**E-Flows Assessments in Ramganga Basin using the habitat simulation model, MesoHABSIM.**

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We introduce an approach for river basin wide determination of environmental flows using the habitat simulation model, MesoHABSIM. The approach follows tenets of the natural flow paradigm and recommends dynamic flow regime adjustments that support the needs of aquatic fauna over a range of bioperiods. We present the demonstration results of the technique on a test site in Ramganga River Basin in India and a concept developed for environmental flows determination across the river basin during an ongoing study. It may serve as a template for country-wide application.

# INTRODUCTION

The importance of and need for integrated river basin management (IRBM) are well acknowledged by Indian stakeholders and decision makers. Assessment and implementation of the most optimal environmental flow (e-flow) regimes were initiated in the early 2000s, under the National Water Policy 2002. As part of the India-EU Strategic Partnership, the European Union (EU) and India established in 2015 the India-EU Water Partnership (IEWP). Under the first phase of IEWP Action component, important headway in methods development and data collection has been accomplished during Ramganga E-flows pilot study and the Guidance Document for E-Flows Assessment and Implementation in India was developed (1). The goal of suggesting an e-flows assessment method for Indian rivers is to outline easy to use, but scientifically sound, procedure applicable across the country. The proposed solution is to apply habitat modeling as a foundation for this method. The Mesohabitat Simulation Model (MesoHABSIM) is being applied for e-flows assessments in Ramganga River Basin during an ongoing study under the IEWP Action in cooperation with the National Mission for Clean Ganga (NMCG) and the Central Water Commission (CWC)

#  MATERIALS AND METHODS

This is an approach to modelling instream habitats at the river and site-specific scale. It uses a computer model, Sim-Stream, that predicts the quantity of habitats available for aquatic communities in rivers for basin management scenarios (2). The procedure of computing MesoHABSIM model results consists of seven steps, which will be demonstrated and discussed below for the Ramganga River.

1. Establish biological targets, indicators and criteria

2. Define habitat survey locations and schedule

3. Collect habitat data

4. Calculate the habitat model

5. Collect available hydrological data representing pre- and post-impact conditions

6. Establish e-flow criteria on the basis of habitat time series analysis

7. Simulate management scenarios

Expected fish community habitat distribution for Ramganga River downstream from the Kalagarh Reservoir was estimated with the use of Target Fish Community and Fish Community Macrohabitat Types (FCMacHT) approaches applied also during the AMBER project (3). Fish species that can be found in the Ramganga River were classified into Habitat Use Guilds (HUG; groups of species using similar habitats) identified for Europe during the AMBER project. Local Indian (ICAR-CIFRI and Wildlife Institute of India) fish biologists suggested that this classification can also be applied for Ramganga River and similar habitat use guilds were used in recent studies of Indian waters (4). For every HUG, habitat use criteria during the fish rearing and growth stage were developed, also following the approach developed during the AMBER project. A fish community structure was developed to serve as a biological target for lean, dry and post-monsoon bioperiods and the equivalent habitat structure (including overlapping habitats), which is necessary to support such community during rearing and growth life stage, as an indicator for eflow determination. A test site on Ramganga River in Seohara was selected to collect habitat data in the river. It consists of a large bend and straight channel with many sand bars and backwaters. Spatial distribution of fish habitat was mapped at 3000l/s flow (Figure 1). Due to unforeseen circumstances of the COVID-19 pandemic, habitat parameter distribution at lower and higher flows were estimated on aerial photographs collected with a UAV during the first survey and from results of hydrodynamic modelling in three cross sections. Subsequently the flow habitat rating curve for the fish community was developed and habitat time series analysis performed leading to determination of habitat stressor thresholds (HST). Each HST consists of habitat magnitude, continuous duration and frequency of allowable and catastrophic events and serve as a criteria describing 3 dynamic e-flow thresholds named subsistence, trigger and habitat base flows. These are presented graphically in ACTograms, where inflection points represent dynamic e-flow thresholds and changes in color represent transitions from typical (green) to persistent (yellow) and catastrophic (red) conditions in terms of continuous duration of flow flows below thresholds. (Figure 2)

