MODELLING OF GOLDEN MAHSEER HABITAT FOR E-FLOWS IN THE ALAKNANDA RIVER USING DIGITAL ELEVATION DATA

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The present study attempts to develop an understanding of the state of natural equilibrium between hydrological and ecological response systems of Alaknanda River, a headstream of Ganga River. The study seeks to assess the current hydrologic regime for its compatibility with ecological demands assessed for endangered Golden Mahseer- *Tor putitora*, a keystone fish species holding the highest trophic level in the aquatic food web of the Alaknanda. For this, variations in Golden Mahseer habitat (Weighted Usable Area) with variations in seasonal flow have been analyzed using the PHABSIM-habitat modelling tool, for its three life stages. Non-availability of detailed and reliable data on observed bed morphology has long been a major hurdle in similar eco-hydraulic study initiatives, including the present study, in India. Accordingly, this study is an initiative that makes use of SRTM 1 Arc-Second Global Digital Elevation Model (DEM) data in support with two observed cross sections and suggests 'most suitable' range of e-flows.

1 INTRODUCTION

Science of assessment of environmental flows (e-flows) is growing vastly in India and owing to its national importance; Ganga River has been a priority interest of the researchers. Simple hydrologic methods of e-flows assessment (as classified by Tharme [1]) are now being replaced by more robust methods like holistic methods. However; despite the unique ecological importance of the river, e-flow assessment methods based on aquatic habitat analysis are not used due to unavailability of high resolution surveyed geomorphological and hydraulic data. In this view, the present study attempts the formation of surrogate geomorphological data from the digital elevation data to obtain the required inputs to perform a habitat analysis for e-flow assessment. Using this geomorphological data, hydraulic data in the form of flow depths and flow velocities are obtained with the help of one-dimensional hydrodynamic modelling tool 'HEC-RAS' (Hydrologic Engineering Centers River Analysis System). Geomorphological and hydraulic data so obtained are used as inputs to habitat analysis tool 'PHABSIM' (Physical Habitat Simulation Model).

River Alaknanda is one of the two major headstreams of Ganga River that originate in Western Himalaya and is much valued for its ecological importance. In between two surveyed cross sections available, a 3150m long stretch of Alaknanda before its confluence with its tributary Mandakini River, has been identified as the study site. On this stretch, 47 cross sections are generated using SRTM 1 Arc-Second Global Digital Elevation Model (DEM) data. Figure 1 shows the location of Upper Ganga Basin and Alaknanda River along with generated cross sections.

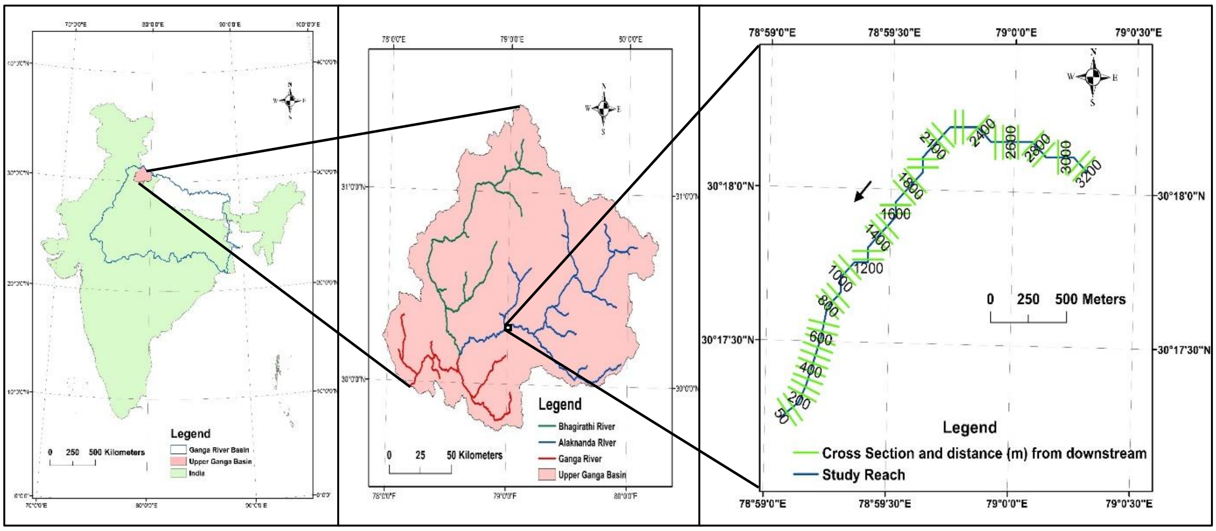

Figure 1. Upper Ganga Basin location on India Map along with study site and generated cross sections.

