch, CU Eichstätt-Ingolstadt

2013, Deemer et al. 2016, Scherer & Pfister 2016). However, is this a reason to rate hydropower as "sustainable" (Moran et al. 2018)? Scaling matters: from a regional to local perspective, rivers are heavily impacted by hydropower, which is a key pressure on aquatic ecosystems (hydrology, hydromorphology) and biodiversity (habitats and biota). In fact, the negative impacts often result in irreversible damage to aquatic ecosystems (Grill et al. 2019).

Major impacts of hydropower on riverine ecosystems are compiled in Table 1. Run-of-river plants mainly disrupt the river continuum. The impounded stretch is transformed into a lake ecosystem lacking riverine dynamics of hydrology (discharge). Over time, reservoirs fill with sediments and need to be flushed in light of stored contaminants and ecological thresholds of suspended solid concentrations. Further, groundwater tables are affected due to altered river infiltration and exfiltration. Diversion plants also cause mainly problems of residual water (ecological flow) and hydropeaking. Storage plants change alpine landscapes, the hydrological and sediment regime and cause significant hydropeaking effects. Sometimes, headwaters from other catchments are diverted to alpine reservoirs with mostly unknown ecological effects. Often, hydrological and temperature regimes are inverted seasonally, with artificial high flow and temperatures in winter (production mode) and low flow and temperatures in summer (storage mode).

The disruption of fish and zoobenthos migration as well as sediment transport by dams is obvious. For example, the Iron Gate dams on the Danube River, operational since 1972 and 1984, have stopped sturgeon spawning migration to the Middle and Upper Danube, thus disrupting their life cycle and threatening natural reproduction (Reinartz 2002). In the Iron Gate reservoir, contaminated sediments accumulate (Milenkovic et al. 2005). Downstream of the hydropower plant Freudenau in Vienna, sediment erosion amounts to some 1.5 cm/year, thus fostering riverbed incision (Klasz et al. 2016). Expensive sediment feeding for compensation and other environmental measures diminish the economic benefits of energy production. In impounded stretches, typical benthic fauna changes from lotic to lentic (Moog 2002, *fig. 2)*. Moreover, sediments become clogged by the settling of fine particles. In large alpine reservoirs, water temperatures downstream can be drastically changed when hypolimnetic cold water is released from the impoundment. In some rivers, one hydropower plant follows the other, and this chain of hydropower plants changes the free-flowing river into a chain

Impact	Ecological consequences	Measures of mitigation	Key literature
Dams, impoundments	Disruption of the river continuum, fish migration and sediment transport; change of habitats and fauna in the reservoir (lotic → lentic); inversion of the hydrological regime and water temperature; river bed incision, lowered groundwater table and disconnected floodplains downstream of the dam	Functional fish passes; (partial) sediment transport through the weirs, removal of barriers	Nilsson et al. (2005)
Water abstraction	Alteration of the hydrological regime (discharge)	Ensure minimum ecological flow with seasonal fluctuation	Bunn & Arthington (2002); Dyson et al. (2003)
Hydropeaking	Fast and strong increase/ decrease of flow affects fish and benthos	Allow a controlled regime by an adapted running mode or special retention basins (reducing amplitudes and slow down the flow changes)	Greimel et al. (2018)

Table 1: Major impacts of hydropower plants on riverine ecosystems (habitats and fauna)

of lakes (e.g., the Danube River has 52 dams upstream of Vienna, and many Danube tributaries have impoundments (ICPDR 2015).

Water abstraction drastically reduces discharge and flow, and many lotic species disappear because their living conditions are lost. In mountains, many stretches remain completely dry and without any aquatic biota *(fig. 3)*. Hydropeaking is another impact of the natural hydrological regime to which aquatic organisms are adapted by evolution. In contrast to stochastic floods and droughts causing high and low flow conditions over the season, hydropeaking is a regular, repeated and rapid change in flow: Both fish and benthos are swept away by the strong peaks in current, or they are stranded to die on shallow dry banks. An overall result is a drastic loss of biodiversity.

Mitigating Impacts to protect our rivers

In the hydropower sector, integrative river protection and management should provide the background

