Balkan rivers are endangered by construction of new hydropower plants

Helena Huđek: *Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany, e-mail: hudek@igb-berlin.de*
Ulrich Schwarz: *Fluvius, Vienna, Austria, e-mail: ulrich.schwarz@fluvius.com*

Abstract

1,480 operating hydropower plants (HPP) were recorded in the Balkan region and 108 are currently under construction, while 1,547 of 3,431 planned HPPs (45%) are located in Natura 2000 and other protected areas (e.g. National parks, Emerald sites, Ramsar sites). There has been a significant increase in HP development, with numbers of operating HPPs doubling between 2015 and 2020. The increase is predominantly, but not only, because of small and medium sized HPP construction that are mostly diversion type. This has led to thousands of kilometres of abstracted and interrupted rivers. Hence, the impacts of small and medium sized HPPs are disproportionately high, while their contribution to overall energy production is low. Furthermore, there are plans to construct HPPs on the Vjosa River, one of the last large free flowing rivers in Europe. There is a need to recognize the widespread impacts caused by HPPs, especially small and medium sized ones, in order to achieve the EU Biodiversity Strategy's aims to reconnect 25,000 kilometres of Europe's rivers by 2030.

1. Introduction

Rivers provide services essential to human well-being, but our use of rivers for power generation, water supply, flood control, navigation and other uses (Tockner et al., 2010) has nearly always involved their fragmentation. Instream structures, such as weirs and dams, have been developed in the past to such a global extent that only a minority especially of large rivers still remains unaffected by their environmental impacts generated (Belletti et al. 2020; Grill et al. 2019).

Weirs and dams may cause significant environmental impacts such as river fragmentation (Liermann et al. 2012), severe modification of river flow (Zimmerman et al. 2010) and temperature regime (Žganec 2012; Zolezzi et al. 2011), dramatic reductions in sediment transport (Hauer et al. 2018) and hydro-morphological degradation of extended downstream river sections (Wiatkowski & Tomczyk 2018). Together they lead to the habitat loss and loss of biodiversity, ecological functions, ecosystem services as well as system resilience resulting in a significant impairment of the ecological integrity of river ecosystems (Richter et al. 2003).

