European Commission

Science for Environment Policy

New global information system to map the extent and fragmentation of free-flowing rivers

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Free-flowing rivers (FFRs) support a complex, dynamic and diverse range of global ecosystems, and provide important economic and societal services. However, infrastructure built to use these services — most notably 2.8 million dams worldwide — has caused many rivers to become fragmented and disconnected, affecting river biodiversity and ecosystem services. This study constructed a global information system with which to map the fine-scale dynamics and fragmentation of FFRs and to determine how human pressures affect the world's river systems.

Despite global commitments to protect and restore FFRs — including the Brisbane Declaration (2007) and the United Nations' Sustainable Development Goals (2015) — need for water is increasing, as the demand for power rises. Plans are underway to construct an additional 3 700 hydropower dams in areas of the Amazon, China, the Himalayas and the Balkans; and areas of Brazil, China and India are planning extensive inland water-transportation systems that will require the dredging of many thousands of kilometres of river.

This study presents the first replicable, high-resolution global information system to map the location, extent, fine-scale dynamics and fragmentation of FFRs — including the effects of dams and other infrastructure. The researchers used high-resolution data to assess rivers comprehensively and in detail, and studied various metrics of fragmentation, including data on over 20 000 damns, at the 'river-reach scale', which corresponds to a section of river with similar hydrologic conditions.

The study defined an FFR as a river where ecosystem functions and services were largely unaffected by connectivity changes, allowing unobstructed movement and exchange of water, energy, material and species within the river system and surrounding landscape. River connectivity comprised four components — longitudinal (river channel), lateral (floodplains), vertical (groundwater and atmosphere) and temporal (intermittency). These four aspects can be compromised by changes to water quality (via pollution, temperature changes), river flow (water abstraction, regulation), or physical infrastructure in, or next to, a river (including along its banks, in adjacent wetlands or floodplains). For the above four connectivity factors, the researchers identified five pressure factors to represent human interferences, for which global data were available:

1. **river fragmentation** (longitudinal) — data available only for large dams;
2. **flow regulation** (lateral and temporal);
3. **sediment trapping** (longitudinal, lateral and vertical);
4. **water consumption** (lateral, vertical and temporal);
5. **infrastructure development in river-adjacent areas, such as banks and floodplains** (lateral and longitudinal).

They then used a river-network model to analyse the data; this had a resolution of 500 metres and contained 8.5 million individual river reaches. A **reach** was defined as the smallest spatial element; a **stretch** as two or more continuous reaches; and a **river** as the collection of reaches that formed a continuous thread from river source to outlet. The model applied various weighted criteria to quantify river connectivity from 0 to 100% for each reach (a connectivity status index, or CSI), and mapped those that qualified as FFRs (with a CSI of 95% or above, over their entire length).

Continued on next page…

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The researchers tested their approach at various scales using case studies — large (the Tapajos River, Brazil), medium (the Luangwa River, Zambia), and small (the headwaters of the River Ganges, India) — supplied with additional local information. This demonstrates that the global methodology is robust for long rivers and may be scalable for regional and local studies with the addition of data not currently available. The researchers say that the limited information available on small damns, barriers and diversions means that the status of short rivers needs to be interpreted carefully: a number of them may be classified as free-flowing despite being impeded by infrastructure projects that are not included in datasets, which is particularly the case in highly developed regions of Europe. Governments and global institutions, say the researchers, need to fund the acquisition of high-resolution geographic water-infrastructure data.

Very long FFRs with CSIs of 100% are restricted to remote regions of the Arctic, and the Amazon and Congo basins. Only 37% of rivers longer than 1 000 kilometres remain free-flowing over their entire length, and only 23% flow uninterrupted to the ocean. This loss of connectivity between very long rivers and the sea is of particular concern, say the researchers, as it is a vital way for deltas, estuaries and the ocean to exchange water, nutrients, sediment and species. Additionally, it means that the few long FFRs connecting to the sea provide disproportionately large levels of ecosystem services.

Dams and reservoirs are the leading contributors to connectivity loss in global river reaches. Dams are the dominant pressure factor for two-thirds of impacted reaches below the 95% threshold, followed by flow regulation (which affects a quarter) and sediment trapping (almost 5%). Where dams are less widespread, for example in urbanised areas of Western Europe, important factors are consumptive water use and the development of infrastructure in river-adjacent areas.

This methodology could be used to inform decisions on how to best maintain and restore FFRs, suggest the researchers. By replacing proxy data with finer-resolution or higher-quality data — for example, local storage of small dams and known migratory pathways of fish — the system could be a useful tool for decision-makers and conservationists. It could also help prioritise rivers with high conservation value for protection and optimise informed selection of low-impact infrastructure developments. The researchers stress that more data is needed for more accurate results.