Golden Mahseer - a keystone fish species of the region has been identified as the target species. For its three different life stages (spawning, juvenile stage and adulthood); ecological data in the form of suitable flow depths and flow velocities are provided as input to PHABSIM modelling. Suitability index of these parameters is defined on the scale of 0 (unsuitable) to 1 (Optimum). As PHABSIM output; discharge-usable habitat area (weighted by its quality) relationships are obtained for three life stages. Using these results; conclusions about most suitable e-flows are drawn.

2 INPUTS

2.1 Generation of geomorphological data

SRTM 1 Arc Second Global DEM data is available with 30 x 30m resolution. For better comparison of surveyed cross sections with generated cross sections and also in the hope to obtain relatively improved and detailed PHABSIM results; this 30 x 30m resolution data has been interpolated. Inverse Distance Weighting (IDW) interpolation tool in ArcGIS software has been used for this and new raster representation is generated with resolution of 5 x 5m. With this newly developed data, 47 cross sections are generated on total 3250 m long river stretch (3150m long study reach with additional 50 m on each side) using Geo-RAS tool in ArcGIS software. Most downstream and most upstream cross sections (at 50m and 3200m from end of the stretch) are compared with surveyed cross sections at that locations. The comparisons shown in figure 2 (A, B and C) suggest that due to limited vertical accuracy of DEM data, longitudinal slope of the region (0.38%) is not followed while shape of the cross sections is more or less matching. So the longitudinal profile of the bed elevations (thalweg) is corrected to yield an overall reach slope of 0.38% as shown by surveyed cross sections.

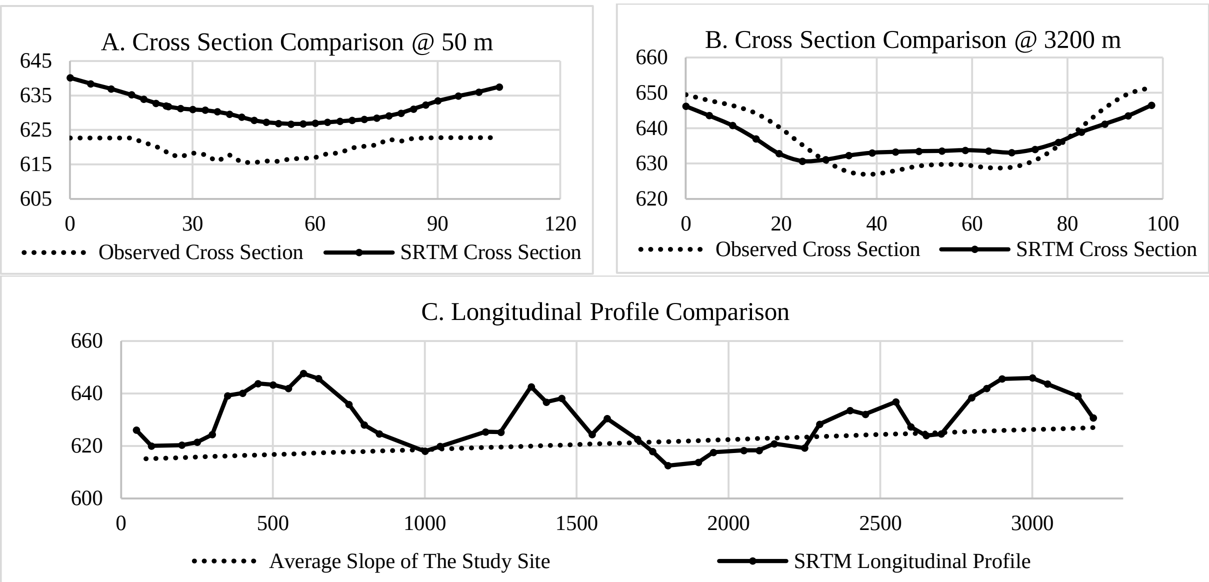

Figure 2. Comparison of surveyed and generated cross sections. A- Downstream cross section, B-Upstream cross section and C-Longitudinal profile

2.2 Identification of target species and Habitat suitability indices

Tor putitora commonly known as 'Golden Mahseer' is a keystone species of fish observed in the study area. Tor species are coveted as legendary game (sport) fish and Golden Mahseer holds a pre-eminent position owing to its size, color and taste. Overfishing, structural developments and introduction of exotic fish species are widely believed by subject experts to be the prime factors responsible for observed dwindling of its population and this has resulted in its inclusion in 'International Union for Conservation of Nature (IUCN) Red List of Endangered Species'.

