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NEWS

Managing Rivers: Ecohydrology an Effective Tool Under Changing Climate

Amiya Kumar Sahoo[1] · **Anil Prakash Sharma**[1,2] · **V. R. Suresh**[1]

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Abstract Rivers, their associated floodplains and wetlands are considered as the lifeline of millions. Globally these ecosystems are now considered as the most degraded, and losing species at a rate faster than the terrestrial and marine systems. Serious anthropogenic pressures and climate change are likely to intensify the degradation processes further. Hence, need of the hour is to develop a holistic management tool for protecting these freshwater ecosystems. Ecohydrology is a tool that integrates hydrology, geomorphology and biodiversity and forms a framework at catchment level for protecting the physical modification and biodiversity in rivers with the basic concept of environmental flows. Though the concept of environmental flows/ecological release for Indian rivers is recently introduced in national water policy, it further needs to be suitably incorporated in the climate adaptation strategies for an effective integrated water resources development and management programme.

Keywords Rivers · Management · Ecohydrology · Climate change

✉ Amiya Kumar Sahoo
Amiya.Sahoo@icar.gov.in

Anil Prakash Sharma
apsharma1@gmail.com

V. R. Suresh
sureshvr64@yahoo.com

[1] Riverine Ecology and Fisheries Division, ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal 700120, India

[2] Aquatic Environment Management College of Fisheries, G. B. Pant University of Agriculture and Technology, U.S. Nagar, Pantnagar, Uttarakhand 263145, India

Rivers form an integral part of social, cultural and livelihood of millions of people providing food and energy, transportation, habitat of aquatic lives and human health. However, at present many of these natural resources are degraded or modified and a new synthesis of threats to world's rivers has found "human footprint" as the main cause [1]. These threats include catchment disturbance, deforestation, water pollution, wetland drainage and entry of exotic species. In addition, reduced river flows due to river impoundments such as dams and barrages coupled with climate change are the biggest threats to river geomorphology and biodiversity. Recognizing the cross cutting challenges, river researchers are now integrating two disciplines (a) physical structures in river (geomorphology and hydrology) and (b) biodiversity (ecology) for an effective river restoration program, that emerges a new concept as river ecohydrology. Ecohydrology is a scientific concept developed by UNESCO-International Hydrological Program (IHP). This quantifies and explains the relationships between hydrological processes and biotic dynamics at a catchment scale [2, 3] bearing principles of integration of catchment and biota into a plantonian super-organism, understanding the evolutionarily established resistance and resilience of such super-organisms to stress and use ecosystem properties as management tools (Fig. 1). Today ecosystem approach in rivers is considered as the best strategy for integrated management of water, land and living resources promoting conservation and sustainable use in an equitable manner. Ecohydrology forms a framework within the ecosystem approach protecting both physical alteration and biodiversity change. Based on the ecosystem management protocol, direct and indirect restoration and mitigation action plans could be formulated to conserve the native species/germplasm.

