Hydrology - Ecology Relationship in Streams: A Review

Capt.(Dr.) N. P. Sonaje, Vidhyashri B.Koli

Abstract— **Hydrology is a prime governor on the ecological quality of river systems, through its effect on flow, geomorphology, water quality and habitat. Sustaining natural hydrologic variability is necessary in safeguarding river ecosystem integrity. Hydrological deviation plays a main role in forming the biotic diversity in and around river ecosystems as it controls crucial habitat situations within floodplains. Variations in streamflow systems may alter many of these habitat attributes and impair ecosystem connectivity. The influences of river directive and land practice changes on the ecological quality of river systems. This paper aims at the review to summarize knowledge of the link between hydrology and ecology and the effects of altered flow regime on ecology.**

Index Terms— **flow regime, hydrology, river ecosystem, ecology, geomorphology**

I. INTRODUCTION

The hydrological cycle is very complex to variations in climate. The hydrological system is being affected by human activities, such as deforestation, urbanization, and high water-resource utilization. These alterations have included habitat fragmentation, conversion of lotic to lentic habitat, variable flow and thermal regimes, degraded water quality, altered sediment transport processes, and changes in timing and duration of floodplain inundation (Cushman 1985, Pringle 2000). Human impact on the hydrology is widespread all over the world but the consequences and the severity of the flow alteration and its effect on hydrology has not been computed on national scale.

The natural flow regime is the fundamental driver of the structural and functional attributes of surface water ecosystems worldwide. The abundance and diversity of aquatic biota in rivers and streams are influenced indirectly by the spatial and temporal effects of flow regime on habitat structure and availability, and directly through the influence of flow regime on life-history strategies and the establishment of alien species. Therefore, impacts on the natural flow regime threaten aquatic biodiversity (Bunn & Arthington 2002). Specific flow events, such as floods, droughts and flow pulses, are key hydrological disturbances that influence ecological processes supporting aquatic and terrestrial biota at population, species and assemblage levels (Resh et al. 1988; Lake 2000).

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Capt. (Dr) Nitin P. Sonaje, PhD (Civil Engineering), Deputy Registrar, Shivaji University, Kolhapur, India

Vidhyashri B.Koli, Research Scolor, Environmental Science and Technology, Department of Technology, Shivaji University, Kolhapur, India.

This paper presents review of various studies carried out to illustrate how changes in flow regimes have affects aquatic biodiversity in streams and rivers.

II. LITERATURE REVIEW

Arthington H. A., *et.al* (2006) studied the challenge of providing environmental flow rules to sustain river ecosystems. The rapid acceptance of the natural flow regime concept has been accompanied by an expectation that ecologists can easily provide specific environmental flow prescriptions for riverine ecosystems. The authors has proposed a generic approach that incorporates essential aspects of natural flow variability shared across particular classes of rivers that can be validated with empirical biological data and other information in a calibration process. Within a region, the ecological characteristics of streams/rivers in each hydrological class are expected to be relatively similar compared to ecological characteristics between the classes; therefore, these classes represent distinct ‘‘management units.’’ There are four basic steps to this proposed approach which are as to develop classification for reference streams, develop frequency distributions for each flow variable in each class, compare frequency distributions from flow modified streams with reference condition in the same class, develop flow-response relationships for ecological health data from reference and flow modified steams for each flow variable. Finally they have concluded that a region-by-region and country-by-country analysis using hydrological classification methods combined with ecological calibration could fairly rapidly provide global environmental flow guidelines.

Christopher P. K. and Derek B. B., (2005) has studied the hydrological changes in urban streams and their ecological significance. Streamflow influences the structure and composition of aquatic communities with four hydrologic changes viz., increased frequency of high flows, redistribution of water from base flow to storm flow, increased daily variation in streamflow and reduction in low flow, resulting from urban development that are potentially significant to stream ecosystems. Long-term streamflow records from eight streams in urbanizing areas of the United States and five additional reference streams, where land use has been relatively stable, were analyzed to assess if streamflow patterns were modified by urban development to an extent that a biological response could be expected and whether climate patterns could account for equivalent hydrologic variation in the reference streams. They have concluded that the urban streams can provide habitat for biological communities even if the hydrologic consequences of urban development are not addressed, but the structure and composition of these communities are likely to depart from those of the predevelopment stream. Ultimately, true restoration of urban streams can only occur if hydrologic processes and the spatial distribution of the water-storage capacity are re-established across the urban landscape.