Based on numerous past studies, abundant literature is available on Golden Mahseer wherein habitat preferences of this species have been investigated in terms of flow depths, flow velocities, spawning periods, migration behavior, water temperature and population dynamics [2], [3], [4] and [5]. These have formed an authentic information base for developing habitat suitability indices corresponding to each of the three different life stages of Golden Mahseer. Suitability indices for flow velocities and depths defined on a scale of 0 (unsuitable) to 1 (Optimum) are shown in figure 3. PHABSIM also needs suitability indices for channel properties; however, due to non-availability of actual observed channel properties in this study, all channels are prescribed a suitability index of 1 thereby representing optimum conditions.

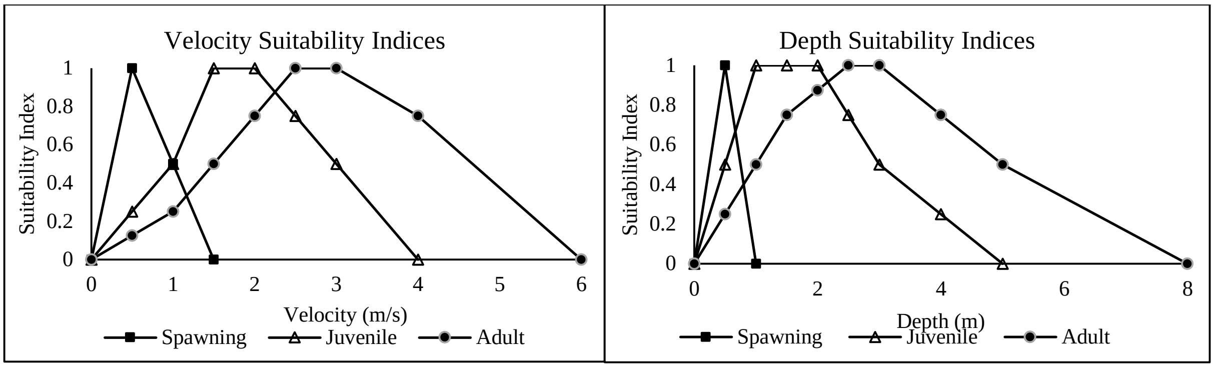

Figure 3. Suitability indices for flow velocities and flow depths for three life stages of Golden Mahseer.

3 HEC-RAS AND PHABSIM MODELLING

3.1 HEC-RAS: 1D HYDRODYNAMIC MODEL

To obtain the stage-discharge relationships pertaining to different flow discharges, 1 dimensional hydrodynamic modelling is done for the above mentioned 47 cross sections using HEC-RAS software. Steady state analysis has been performed for a range of flow discharges ranging from 10 to 1000 cumecs. This range of flow is expected to cover the lean flows as well as peak monsoon values. Figure 4 shows longitudinal bed profile corrected for predefined slope of 0.38% along with water surface profile at 10 cumecs flow.