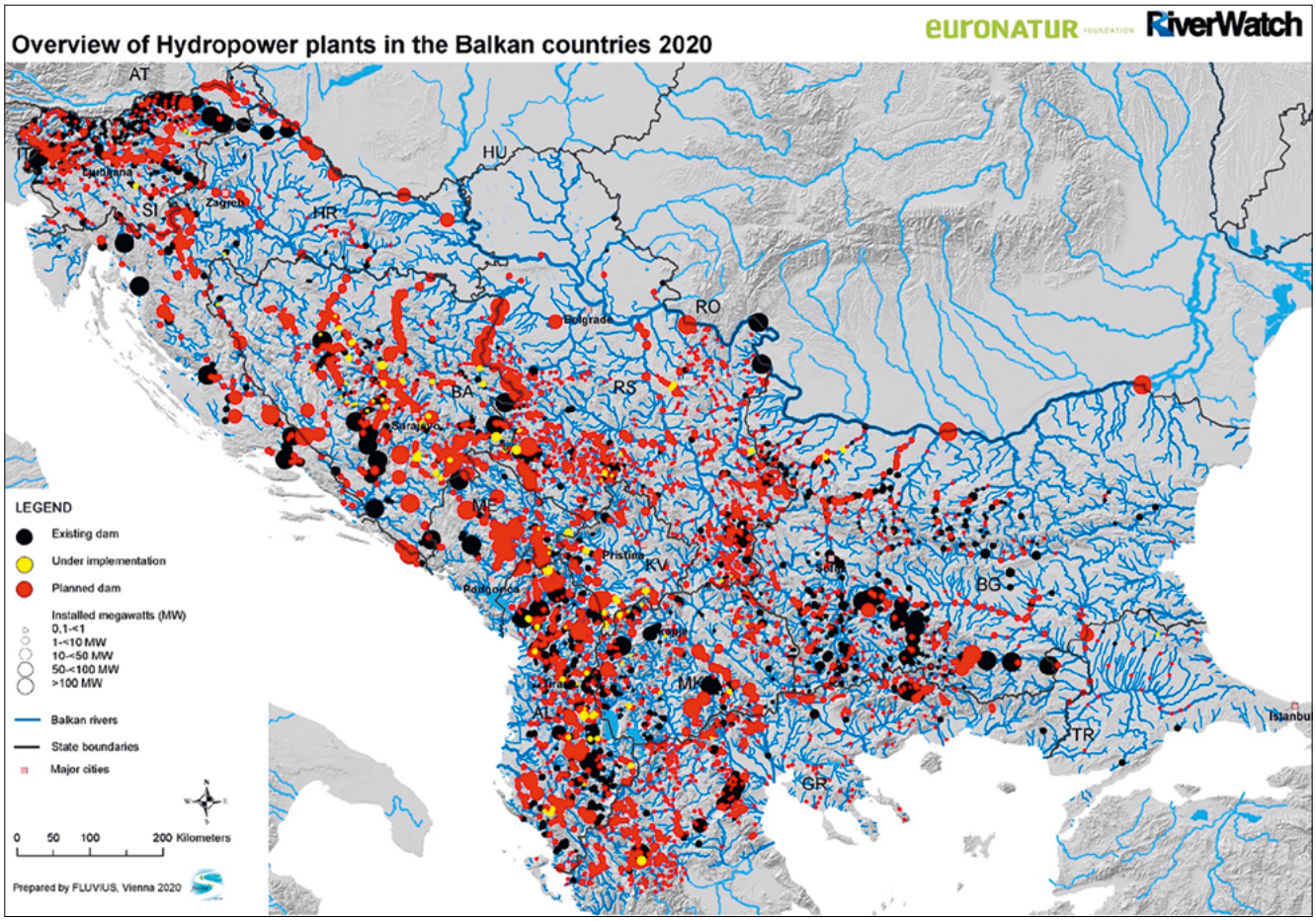

Figure 1: *Distribution of existing (black circles) and planned (red circles) hydropower plants and hydropower plants under implementation (yellow circles)*

Relatively unfragmented rivers are still found in the Balkan region, the Baltic states and parts of Scandinavia and southern Europe (Belletti et al. 2020). According to Schwarz (2012a), the morphology of up to 80% of rivers, of a total of 35,000 km of rivers in the Balkan region, had been assessed as still having a good condition. This was by far the highest percentage in Europe, where 80% of rivers have been found to be in poor hydro-morphological condition. For biogeographical reasons, the river systems of the Balkan region are home to very diverse and highly endemic freshwater fauna (Ćaleta et al. 2015; Freyhof 2012; Griffiths et al. 2004; Ivković & Plant 2015; Schiemer et al. 2020; Weiss et al. 2018), and therefore have been identified by the WWF as one of the key places (Global 200 Ecoregions) for biodiversity conservation on a global scale. For example, 49 (11 endemic) of 113 freshwater fish species in the Balkan region are faced with either the threat of extinction or loss of between 50 and 100% of their distribution (Weiss et al. 2018).

All EU countries as well as some non-EU states have established national plans aiming to reduce greenhouse gas emissions that include financial subsidies (e.g. feed-in-premium) for renewable energy production including hydropower (Gallop et al. 2019). These in turn, have triggered a revival in the construction of weirs and dams for hydropower production (HPPs), especially small HPP (Huđek et al. 2020; Schwarz 2020; Zarfl et al. 2014). Like in many other regions of the world, the Balkan area is currently planning to develop significantly more HPPs on many rivers that have so far mostly remained undammed (Huđek et al. 2020; Schwarz 2020; Zarfl et al. 2014). Already the hydropower boom in the last decade, especially in countries like Albania, Bosnia and Herzegovina, but also Serbia devastated numerous rivers. Furthermore, there are plans to build HPP even in national parks and other protected areas (e.g. EU Natura 2000 sites, regional parks) (Schwarz 2020, 2012b), which would have a massive impact on river ecosystems in the Balkan region. Therefore, rivers of the Balkan region require urgent protection from proposed dam developments (Belletti et al. 2020).

