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CONVERSATIONS 1: Water Governance

Environmental flow concepts and holistic applications in river basin governance

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The global decline in freshwater biodiversity – and the degraded ecological condition of riverine, wetland, and groundwater-dependent ecosystems – is largely caused by pressures from pollution, habitat degradation, excessive abstraction of surface water and groundwater, the barrier effects of dams, and modified flow regimes. As freshwater ecosystems degrade and species are lost, rivers and estuaries lose productivity; invasive plants and animals flourish; natural resilience weakens; and human communities lose important social, cultural, and economic benefits. The concept of environmental flows (e-flows) has emerged as a scientific resource and policy framework to protect or restore the freshwater regimes that sustain aquatic ecosystems and the ecological services they provide to society. As Bandyopadhyay (2011) so succinctly states, 'environmental flows are a critical contributor to the health of these ecosystems' and the 'long-term absence of environmental flows puts at risk the very existence of dependent ecosystems, and therefore the lives, livelihood and security of downstream communities and industries'.

Environmental flows have recently been defined as 'the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being' (Arthington *et al.* 2018). Aquatic ecosystems included in the scope of e-flows include rivers; streams; springs; riparian zones, floodplains, and other wetlands; lakes; coastal water bodies, including lagoons and estuaries; and groundwater-dependent ecosystems. This definition of e-flow embodies recognition of the dependence of 'human cultures, economies, sustainable livelihoods, and well-being' on

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healthy, resilient freshwater-dependent ecosystems. It is consistent with the United Nations (UN) Sustainable Development Agenda 2030 and its Sustainable Development Goals and targets (UN 2015), all of which promote the wise use of water, other natural resources, and global life support systems for human and environmental benefits.

The first methods to estimate e-flows were simple hydrological rules, such as minimum flows or baseflows, or the retention of an arbitrary proportion (percentage) of annual river flows for environmental purposes. However, simple hydrological rules such as a fixed percentage of flow are totally inadequate to protect the biodiversity, ecological processes, and ecosystem services of interconnected riverine, wetland, and groundwater-dependent ecosystems. The entire flow regime in all its complexity and variability in space and time must be considered in agreements over the allocation of water for ecosystems and for human uses.

A broader (holistic, ecosystem) approach to e-flows emerged in the 1990s. Holistic e-flow assessments recommend the water requirements of diverse aquatic and riparian flora and fauna; ensure hydrological and ecological connectivity; discourage exotic and translocated flora and fauna; and ensure ecosystem functions such as trophic structure and productivity. These ecosystem frameworks include the flow needs of connected aquatic ecosystems such as riparian zones, floodplains, estuaries, and groundwater-dependent ecosystems. Each river needs an e-flow regime described in terms of flow magnitude (discharge); seasonal or other patterns of flow timing; the frequency of particular flows (e.g., baseflows, channel maintenance flows, floodplain inundation events, end of system flows); and overall flow variability (Poff, Tharme, and Arthington 2017). These facets of an e-flow regime protect or restore certain ecological attributes and processes. Understanding and quantifying eco-hydrological relationships in the interconnected surface and groundwater parts of a river system lays the foundations for contemporary environmental flow management. As Shah aptly comments in this Conversation, 'Without taking a unified view of surface and groundwater and understanding their inter-connections at the river basin level, we will not be able to save our rivers.'

Environmental flow requirements vary with location along a river—from river to river, basin to basin, and region to region—depending on climate, hydrology, geomorphology, and landscape characteristics as well as the social-ecological characteristics of the river basin. Spatial patterns must be accommodated in basin-scale e-flow assessments. The desired social-ecological benefits are achieved by sharing the available basin water—in space and time—according to a balance decided by collaborative decision-making and trade-off processes. The challenge is to agree on a desired future state of the river basin's aquatic ecosystems, including their societal, cultural and spiritual values, and then to agree on a socially acceptable level of water diversion at basin scale.

Environmental flows form an essential component of integrated water resources management (IWRM) at the basin scale. Basin water plans may involve a mixture of conservation objectives (e.g., to protect the species and ecosystems of relatively unimpaired reaches or sub-catchments) and restoration objectives (e.g., returning a more natural flow regime in areas impacted by dams and water extraction). Understanding the range of options across a large river basin can be complex; it requires a negotiated agreement over the balance between river ecosystem protection in some parts of the basin and the level of flow and ecosystem restoration in regulated reaches or tributaries within each social-economic context. Australia's Murray-Darling Basin Plan offers a fascinating ongoing case study of basin-scale ecosystem conservation in some catchments, and restoration in many others, using e-flows and other strategies (e.g., ensuring fish passage).

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In this Conversation Ghosh has called for a change in India's water governance policy narrative 'from a reductionist paradigm to a more holistic paradigm based on transdisciplinary thinking'. To achieve this will require significant advances in transdisciplinary knowledge of river basins 'combining fluvial geomorphology, engineering, hydrology, hydro-geology, ecological sciences, tectonic sciences, ecological economics, law, international relations, political sciences, sociology, social anthropology, humanities and culture, and institutional theory'. The Living Ganga Programme (2007–2012) and the groundbreaking upper Ganga e-flows study embody the holistic perspective now being promoted in India. This e-flows study is remarkable for its special emphasis on the social-cultural, religious, and livelihood importance of this river – cultural bathing rituals during Kumbh events cannot be performed unless river flows are sufficient and water levels adequate. Applying a more holistic paradigm to water management and governance in India can help to lead and inform similar developments in e-flows science and management throughout South Asia.

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