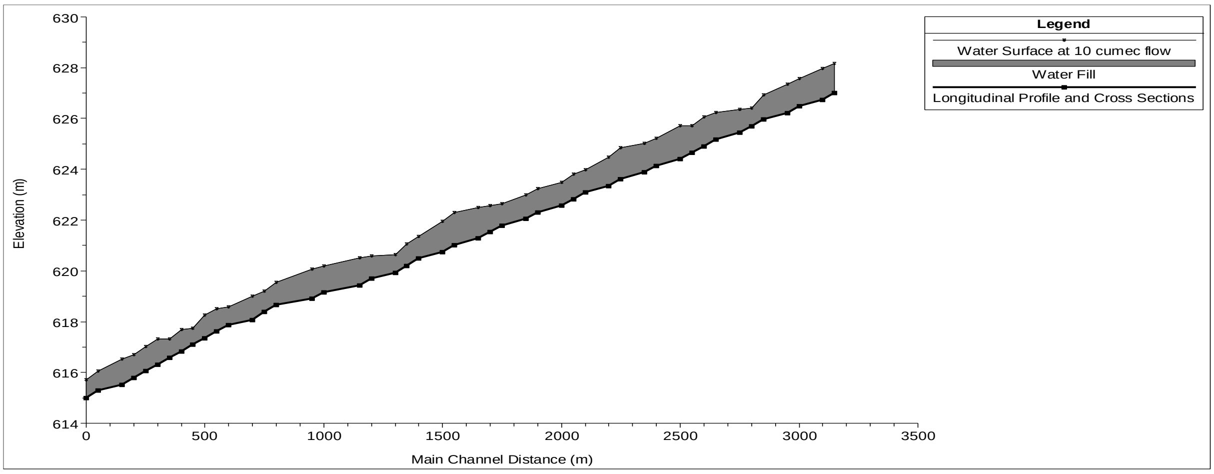

Figure 4. Longitudinal bed profile and water surface profile at 10 cumecs flow

3.2 PHABSIM: PHYSICAL HABITAT SIMULATION

PHABSIM model has been set up using 4 upstream cross sections obtained from Geo-RAS tool to analyze the effect of flow variation on habitat quality and quantity. These cross sections represent riffle and pool sections in the reach in the Google Earth imagery. Total 200 m reach has been analyzed and input data needed in terms of Stage-Discharge curves are obtained from HEC-RAS modelling. Using PHABSIM, flow depths at different flows conditions are validated and flow velocities pertaining to same range of flows are obtained. Finally relating these hydraulic outputs with ecological data provided in terms of habitat suitability indices; results in the form of Discharge versus Weighted Usable Area (WUA) are obtained for three life stages of Golden Mahseer. Weighted Usable Area is a measure of quality and quantity of the usable habitat area and it is obtained by multiplying habitat area by its quality calculated on the scale of 0 to1. The PHABSIM results are shown in Figure 5 which represents variation in WUA (square meter per km) for three life stages (Spawning, Juvenile and Adult) of Golden Mahseer for the flows ranging from 10 to 1000 cumecs.

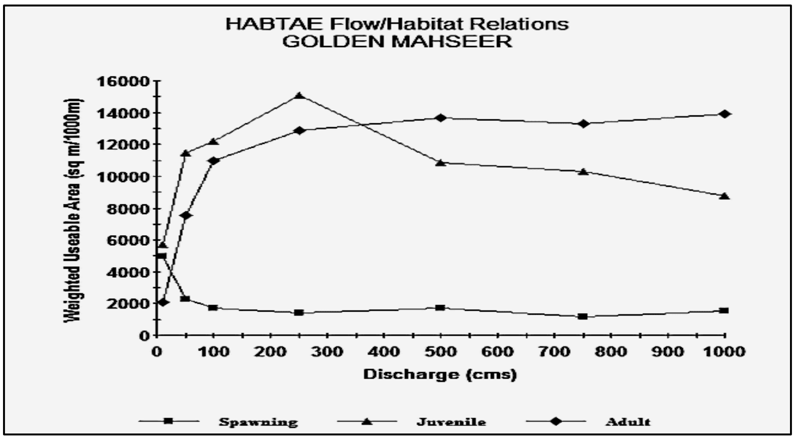

Figure 5. PHABSIM Results: WUA versus Discharge Curves for three life stages of Golden Mahseer

4 RESULTS AND CONCLUSIONS

It is seen from the results that low flows in the vicinity of 10 cumecs are optimum for spawning. However; it is known from [3] and [4] that the Golden Mahseer prefers shallow upstream reaches of Alaknanda and its tributaries for spawning. Also spawning happens in post-monsoon months (September and October) during which, flows in the study reach are expected to be high. So, it is unreasonable to conclude the e-flows for this period solely based on spawning results; at least for this study site.

For Juveniles, it is observed that 250 cumecs flow is best suitable and up to this value increase in flow is resulting in increase in available habitat, however, further increase in flow value is leading to loss of habitat. This indicates that very high flow values are not best suitable for Juveniles. It's also interesting to see that available habitat for juveniles is higher than habitat for adults within this range of flows. Population dynamics of this fish suggests that dominant proportion of the total population is represented by juveniles i.e. up to 2 year old fishes and this above mentioned observation seems to comply with this ground reality.

Results for adult fish show that rate of increase in habitat area with per unit increase in flow value is much higher up to 250 cumecs, after which per unit increase in flow values is not leading to substantial increase in habitat area (change in the slope of the curve shows reduced rate of increase in habitat area with per unit increase in flow).

From the overview of basin hydrology, it is known that the four month period between December and March is lean period with average seasonal flow of 70-80 cumecs. It is seen from the results that this season is crucial in terms of e-flows. So, it can be concluded that for this period, minimum abstraction should be allowed and flows at least in the range of 25-50 cumecs should be released, so as to maintain at least about 50% of habitat area. Flows below this range may result in serious environmental degradation.

ACKNOWLEDGMENT

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