Here we present the distribution and trends of existing and planned hydropower plants in the Balkan region.

2. Study area

The study area comprises the EU countries Slovenia (SI), Croatia (HR), Bulgaria (BG) and the northern Balkan area of Greece (GR), as well as the non-EU countries Bosnia & Herzegovina (BA), Serbia (RS), Montenegro (ME), Kosovo (KV), North Macedonia (MK), Albania (AL), and the European part of Turkey (TR).

	Existing	Planned	Under implementation
Slovenia	366	375	3
Croatia	60	147	1
Bosnia and Herzegovina	139	390	35
Serbia	122	824	14
Kosovo	22	87	10
Montenegro	20	92	4
North Macedonia	99	193	12
Albania	290	410	24
Greece	50	565	2
Bulgaria	307	323	2
Turkey	5	25	1
In protected areas*	675	1547	48
Total	1,480	3,431	108

**National parks, Ramsar sites, Biosphere Reserves, World Heritage sites, Natura 2000 network, Emerald sites, Landscape protection*

Table 1: *Number of existing, planned and under implementation hydropower plants in the study area and in the protected areas of study area*

3. Material & Methods

For more information see the report of Schwarz (2020).

4. Results & Discussion

1,480 operating HPPs were recorded in the study area, 89% of which were small (≤ 10MW) and 108 are currently under construction *(tab. 1; fig. 1; fig. 3)*. The largest number of operating HPPs was located in Slovenia (N = 366), followed by Bulgaria (N = 307) *(tab. 1)*. A large number of HPPs, 3,431, are in the planning phase, 92% of which are small (≤ 10MW). Serbia, Bosnia and Herzegovina, Albania and North Macedonia are current hotspots of HPP construction, while in Greece the large number of planned HPPs (N = 571) seems to remain fictive (tab. 1).

1,547 of 3,431 HPPs (45%) are planned in Natura 2000 and other protected areas (e.g. National parks, Emerald sites, Ramsar sites) *(tab. 1)*. In national parks in Bosnia and Herzegovina, Kosovo, North Macedonia and Albania currently at least 14 HPP are under construction.

The designation of many rivers as Natura 2000 areas, in Croatia or Bulgaria, has led to a reduced development of HPPs. However, non-EU countries have not developed Natura 2000 network yet. For example, the total inland area designated as protected in Bosnia and Herzegovina and Serbia is small; indeed, the percentage of total state territory is significantly below the European average (1.4% in Bosnia and Herzegovina, 7.56% in Serbia) (Appleton et al. 2015b, 2015a). This means that the percentage of planned HPPs that would significantly affect species that are protected in the EU under the Natura 2000 network would be high. Furthermore, the booming HP sector in the Balkan region

defies the EU's political ambitions of improving the state of rivers in line with the Water Framework Directive and to reconnect 25,000 km of rivers by removing dams and water abstraction systems.

There has been a significant increase in hydropower development, with numbers of operating plants doubling between 2015 (N = 714) and 2020 (N = 1480) *(fig. 3)*. Hot spots of HPP development in the recent years are Albania, Bosnia and Herzegovina, followed by Serbia, North Macedonia and Kosovo. The increase is predominantly because of small HPP construction that are usually diversion type, but also of some larger dams e.g. on Devoll in Albania (Moglice). Diversion HPPs operate by water abstraction from an upstream reservoir or river reach and transport through pipe to a hydroelectric powerhouse located more downstream in order to increase the difference in hydraulic head for power generation. This operation type raises the risk of the river channel to fall dry in the river reach between the dam and the return point of abstracted water *(fig. 2)*. This has already led to hundreds, even thousands of kilometres of abstracted rivers and habitat destruction, as well as to deforestation and erosion in order to build access roads. Local people have been often left without water for irrigation and livestock (Gallop et al. 2019). The amount of flow abstracted for hydropower generation can vary widely depending on national, regional, or local regulations. However, those regulations are often disregarded. HPP projects, particularly small diversion schemes, are the most important driver of potential fish species extinctions in the Mediterranean Basin Biodiversity Hotspot (Freyhof et al. 2020).

