



Ecological Flows Assessment of Significant Fish Species in Iril River, Northeast India Through PHABSIM

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ABSTRACT

Background: Freshwater fishes are facing alarming threats due to various anthropogenic activities. The present study estimates the ecological flow requirements for *Bangana dero* and *Wallago attu* fish species in the Iril River through a habitat modeling approach.

Methods: The habitat suitability modeling of the target species was carried out using the physical habitat simulation model (PHABSIM). PHABSIM model was developed for the river stretch extending about 6,000 m in Iril River. 11 cross-sections at a distance of about 500 m were specified in the model. In the model, habtae was set to run and weighted usable area (WUA) was obtained as output from the habitat model.

Result: The highest WUA for the two fish species is estimated at 21 cumecs of discharge. The mean flow of the Iril River is about 27.7 cumecs, which is 6.7 cumecs higher than the optimal ecological flow requirements. The estimation of ecological flow requirements is required to have a better understanding of Weighted Usable Area (WUA) for planning and management strategies. This information may enable stakeholders to develop ameliorative strategies and adopt meaningful measures suitable for the conservation of significant fish species.

Key words: Conservation, Ecological flows, Fish species, PHABSIM.

INTRODUCTION

Freshwater ecosystems are highly threatened ecosystems in the world. Though it constitutes less than 1% of the earth's surface, it supports more than 42% of the fish species (Magurran *et al.*, 2011; Nelson, 2006). Fishes exhibit extraordinary diversity in their morphology, behavior and reproductive strategies. Due to their tolerance to a narrow band of physicochemical variables, they have adapted to diverse habitats ranging from cold-water lakes and mountainous streams to estuaries. Among the freshwater ecosystems, the tropical Asian river systems are the second richest in terms of aquatic biodiversity, supporting the livelihoods of fishermen in many developing countries (Darwall *et al.*, 2008). Presently, tropical river systems are facing alarming threats due to increasing developmental pressure for water and energy needs. Hydrological modifications in the form of dams, hydropower projects, irrigation canals and various human activities have led to the decline of the native and threatened fish communities and enabled non-native fish species to invade some of the undisturbed river stretches. This, in turn, threatens freshwater aquatic species, which leads to the decline of fish species and their abundance. It indicates that certain timely measures are needed to be taken to avoid further decline of fish species.

Freshwater biological communities depend on the interactions of physical, chemical and biological characteristics of streams and rivers. It is necessary to determine a suitable flow rate for target species and to adapt its variability (*i.e.* minimum ecological flows) for planning and developing efficient management of rivers and streams. Several methods are used to determine such environmental

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flows, such as holistic methodologies, hydrological, hydraulic rating and habitat simulation. Hydrodynamic habitat simulation is one of the commonly used methods (Tharme, 2003). Environmental flows are determined on the basis of hydraulic conditions favorable for the most sensitive or significant species at various life stages. Generally, this method uses the output of the hydraulic model (water depth and water velocities) and biological models (*e.g.*, suitability curves) for estimating a suitable flow rate along its required variability. The physical habitat simulation model (PHABSIM) is a broadly used hydrodynamic habitat simulation model (Booker and Dunbar, 2004; Dunbar *et al.*, 2002; Gard, 2009; Glozier *et al.*, 1997; Johnson *et al.*, 2017; Knack *et al.*, 2020; Souchon and Capra, 2004). Johnson *et al.*, (2021) developed the habitat suitability of the black-necked crane in the Nyamjang Chu River of Eastern Himalaya, India, in correlation to the proposed hydroelectric project. Oyague *et al.*, (2020) used PHABSIM for a physical habitat simulation system using benthic and pelagic fish species in the Peruvian Andes-Amazon Rivers.