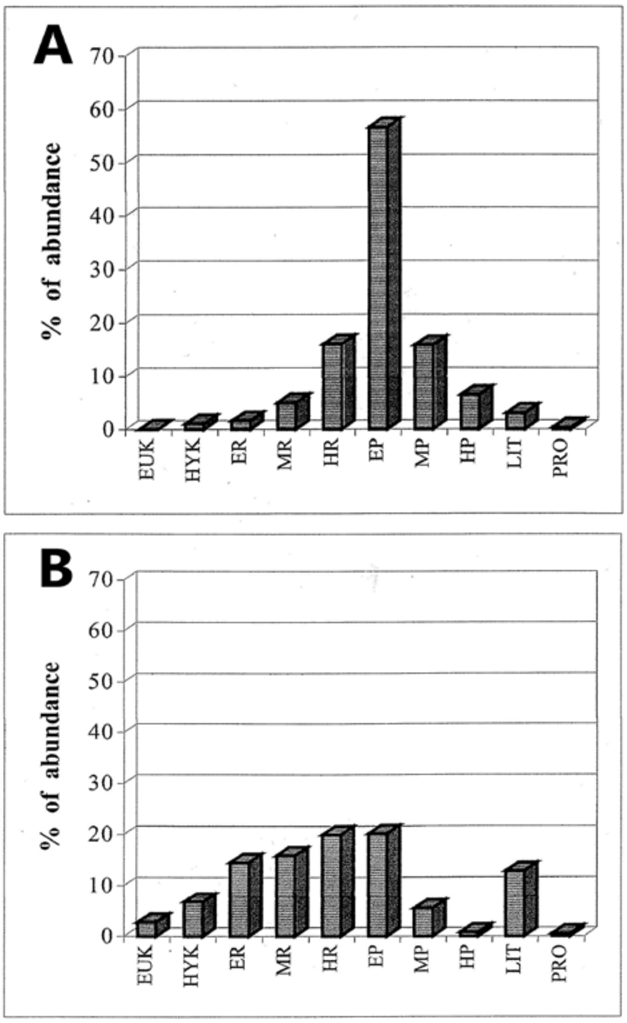

Figure 2: Changes of benthos communities due to impoundment by a hydropower dam. An example of River Traun, Upper Austria (Moog 2002). (A) Epipotamal character of the river (reference); (B) Region of Danzermühl (impoundment). River zonation: EUK = Eucrenal, HYK = Hypocrenal; ER = Epirhithral, MR = Mesorhithral, HR = Hyporhithral, EP = Epipotamal, MP = Mesopotamal, HP = Hypopotamal, LIT = Litoral, PRO = Profundal

guidelines (Bloesch et al. 2012). A general concept to be considered is the prioritization of conservation over restoration (Boon 2005). Mitigation measures need to be balanced in a cost-benefit analysis and should follow the sequence: avoid – mitigate – compensate the impact. Hence, we consider protected areas (national parks, nature parks, Natura 2000, etc) as “no-go zones” for new hydropower plants, but are accepted by authorities for exemptions according to Articles 6.3 and 6.4 of the EU Habitats Directive (Council Directive 92/43/EEC of 21 May 1992, ICPDR 2013). Many catchments in Lower Danube countries still feature free-flowing rivers that are under strong political pressure to promote hydropower (Schwarz 2016; Hudek et al. 2020). Theory and practice are not always in agreement, as demonstrated, e.g., by the hydropower case on the Jiu River in Romania (Dejeu & Carpa 2020) and the poor performance of the badly needed feasibility study for sturgeon fish passages at the Iron Gate dams. Clearly, implementation of the respective national environmental law is prescribed by the WFD and other relevant EU Directives. However, this is in conflict with the EU Energy Strategy and several EU Renewable Energy Directives combating greenhouse gas emissions and climate change.

To restore or ensure the river continuum, at least partly, dams and weirs need to be equipped with functional fish passes for upstream and downstream migration, as well as technical facilities to allow uncontaminated bottom sediment transport during high flow. In large rivers (about > 300 m^3/s), two fish passes are needed because most fish migrate along the banks. Depending on the local situation, migration aids can be a technical fish latter, a fish lift, a fish lock, or a near-natural by-pass. The ICPDR (2015) documents numerous missing and built fish passes in the DRB, but without indicating their function. It is extremely difficult and debated to quantify and rate the proper function of a fish pass (Schmutz & Mielach 2013; ÖFV 2020). Key issues are flow attraction at the entrance and timely passability. Apart from technical controls of proper dimensions, a biological success control after construction is indispensable. To note, far less attention has been given to downstream facilities. Guiding barriers, screens and racks may be supported by so-called fish-friendly turbines with low fish mortality rates, but these need to be rated with utmost caution, particularly with regard to eels. A long-term monitoring of fish passes (success control) during the whole concession period is highly recommended.

Since around 2000, old and rather small or medium dams, where the negative environmental impacts outcompeted the economic benefits, became subject to dam removal (demolition), particularly in the USA, but also in Europe. Presently, some 4984 barriers have been removed already in 13 European countries (www.damremoval.eu).

Further, stretches with residual flow through water abstraction need to have minimum ecological flow (Allan 1995, Arthington et al. 2006). Since the amount of compensation water is debated as every liter given diminishes electricity production and thus profit, this topic requires very good scientific investigations. The negative effects of hydropeaking can be mitigated by reducing discharge amplitudes, by slowing the increase/decrease of flow, and by construction of special retention basins to offset high peaks. As mentioned above, floodplains need special treatment and protection.

Figure 3: Madriser Rhine, Avers Valley, Grisons, Switzerland. Upstream and downstream of the water abstraction. The dried out river section has no aquatic life and disrupts the river continuum. Credit: SGS, Schweizerische Greina-Stiftung Zürich

A thorough impact analysis suggested above provides a set of measures of how to mitigate environmental damage. The Strategic Environment Assessment (SEA), Environmental Impact Assessment (EIA), and final concession (permit) provide the political basis for any large construction. These should be executed by the competent authorities in an open procedure, and using Public Participation (as prescribed by the Aarhus Convention). Simply organizing a public workshop for presenting finalized construction plans is quite insufficient. Local communities and the people affected as well as environmental NGOs should be involved in the process as early as possible, ideally before any plans are elaborated. Experience shows that the sincere cooperation between engineers, biologists, authorities, stakeholders and local people may be a laborious and difficult task, but at the end the project will be less expensive and better.

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