Furthermore, the pressure of climate change argumentation and renewable energy policies (e.g. EU Renewable Energy Directive) encourage the ongoing HPP development. In fact SHPP development does not contribute much to electricity share if we see that in 2018, SHPPs generated only 3.6 per cent of electricity overall, but received 70 per cent of renewable energy incentives in the Western Balkans (Gallop et al. 2019). Renewable energy incentives were received mostly through feed-in tariffs and they are considered as the main driver for SHPPs and the main burden on bill payers. There is the obvious conflict of interest between EU strategies for the development of renewable energy (EU RES) and for the protection of biodiversity (International Convention of Biological Diversity, EU Biodiversity Strategy, Natura 2000 network). There is a need for the harmonization of EU and national policies on the development of renewable energy

Figure 2: *Small hydropower plant Garvanitsa on Strane River in Bulgaria. Operation of this HPP causes regular drying of Strane River's riverbed; credits: dams.reki.bg*

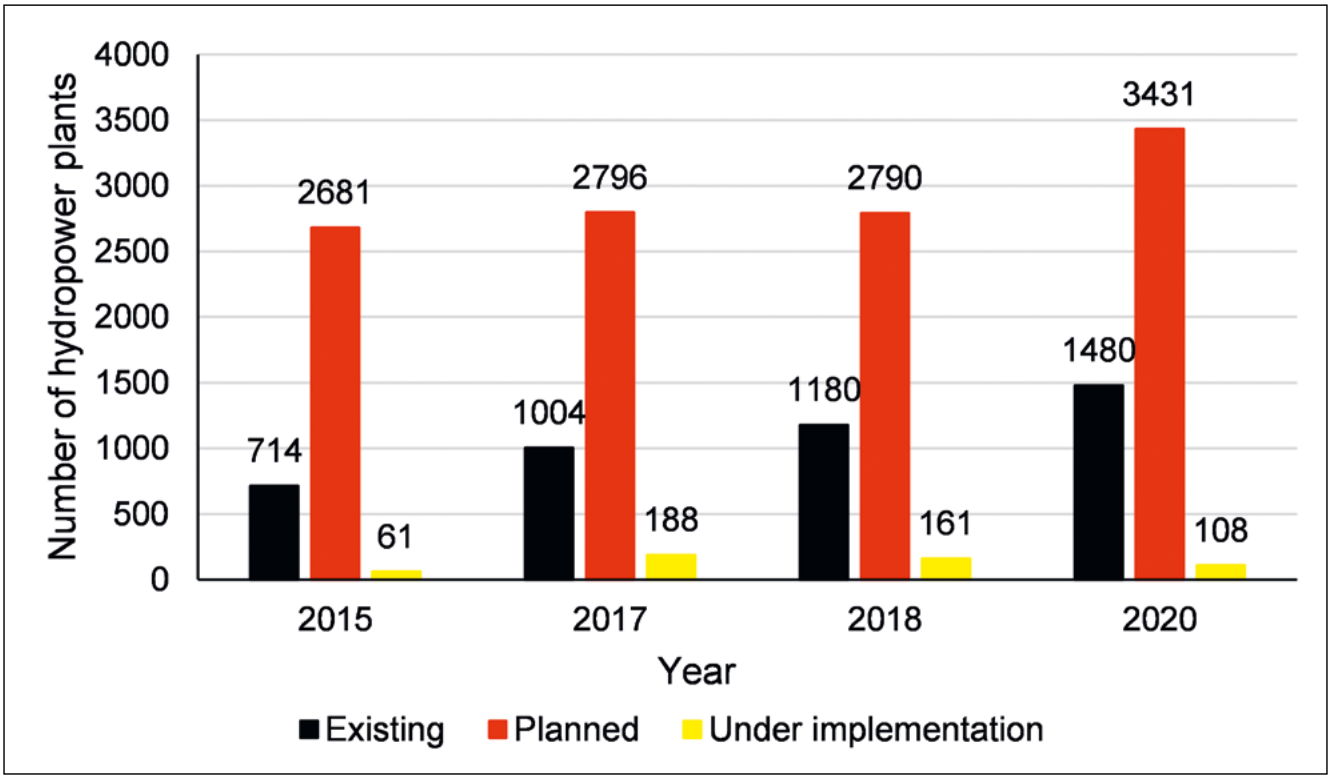

Figure 3: Number of existing, planned and under implementation hydropower plants in years 2015, 2017, 2018 and 2020

sources, on water management and on nature conservation in rivers and floodplains.

Conclusions

Numbers of operating HPPs doubled between 2015 and 2020. The increase was predominantly because of small and medium sized HPP construction that are mostly diversion type. The environmental impacts of small and medium sized HPPs are disproportionately high, while their contribution to overall energy production is low (Huđek et al. 2020). Therefore, there is an urgent need to mitigate the escalating ecological damage caused by the boom in HPP construction through preservation and restoration of free-flowing rivers. In addition to small HPPs also larger HPPs are planned on some of the most valuable rivers from the ecological point of view in the