Loktak Lake is an internationally important wetland listed under the Ramsar Convention. It is located in Manipur, Northeast India. The major rivers flowing into the Loktak Lake include the Nambul, Iril, Thoubal, Imphal, Kongba, Khuga, Heirok and Sekmai Rivers. Maibam *et al.* (2015) and Devi *et al.* (2017) studied the fish diversity of Loktak Lake. Eliza *et al.* (2019) studied the water quality of all rivers draining into the Loktak Lake, including the Iril River. Eliza *et al.* (2020) studied the correlation between fish habitat and the water quality of Loktak Lake and its river basin. Chanmthabam and Waikhom (1999) studied *Bangana dero* as a potential indigenous fish species for the diversification of carp culture in Northeast India for sustainable aquaculture. Dohutia *et al.* (2023) studied water quality and fish species, including *Bangana dero* and *Wallago attu*, in the Ranganadi River of northeast India. However, there is no study defining the ecological flow requirement for fish in Loktak Lake and its river basin. Considering the research gap, the present study estimates the ecological flow for *Bangana dero* and *Wallago attu* fish species in the Iril River. Defining ecological flow requirements can be considered an essential step toward the conservation of significant fish species. This will also facilitate stakeholders development of ameliorative strategies and the adoption of meaningful measures.

Study

The present study area is a river stretch of about 6,000 m of Iril River located in Manipur, Northeast India, as shown in Fig 1. The river originates from Lakhamai village of Senapati

District and flows through Ngamju village. The river runs through Saikul, Lamlai and Irilbung before it joins the Imphal River. The river can be considered to play an important role in the social and economic factors of the villagers (Singh, 2019). The elevation of the Iril sub-catchment varies from about 770 to 2,453 m above mean sea level (Source: EROS DEM). The total area of the Iril sub-catchment is about 1,338.82 km². Landuse of the sub-catchment consists of agriculture (307 km²), dense forest (594 km²), degraded forest (270 km²), Jhum (141 km²), settlement (20 km²), water (5 km²) and Phumdis (1 km²). Phumdis are vegetative floating masses found in Loktak Lake of Manipur. Jhum, also known as shifting cultivation, is the traditional shifting cultivation farming technique that is practiced in certain parts of Northeast India. *Bangana dero*, *Botia Dario*, *Glossogobius giuris*, *Labeo dero*, *Lepidocephalichthys guntea*, *Mastacembelus armatus*, *Mystus bleekeri*, *Mystus cavasius* and *Ompok pabda* are some of the fish species observed during field sampling. Among these species, *Bangana dero* and *Wallago attu* were selected based on their importance and availability. *B. dero* is found throughout the Himalayan foothills in India, Nepal, China and Bangladesh. The species has been introduced in peninsular India and Sri Lanka. *Bangana dero* has been categorized as the least concern species under the International Union for Conservation of Nature (IUCN) red list of threatened species. *Wallago attu* has also been categorized as vulnerable in the IUCN red list of threatened species. This freshwater species is distributed widely occurring all across India, Pakistan, Sri Lanka, Nepal and Bangladesh.

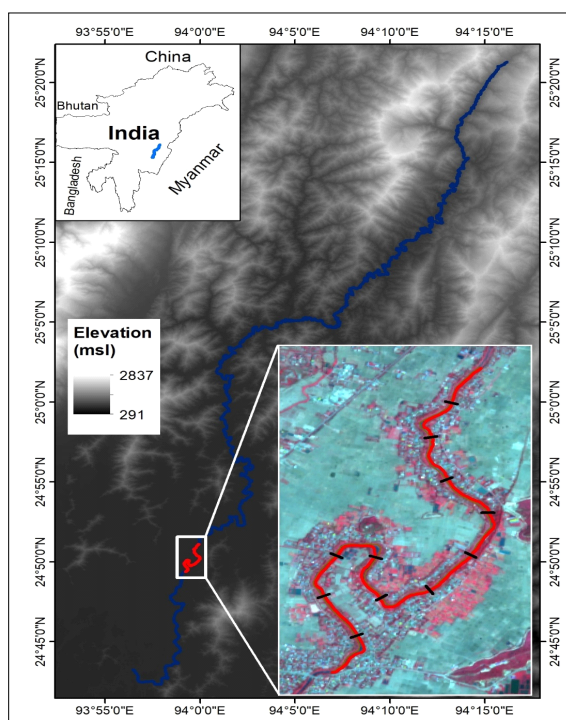


Fig 1: Location map of study area in Iril River, Manipur, Northeast India.