# RESULTS

The ACTograms are interpreted in the following way:



Figure 1: Habitat suitability distribution for Habitat Use Guild of Rheophylic water column preferring sandy-gravel bottom substrate species at flow of 3000 l/s

If the flows recorded in the site were lower than any of listed on the X-axis flows for period of time, which, if plotted on Y-axis, puts the result in yellow or red area then action is required. For example, if during the lean season flow measured in the river is under a threshold of 0.3 m3/s for a continuous duration of 20 or 60 days (putting the event in yellow or red field), then this is a persistent or catastrophic event respectively. To prevent the damage to the fish community, the following rules need to be followed:

1) Catastrophic events cannot happen more often than every 10 years, as this is the natural frequency.

2) Three persistent events in a year are equivalent to a catastrophic duration.

3) The flows cannot be lower than Absolute Minimum.



Figure 2. ACTograms for Ramganga River during lean bioperiod.

To prevent second catastrophic duration in a decade an operator can:

1) Release habitat base flows from an upstream reservoir for two days bringing the reading to the green field.

2) Stop water withdrawals during persistent durations.

3) Improve habitat morphology to provide refugia i.e. increase habitats available under lower flow conditions.

# STEPS FORWARD

The e-flow thresholds expressed as specific flows (in liters per seconf per square km, lskm) can be used to calculate e-flows at any location of the watershed where the expected fish community structure is similar to the studies site. Hence, to expand the application of the model to the entire basin, the river sections are grouped into those with similar expected community structures i.e. macrohabitats. This has been accomplished by applying Fish Community Macro Habitat type model developed within AMBER project for Europe, which relates macroscale geographic attributes to expected fish community structures (Parasiewicz et al in review). We performed non-hierarchical cluster analysis of attributes such as basin area, valley slope, geology and climatic zone to identify 13 Macrohabitat Types in Ramganga Basin (Figure 3). For each of the clusters a representative site is selected, where the MesoHABSIM model is being applied and e-flows criteria are being established as described above. The specific e-flow thresholds standardized by mean annual runoff (index p) will be used to define e-flows for all rivers form the same cluster.



Figure 3. Ramganga River Watershed divided into Macrohabitat Types (1-13) and selected representative sites

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# DISCLAIMER:

The views and opinions expressed in this article are those of the authors and do not reflect the official statement or position of IEWP Action/GIZ India and/or Water Authorities of Indian (Central or State) Government.

 REFERENCES

[1] Nale J., Sigh B., Rai N., Srivastava R., Johnson J. A., Sahoo A., McClain M., Schmutz S., Parasiewicz P., Hayes D., Schinegger R., Laizé C. L R, Suska K. (2020). Guidance document for environmental flows assessment & implementation in India. GIZ. New Delhi, pp 100.

[2] Parasiewicz, P., (2001). “MesoHABSIM: A concept for application of instream flow models in river restoration planning”. Fisheries, 26(9), pp.6-13.

[3] Parasiewicz P., Belka K., Łapińska M., Ławniczak K., Prus P., Adamczyk M., Buras P., Szlakowski J, Kaczkowski Z., Krause K., O’keeffe J. , Suska K., Ligięza J., Melcher A., O’hanley J., Birnie-Gauvin K., Aarestrup K., Jones P.E., Jones J., De Leaniz C.G., Tummers J. S., Consuegra S., Kemp P., Schwedhelm H., Popek Z., Segura G, Vallesi S., Zalewski M., Wiśniewolski W. ( in review). Over 200,000 kilometers of river-fish habitat is lost to impoundments in Europe. Nature Communications. DOI: 10.21203/rs.3.rs-1287087/v1

[4] Johnson, J.A., Sharma, A. Rajput, V. A., Dubey, V.K., Sivakumar, K. (2020). Taxonomic and guild structure of fish assemblages in the streams of Western Himalaya, India. Community Ecology, DOI 10.1007/s42974-020-00026-3