Balkan region e.g. on Vjosa (AL), Morača (ME) but also on upper Sava (SI), Vrbas (BA), Bosna (BA), Drina (BA, RS), Vardar (MK) or Maritsa (BG). Vjosa River is one of the last large free flowing rivers in Europe and should be subjected to protection as national park instead of being exploited for hydropower. In order to achieve the EU Biodiversity Strategy's aims of improving the state of rivers and to reconnect 25,000 km of rivers by removing dams and water abstraction systems will require recognition and prevention of the widespread and devastating impacts caused by HPPs.

References

Appleton MR, Ioniță A, Nițu R, Sekulić G, Stanciu E (2015a): Assessment of capacity development needs of protected area staff in Eastern Europe, Serbia. ProPark Foundation, Brasov.

Appleton MR, Ioniță A, Nițu R, Sekulić G, Stanciu E (2015b): Assessment of capacity development needs of protected area staff in Eastern Europe, Bosnia and Herzegovina. ProPark Foundation, Brasov.

Belletti B, Garcia de Leaniz C, Jones J et al. (2020): More than one million barriers fragment Europe's rivers. Nature 588, 436–444. https://doi.org/10.1038/s41586-020-3005-2.

Ćaleta M, Buj I, Mrakovčić M, Mustafić P, Zanella D, Marčić Z, Duplić A, Mihinjač T, Katavić I (2015): Endemic Fishes of Croatia. Croatian Environment Agency, Zagreb.

Freyhof J (2012): Threatened freshwater fishes and molluscs of the Balkan. ECA Watch Austria and EuroNatur. https://doi.org/10.1007/s13398-014-0173-7.2.

Freyhof J, Bergner L, Ford M (2020): Threatened Freshwater Fishes of the Mediterranean Basin Biodiversity Hotspot: Distribution, extinction risk and the impact of hydropower. EuroNatur and RiverWatch, 348pp.

Gallop P, Vejnović I, Pehchevski D (2019): Western Balkans hydropower Who pays, who profits? EuroNatur and RiverWatch, 1-46.

Gracey EO, Verones F (2016): Impacts from hydropower production on biodiversity in an LCA framework—review and recommendations. Int. J. Life Cycle Assess. 21, 412–428. https://doi.org/10.1007/s11367-016-1039-3.