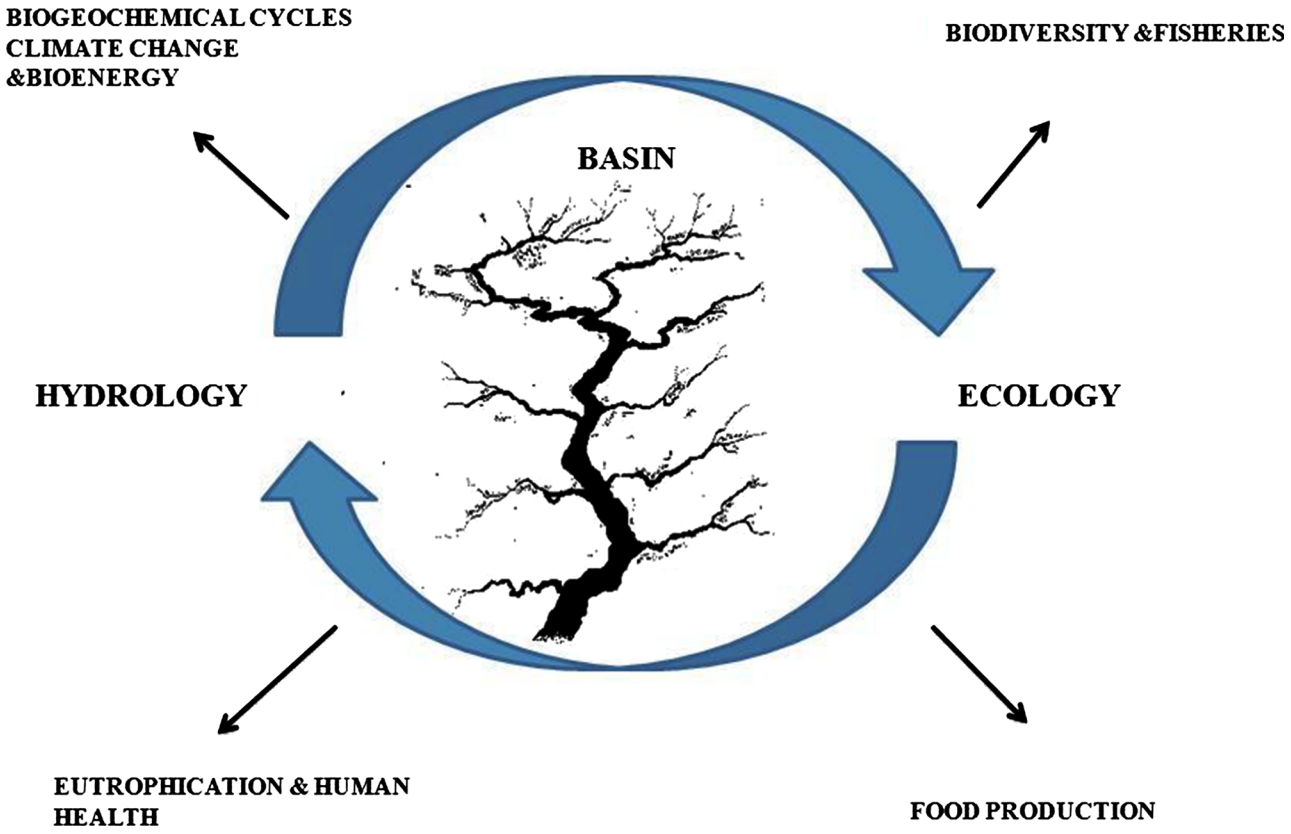

Fig. 1 Functional components of ecohydrology in river management (modified Zalewski and Wagner-Lotkowska [11])

Primarily, linked with integrated catchment management mostly based on abiotic parameters such as landscape planning, afforestation, catchment management and hydrology and secondly, associated with biodiversity management viz. habitats restoration and rejuvenation of connectivity between river channels and floodplains for efficient energy flows and enhance productivity. It has been observed that river/sea mouth connectivity has resulted in significant increase in fish diversity, livelihood income and habitat restoration in wetlands [4]. Furthermore, several studies and the European Inland Fisheries Advisory commission (EIFAC)'s workshop on "Ecohydrology as a tool for restoration of physically degraded fish habitats" have emphasized that the highest biodiversity and productivity of fish could be achieved at the intermediate level of human disturbances of biogeochemical cycle and catchment cover [5].

Ecohydrology is a sub-discipline of hydrology that focuses on ecological processes occurring within the hydrological cycle and strives to utilize such processes for enhancing environmental sustainability. Ecohydrology has profound role in river ecosystem and biodiversity management based on the classical concept of environmental flows [6]. Environmental flow defines the quantity, timing and the quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well being that depends on these ecosystems. Further it refers to the water that considered sufficient for protecting the structure and function of an ecosystem and its dependent species. Environmental flow is required to be maintained for sustaining its ecosystem through a river reach. It means enough water must be released in the downstream of the river after utilizing the water for the developmental projects in order to ensure downstream environmental, social and economic benefits. Realizing its importance, several countries have implemented environmental flows as mandatory for river management policy. For example, the Mekong River Agreement, 1995; South Africa's National Water Act, 1998 and the Swiss Water Protection Act, 108. For the first time in India, the environmental flows also known as ecological water release in river was introduced in National Water Policy, 2012. The policy states that "ecological needs of the river should be determined, through scientific study, recognizing that the natural river flows are characterized by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow

contribution in the low flow season through regulated ground water use". These legislations attempt to ensure that the required flows in the river must provide a sustainable ecosystem services. However, the biggest task before the researchers is to develop standard methodology for estimating the environmental flows in a holistic approach, considering sustainable demand from all the stakeholders representing social, cultural, economical/industrial and environmental sectors. Though, a wide range of environmental flows methodologies (EFMs) have been developed to determine flow thresholds for various objectives such as the preservation of natural conditions, the maintenance or restoration of ecological integrity and recreational values, these methods are river or species/fish (Salmon) specific. Till now, these methodologies have been mostly applied to small upland rivers and headwater streams. Although a growing body of literature summarizes the status of available EFMs, the question remains whether or not these EFMs are suitable to protect fish diversity and fisheries resources in regulated large lowland rivers. Hence, the need of the hour is to develop river specific EFMs for protecting the water demands of ecosystem, biodiversity and the water users in Toto. Countries like Australia, South Africa, UK, USA and Canada are ahead of us in implementing river management protocols. Off late, India has initiated environmental flows studies in few river systems such as "*Nirmal (Clean) and Aviral (Continuous) Ganga* to restore the holy river Ganga and its fisheries" through a research consortium of seven Indian Institute of Technology (IITs). In addition, the Central Inland Fisheries Research Institute (CIFRI), Barrackpore has taken up several independent research studies on Environmental flows specific to fish and sustainable fisheries in certain stretches of rivers including the Sone, the Teesta, the Tangon and the Mahanadi. Our studies felt that for developing a standard EFM, conglomeration of multi-discipline subjects including hydrology, hydraulics, biology, economics, and geomorphology with a basin approach are of paramount importance. Furthermore, our studies highlighted the importance of seasonal flows for fish migration, reproduction and feeding [7]. Hence, our results strongly support the scientific basis of ecohydrology that must be warranted as a tool for restoration of river ecosystems and its biodiversity. It has been evident from several studies that surface runoff forms the major driver for sustenance of river ecosystem, but at present is under serious threats by climate change in the form of severe floods, water scare and water shortage conditions [8]. The rivers and wetlands form a major source of surface runoff supporting millions of aquatic organisms. These aquatic lives are particularly sensitive to climate change to the high heat capacity of water, the probability of altered thermal regimes and hydrological tolerances. The characteristics and dimensions of both the thermal and hydrological regime have specific ecological relevance for freshwater organisms throughout their life history [9]. As the hydrology of the landscape is altered by new runoff patterns, the organisms like fishes may experience several types of stress. Reduction in precipitation in the severely water limited aquatic ecosystems of arid and semiarid areas may threaten species that are endemic, already rare or endangered [10]. More prolonged periods without flows will bring about increasing fragmentation of aquatic habitats and will likely reduce the number and quality of dry seasons which are essential for fish persistence. It is reported that species that are susceptible to elevated temperature may also be vulnerable to reduced flows and habitat fragmentation. Some of the observed hydro-ecological changes and impacts due to climate change and anthropogenic stressors have been shown in Table 1.

It is evident that many of the world's rivers and wetlands are increasingly threatened by catchment processes that affect flows, flow regime alterations by dams and diversions and excessive ground water pumping. Predicated climate change scenarios are likely to exacerbate the risks associated with existing flow regime alterations through altered rainfall, temperature and runoff patterns, loss of connectivity and cumulative disruptions to geochemistry,

Table 1 Ecosystem impacts of climate change and anthropogenic stressors

Effects of climate change	Stressors	Impacts
Droughts, intense heat, increased evapotranspiration	Over extraction of surface water and ground water and invasive species	Shrinking habitat, habitat fragmentation, local species extinctions, loss of connectivity and drought mortality
More flooding	Development in watershed and levee banks	Flood mortality, channel erosion, spread of invasive species, poor water quality, reduced survivorship and population viability
Early snowmelt	Dams, flow diversions or change in reservoir release	Species life histories out of synchrony with flow regime, reproductive or recruitment failure, decreased population viability
Little change in rainfall, moderately warmer	Development of watershed	Ecological impacts modest unless complexes of stressors present

Source modified Palmer et al. [12]

biological communities and ecosystem. Furthermore, increasing human populations and projected future climate change will place increasing pressure on water resources and infrastructure. Under these situations, the ecohydrology would act as a tool in assessing the implications of climate change on water supply and demand, and consequently on management of basin systems as well as in assessing the impact of climate change on the physical, chemical and biological processes in river ecosystem. Hence, proper ecosystem based management policy decisions could be formulated for rivers and associated floodplain wetlands. Though the National water policy 2012 has incorporated different strategies to adopt the climate changes, environmental flows and water regime management (eco-hydrology) must suitably find place at the heart of the climate change adaptation strategies for an efficient integrated water resource development and management plan on rivers. As water is the main medium and vehicle for climate change impact, strategies to protect or restore environmental flows regimes in free flowing and highly regulated rivers and wetlands need an urgent attention for Indian rivers. With the concept of eco-hydrology, all stakeholders including governments, research institutes, NGO's and public sectors need to work together for developing steps towards sustainable river ecosystem management under the changing climate.

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