Daren M. Carlisle, *et.al.*, (2010) has assessed streamflow magnitudes and associated biological communities across the conterminous US covering 2888 streamflow monitoring sites. With an objective to assess whether observed magnitudes of annual minimum and maximum flows differed from reference (i.e. estimated least disturbed) conditions and to determine whether the integrity of two aquatic communities (i.e. fish and macro invertebrates taxa) is associate with the type and severity of streamflow alteration of the streams in US. At each monitoring site, alterations in either stream flow or biological communities were quantified as the ratio of observed conditions to expected reference conditions. They have quantified stream flow alteration at each assessed site as the ratio of observed mean annual (1980–2007) minimum and maximum magnitudes to expected mean annual magnitudes. By aggregating the lists of decreaser and increaser taxa across sites within each class of streamflow alteration and evaluated (using Fisher's exact test) whether the two sets of taxa differed in the frequencies of functional traits associated with hydrological attributes, including reproductive strategy, mode of mobility, and geomorphic habitat and substrate preferences. Author have also examined biological and hydrological characteristics in terms of their deviations from reference conditions, seeking to understand the potential ecological consequences of anthropogenic changes to the natural flow regime. Daren M. Carlisle, *et.al.,* have found that the most of the monitored streams experience altered flow magnitudes and there is a strong association between diminished streamflow magnitudes and impaired biological communities across the conterminous US.

Mark J. Kennard, *et.al* (2007) has studied the multiscale effects of flow regime and habitat and their interaction on fish assemblage structure in eastern Australia. They examine the multiscale influence of environmental and hydrological features of the riverine landscape on spatial and temporal variation in fish assemblages in eastern Australia. They have sampled sixteen sites in the Mary river seasonally on nine or ten occasions between 1994 and 1997. Eleven sites in the Albert river was sampled seasonally on six and seven occasions between 1995 and 1997. Fish survey was conducted in wadeable stream reaches (<1.5m maximum depth). Long- term variations in flow magnitude and the timing, frequency and the duration of flow events define the physical habitat template over large spatial scale (e.g., catchments and subcatchments), whereas the short-term history of hydrological events influence habitat availability and connectivity at smaller spatial scales(e.g., within and among river reaches). The authors have used hierarchical conceptual framework to address two issues that have impeded issues efforts to link variations in local fish assemblages to the independent and interactive effects of hydrological variation with the physical features of stream channels at multiscales. Spatial and temporal patterns of fish assemblages structure in the Mary river southeastern Queensland were expressed as three biotic measures (species presence-absences, species relative abundance and species relative biomass). These measures were modelled as a function of hierarchy of environmental and hydrological variables using multi-response artificial neural network. They have then tested the transferability of Mary river predictive models on a smaller set of independent data from the nearby Albert river. Thus the ultimate objective was to gain insight into the relative influence of multiscaled environmental and hydrological features of the riverine landscape on different properties of fish assemblages and to evaluate the generality of these relationships among nearby catchments.

Naik V.K. and Manjappa S. (2008) have studied modeling simulation of sediment analysis for Malaprabha river in Karnataka State, India. Transport, settling and quantity of solutes in rivers, streams, lakes and reservoirs are the important aspects in water-quality modeling. The solids considered for the study was mainly allochthonous which are inorganic in nature and the rate of decomposition is negligible. The data collected refers to the part of the research work on Malaprabha River, near Belgaum – a district headquarters in the State of Karnataka, India. This river is a non-perennial one, and the flow is very less during the pre-monsoon period, which is favorable for application of these sediment models. The results obtained for the re-suspension and burial velocities showed marked variations during the different seasons of the year. The inflow concentration of solids increased during the monsoon period. This is due to the fact that the discharges in to the stream from non-point and point sources increased considerably during this period.Re- suspension velocities predominated during the monsoon period resulting in the non settlement of the solids and the burial velocity during the non-monsoon period.

N. LeRoy Poff, *et.al.*, (1997) has carried out decades of observations of the effects of human alteration of natural flow regimes have resulted in a well-grounded scientific perspective on why altering hydrologic variability in rivers is ecologically harmful. It is concluded that five critical components of the flow regime regulate ecological processes in river ecosystem: the magnitude, frequency, duration, timing and rate of change of hydrologic conditions. These components can be used to characterize the entire range of flows and specific hydrologic phenomena, such as floods or low flows which are critical to the integrity of river ecosystem. Furthermore by defining flow regime in these terms, the ecological consequences of particular human activities that modify one or more components of the flow regime can be considered explicitly.

Owen C. R., (1999) has studied the impacts of changing land use on hydrology and dominant plant species from 1850–1990 in a palustrine wetland in southern Wisconsin, USA. Aerial photographs, historic maps and water levels of the area were used to determine changes in land use, wetland vegetation, and groundwater and surface flows over time. Linear regression models and multivariate ordinations were used to relate wetland plant species to hydrologic, chemical and spatial variables. The current hydrologic budget of the wetland was dominated by precipitation and evapotranspiration, although overland flow into the wetland from the subwatershed has increased twenty-fold since 1850. Water level stabilization in the adjacent Yahara River, creek channelization, and groundwater pumping have decreased inputs of groundwater and springfed surface water, and increased retention of precipitation. It is observed that the *Typha* spp. and *Phalaris arundinacea* L. has increased in the wetland, while *Carex* spp. has decreased. *Phalaris arundinacea* was found most often in the driest sites, and the sites with the greatest range of water levels. *Typha* spp. dominated in several hydrologic settings, indicating that water depth was not the only factor controlling its distribution. The distributions of dominant plant species in the wetland were most closely correlated with site elevation and average water levels, with some weaker correlations with vertical groundwater inflows and specific conductance.