Griffiths HI, Kryštufek B, Reed JM (2004): Balkan Biodiversity: Pattern and Process in the European Hotspot, 1st Edition; Kluwer Academic Publishers: Dordrecht, Netherlands. Kluwer Academic, Dordrecht. https://doi.org/10.1007/978-1-4020-2854-0.

Grill G, Lehner B, Thieme M, Geenen B, Tickner D, Antonelli F, Babu S, Borrelli P, Cheng L, Crochetiere H, Ehalt Macedo H, Filgueiras R, Goichot M, Higgins J, Hogan Z, Lip B, McClain ME, Meng J, Mulligan M, Nilsson C, Olden JD, Opperman JJ, Petry P, Reidy Liermann C, Sáenz L, Salinas-Rodríguez S, Schelle P, Schmitt RJP, Snider J, Tan F, Tockner K, Valdujo PH, van Soesbergen A, Zarfl C (2019): Mapping the world's free-flowing rivers. Nature 569, 215–226. https://doi.org/10.1038/s41586-019-1111-9.

Hauer C, Wagner B, Aigner J, Holzapfel P, Flödl P, Liedermann M, Tritthart M, Sindelar C, Pulg U, Klösch M, Haimann M, Donnum BO, Stickler M, Habersack H (2018): State of the art, shortcomings and future challenges for a sustainable sediment management in hydropower: A review. Renew. Sustain. Energy Rev. 98, 40–55. https://doi.org/10.1016/j.rser.2018.08.031

Huđek H, Žganec K, Pusch TM (2020): A review of hydropower dams in Southeast Europe – distribution, trends and availability of monitoring data using the example of a multinational Danube catchment subarea. Renew.

Sustain. Energy Rev. 117, 1–11. https://doi.org/10.1016/j.rser.2019.109434.
Ivković M, Plant A (2015): Aquatic insects in the Dinarides: Identifying hotspots of endemism and species richness shaped by geological and hydrological history using Empididae (Diptera). Insect Conserv. Divers. 8, 302–312. https://doi.org/10.1111/icad.12113.
Liermann CR, Nilsson C, Robertson J, Ng RY (2012): Implications of Dam Obstruction for Global Freshwater Fish Diversity. Bioscience 62, 539–548. https://doi.org/10.1525/bio.2012.62.6.5.
Richter BD, Mathews R, Harrison DL, Wigington R (2003): Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. Ecol. Appl. 13, 206–224. https://doi.org/10.1890/1051-0761(2003)013.
Schiemer, F., Drescher, A., Hauer, C., Schwarz, U., 2020. The Vjosa River corridor: a riverine ecosystem of European significance. Landsc. Ecol. 35, 953–968.
Schwarz U (2012a): Balkan Rivers–The Blue Heart of Europe. Hydromorphological Status and Dam Projects. RiverWatch and EuroNatur. Vienna/Radolfzell.
Schwarz U (2012b): Hydropower Projects in Protected Areas on the Balkans. RiverWatch and EuroNatur. Vienna/Radolfzell.
Schwarz U (2020): Hydropower Projects on Balkan Rivers 2020 Update. RiverWatch and EuroNatur. Vienna/Radolfzell.
Tockner K, Pusch M, Borchardt D, Lorang M S (2010): Multiple stressors in coupled river-floodplain ecosystems. Freshw. Biol. 55, 135–151.
Weiss SJ, Apostolou A, Đug S, Marčić Z, Mušović M , Oikonomou A, Shumka S, Škriljej R, Simonović P, Vesnić A, Zabric D (2018): Endangered Fish Species in Balkan Rivers: their distributions and threats from hydropower development. Riverwatch & EuroNatur, 162 pp.
Wiatkowski M, Tomczyk P (2018): Comparative Assessment of the Hydromorphological Status of the Rivers Odra, Bystrzyca, and Sleza Using the RHS, LAWA, QBR, and HEM Methods above and below the Hydropower Plants. Water 10, 1–16. https://doi.org/10.3390/w10070855.
Zarfl C, Lumsdon AE, Tockner K (2014): A global boom in hydropower dam construction. Aquat. Sci. 161–170. https://doi.org/10.1007/s00027-014-0377-0.
Žganec K (2012): The effects of water diversion and climate change on hydrological alteration and temperature regime of karst rivers in central Croatia. Environ. Monit. Assess. 184, 5705–5723. https://doi.org/10.1007/s10661-011-2375-1.
Zimmerman JKH, Letcher BH, Nislow KH, Lutz KA, Magilligan FJ (2010): Determining the effects of dams on subdaily variation in river flows at a whole-basin scale. River Res. Appl. 26, 1246–1260. https://doi.org/10.1002/rra.
Zolezzi G, Siviglia A, Toffolon M, Maiolini B (2011): Thermopeaking in alpine streams: Event characterization and time scales. Ecohydrology 4, 564–576. https://doi.org/10.1002/eco.132.