MATERIALS AND METHODS

PHABSIM

Instream Flow Incremental Methodology (IFIM) provides a problem-solving outline for water resource issues in rivers and streams. PHABSIM is part of a broad conceptual and analytical framework to address issues of stream flow management (Bovee *et al.*, 1998; USGS, 2001). PHABSIM habitat model uses suitability index curves for a particular fish species and life stages. It defines the suitability of the fish species for certain physical habitats, such as depth, velocity, substrate and availability. PHABSIM allows users to simulate the condition of various hydraulic geometry variables, such as depth, velocity, wetted area and cover at different flows. Thereby, the model has the ability to predict the amount of available habitat for the target species at different flows. The total weighted usable area (WUA) using all cells at a specific discharge is computed according to the following equation (1):

$$WUA = \sum_{i=1}^n A_i * C_i \quad \dots(1)$$

Where

WUA = Total weighted usable area.

A_i = Vertical view area of cell i (bed area or volume).

C_i = Composite suitability for cell i .

Biological data such as the habitat suitability curve (HSC) can be considered critical for defining the requirements to sustain and conserve the biotic species. Further details can be referred to USGS (2001).

Habitat suitability modeling

The hydrodynamic habitat simulation approach was selected for the present study. PHABSIM model was developed for the river stretch extending about 6,000 m in Iril River. 11 cross-sections at a distance of about 500 m were specified in the model. The depth and velocity at every 2m were observed during field sampling. Depth was measured using a handheld depth finder, and velocity was measured using a flowmeter. Model inputs and source of data collection are shown in Table 1. The elevations of the river stretch were specified in the model. Manning's coefficient was set to be 0.04 according to the substrate observed during field sampling and the literature (Chow 2007; Eliza *et al.*, 2018). Discharge observed during four different seasons was specified in the model as calibration data. Initially, the water surface level (WSL) was set to run using the STGQ model, which uses a stage-discharge relationship (rating curve) to calculate water surface elevations at each cross-section. Further, the water surface level was simulated for different discharges (2, 5, 10, 20, 50, 100, 200 and 350 cumecs) covering the lean and rainy seasons. Observed daily discharge (1st June 1999 to 31st May 2003) was obtained from Loktak Development Authority (LDA), Government of India, as shown in Fig 2. The figure shows that the highest discharge is found to be 348 cumecs as observed on 31st August 1999. The lowest discharge is found to be 0.13 cumecs as observed on 21st April 2002.

The velocity was also simulated for all the discharges at all cross sections. There is an assumption within the

Table 1: Data input and source.

Data	Source
Geographical location	Field sampling
Elevation	Field sampling
Velocity and width	Field sampling
Substrate available	Field sampling
Manning's n	Substrate and literature (Chow, 2007; Eliza <i>et al.</i> , 2018)
Observed discharge for calibration	Field sampling
Observed discharge throughout the year	Loktak Development Authority, Government of India
Suitability indices	Johnson <i>et al.</i> (2017)