Richard F. Keim, *et.al* (2006) has studied the ecological consequences of changing hydrological conditions in wetland forests of coastal Louisiana. Large-scale and localized alterations of processes affecting deltaic coastal wetlands have caused the complete loss of some coastal wetland forests and reduced the productivity and vigor of many areas in coastal Louisiana. This loss and degradation threatens ecosystem functions and the services they provide. The authors summarizes that the ecological relationships controlled by hydrological processes in coastal wetland forests of the Mississippi River delta and presents two case studies that illustrate the complexity of assessing hydrological control on swamp forest establishment and growth. Productivity of overstory trees has been affected by these changes, but the first case study illustrates that the relationship between flooding and growth may be site-specific. An important effect of increased flooding has been to reduce regeneration of swamp forest trees. The second case study is an outline of the kind of hydrological analysis required to assess probability of regeneration success. Productivity of coastal wetland forests has been reduced by this increased flooding, but the mechanisms responsible for changes in site-specific productivity are not clear. Regeneration of coastal wetland forest tree species has also been reduced by the increased flooding.

Stephen K. Hamilton (2002) has studied the hydrological controls of ecological structure and function in the Pantanal wetland (Brazil) with an objective to provide an overview of the critical linkages between hydrology and ecological structure and function of the vast flood-plain region. From the study it is observed that the principal hydrological processes likely to control ecological structure and function in the flood plains of the Pantanal which deduced from work on other fluvial systems as well as the existing body of knowledge. Flood plains of the Pantanal were in a constant state of disturbance, and many of the plant and animal species were resilient to flourish in such an environment. For many terrestrial animal species, the existence of dry refuges during inundation was critical, and exceptional floods are known to cause high mortality of these species. It has been also observed that many aquatic animals, the persistence of some flooded areas during the dry season was critical. In addition to its role as a dry-season refuge, the main river channel in a river–floodplain system serves as a migration and dispersion route for aquatic animals that depend on the flood plain for sustenance and shelter. The paper has concluded that it is essential to maintain the environmental integrity of the river in order to preserve the high productivity and species diversity of associated flood-plain ecosystems.

Aaron L. Hoffman *et.al.,(***2006)** have examined how habitat availability in a streambed landscape interacts with current velocity to affect movement patterns of two benthic grazers: glossosomatid caddisfly larvae (Agapetus boulderensis) and pulmonate snails (Physa sp.). Using experimental streambed landscapes, they have founded that Agapetus traveled farther as availability of smooth habitat (composed of low diatom turfs) increased compared to tall, structured filamentous stands, but only did so in slow current velocities. Their results illustrate a strong interaction between benthic habitat structure and current velocity in shaping patterns of grazer movements in a streambed landscape. Their study also suggests that the flow of water be considered not only a strong environmental gradient in streams, but also an interactive landscape feature that can combine with streambed structure to determine the permeability of patches to the movement of benthic organisms. Landscape ecology has mainly focused on terrestrial environments, and this study offers insight into some of the unique processes that may shape animal movement in aquatic environments. Swifter flows caused restricted movement of Agapetus and more upstream-oriented paths, but only in smooth landscapes where the potential for flow refugia from filamentous stands was minimal. Similarly, increasing proportions ofsmooth habitat facilitated greater net displacement of Physa using more upstreamoriented paths. Higher current velocities caused Physa to move faster, a pattern demonstrated only in smooth landscapes.

Robert J. Rolls *et.al***.,(2012) has studied** mechanistic effects of low-flow hydrology on riverine ecosystems considering the ecological principles and consequences of alteration. They have identified 6 ecologically relevant hydrological attributes of low flow (antecedent conditions, duration, magnitude, timing and seasonality, rate of change, and frequency) that act within the temporal hierarchy of the flow regime and a spatial context. They have synthesized the literature to propose 4 principles that outline the mechanistic links between these low-flow attributes and the processes and patterns within riverine ecosystems. First, low flows control the extent of physical aquatic habitat, thereby affecting the composition of biota, trophic structure, and carrying capacity. Second, low flows mediate changes in habitat conditions and water quality, which in turn, drive patterns of distribution and recruitment of biota. Third, low flows affect sources and exchange of material and energy in riverine ecosystems, thereby affecting ecosystem production and biotic composition. Last, low flows restrict connectivity and diversity of habitat, thereby increasing the importance of refugia and driving multiscale patterns in biotic diversity.

CONCLUSION

Extensive changes in hydrology have affected the riverine ecosystem. The natural flow regime has a deep effect on the biodiversity of streams, rivers and their floodplain. River ecosystems management should be centered on best available science. But there are many areas where absence of understanding hinders management of riverine ecosystems. In many cases, the way in which biota living in and around river channels respond to changes in habitat variables is less understood and there are still gaps in our knowledge with respect to the relationship between hydrological developments and the ecological quality of rivers and streams. Hydrological changes are wide spread around the world, but the rate and severity of river flow alteration and its ecological consequences have not been studied on national level. Although growing recognition of relation between hydrology and ecology, ecologist are still struggling to predict and compute biotic responses to changes in flow regimes.

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