Fish Ecological Monitoring at Innovative and Conventional Hydropower Stations in Bavaria, Germany

Juergen Geist: *Technical University of Munich, Aquatic Systems Biology, Freising, Germany, email: geist@wzw.tum.de*

Josef Knott: *Technical University of Munich, Aquatic Systems Biology, Freising, Germany, email: josef.knott@tum.de*

Melanie Mueller: *Technical University of Munich, Aquatic Systems Biology, Freising, Germany, email: melanie.mueller@tum.de*

Hannah Ingermann: *Bavarian Environment Agency, Augsburg, Germany, email: Hannah.Ingermann@lfu.bayern.de*

Madlen Gerke: *Bavarian Environment Agency, Wielenbach, Germany, email: Madlen.Gerke@lfu.bayern.de*

Christoph Mayr: *Bavarian Environment Agency, Wielenbach, Germany, email: Christoph.Mayr@lfu.bayern.de*

Birgit Lohmeyer: *Bavarian Environment Agency, Augsburg, Germany, email: Birgit.Lohmeyer@lfu.bayern.de*

Joachim Pander: *Technical University of Munich, Aquatic Systems Biology, Freising, Germany, email: Joachim.pander@tum.de*

Abstract

The use of hydropower is ambivalent, providing a contribution to decarbonisation of energy supply on the one hand, and impacting aquatic habitats and their connectivity with consequences for fish and biodiversity on the other hand. The aims of this project were to compare different types of innovative and conventional hydropower technology in terms of direct and delayed fish mortality, external and internal fish injuries as well as the impacts on habitat quality and aquatic biodiversity up- and downstream of the hydropower dams. The main findings suggest considerable species- and site-specific mortality and injury patterns that are strongly governed by local fish communities as well as construction aspects (such as screen properties, turbine type, hydraulic head) and operational modes. In contrast to the expectation, innovative technologies were not generally less harmful to fish than conventional ones equipped with specific fish protection screens. Even within one type of technology, site-specific differences strongly governed the observed impacts. The main impact on habitat quality and aquatic community structures was a result of the dam construction, irrespective of the installation of hydropower turbines. The observed seasonal and diurnal patterns of downstream fish movement along different corridors as well as the findings on fish mortalities and injuries can be used for an objective discussion on reducing adverse ecological effects of hydropower utilisation including its operational management.

Introduction

The contribution of hydropower utilisation to energy decarbonisation on the one hand, and its ecological impacts on river ecosystems, fish and aquatic biodiversity on the other hand, all contribute to the controversy on whether hydropower utilisation should be considered a “green” or “red” energy (Geist 2021). Minimising the ecological impacts of hydropower utilisation has become a target of conservationists and hydropower producers alike, requiring information on the impacts of different types of hydropower plants on fish mortality and injury patterns as well as the impacts on physicochemical habitat quality and biota other than fish. A systematic and comparative analysis based on field experimentation was conducted in the course of the project “Fish Ecological Monitoring at Innovative and Conventional Hydropower Plants” at the Chair of Aquatic Systems Biology of Technical University of Munich, Germany, funded and supported by the Bavarian State Ministry of the Environment and Consumer Protection and the Bavarian