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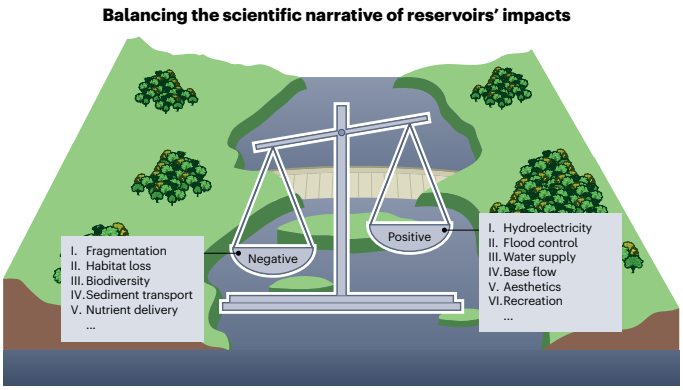
Need for balance in reservoir impact research

Reservoirs are among the most transformative water infrastructures of the Anthropocene, with a construction history spanning over 4,300 years. They have played a crucial role in ensuring water supply, flood management, and hydropower generation for human societies, while profoundly reshaping hydrological regimes and landscape-scale ecological and biogeochemical processes[1]. The pros and cons of reservoirs have long been actively debated[2,3]. Over recent decades, research has advanced our understanding of their eco-environmental costs, including river fragmentation, disrupted sediment and nutrient transport, greenhouse gas emissions and aquatic biodiversity loss[1,4–7]. While these studies are unquestionably vital for identifying and mitigating the negative impacts of reservoir construction and operation, the prevailing research landscape exhibits a pronounced asymmetry: the detrimental environmental effects of reservoirs have been extensively examined, whereas their broad ecological benefits remain insufficiently explored or treated as secondary (pictured). This imbalance leads to an incomplete and skewed evaluation of reservoirs' full range of ecological, environmental, and socio-economic impacts.



A balanced evaluation of the positive and negative effects of reservoirs will enable minimization of harm while maximizing the socio-ecological benefits.

The under exploration of the ecological benefits of reservoirs may be a consequence of multiple intersecting factors including the methodological ease of detecting adverse impacts, the growing societal sensitivity to environmental degradation, and academic incentives that privilege narratives of ecological crisis. However, many reservoirs provide indispensable ecological functions, such as sustaining downstream baseflows during droughts, stabilizing local climates through evapotranspiration, recharging groundwater aquifers, and creating habitats for migratory birds and aquatic species in seasonally dry regions[8]. In addition, reservoirs play a key role in reducing ecological risks from extreme events by buffering floods and supporting water availability during climate anomalies[9]. These benefits are often diffuse, indirect, and context-dependent, making them harder to quantify and generalize. However, comprehensive research is essential to develop robust evaluation frameworks and methods, along with quantitative indicators and models, to assess the ecological service functions of reservoirs.

When only the negative effects of reservoirs are assessed, environmental narratives and policy frameworks become skewed. A narrow focus leads to generalized conclusions that overlook the diversity of reservoir systems, their complex interactions with local ecosystems, and valuable ecological services. This imbalance not only misrepresents the full scope of reservoirs' environmental impact but also guides policies that prioritize mitigating negative effects while missing opportunities to enhance positive outcomes. In addition, ecosystems have some adaptive ability at a long-term or geological scale. For example, in certain seasonally dry regions, reservoirs have created new wetland habitats that have become critical for migratory birds, or aquatic communities have reorganized around novel nutrient and flow conditions[8]. Therefore, it is crucial to integrate both positive and negative ecological effects in shaping adaptive, effective reservoir management strategies.

We argue a more balanced research agenda is urgently needed that moves beyond binary framings of 'good' versus 'bad' reservoir impacts and instead embraces their dynamic and context-dependent functional complexity. Such an agenda would recognize that reservoirs operate within coupled socio-ecological systems, where their ecological roles vary across spatial, temporal, and institutional scales. We can then better understand the nuanced interactions between reservoirs and their environments, and design more targeted and effective management strategies.

Advancing this agenda demands interdisciplinary collaboration, with geosciences at its core, by integrating ecosystem service science, socio-ecosystem analyses, and tools for long-term ecological monitoring. Alongside this, development of new metrics and modelling approaches are needed to make the intangible or cumulative benefits of reservoirs more visible and policy-relevant.

To be clear, we do not intend to de-emphasize the harms that reservoirs have caused and may continue to cause. Instead, we advocate for a balanced evaluation of both positive and negative effects. This will enable us to design management strategies that minimize harm while maximizing the socio-ecological benefits that reservoirs can provide. Supporting equitable, adaptive, and ecologically sound water governance in a rapidly changing world depends on this.

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Competing interests

The authors declare no competing interests.