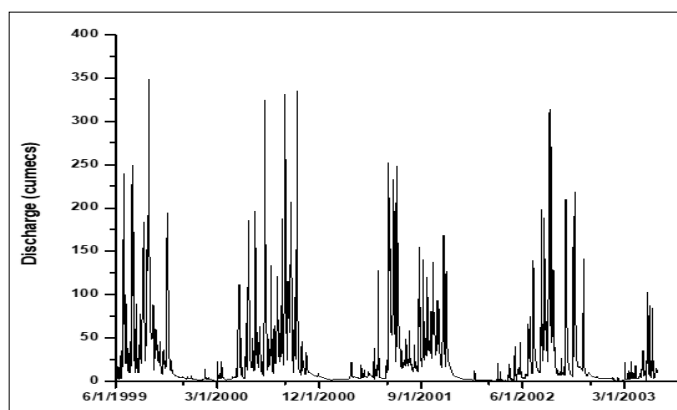


Fig 2: Observed discharge at Moirang Kampu in Iril River (Source: LDA, Gol).

PHABSIM that aquatic species will respond to variations in the hydraulic environment (USGS, 2001). The river simulation depicts the form of a multi-dimensional matrix of

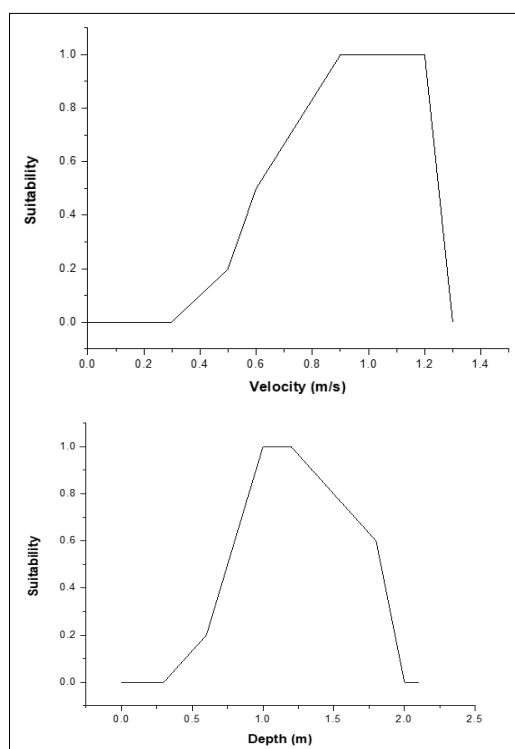


Fig 3(a): Habitat suitability curves for *Bangana dero* (mature).

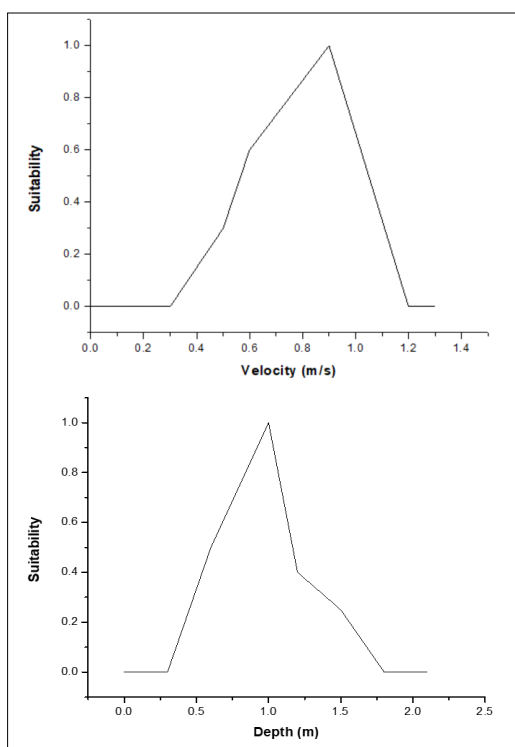


Fig 3(b): Habitat suitability curves for *Wallago attu* (mature).

the calculated surface areas of a river having various combinations of hydraulic parameters such as velocity and depth. The velocities and depth vary with the change of discharges, leading to changes in the quantity of available habitat for target fish species.

The availability of fish species was observed during field sampling. However, due to the complexity of finding preference, the suitability indices for velocities and flow depths were obtained from Johnson *et al.*, (2017). Figures 3(a) and 3(b) show the habitat suitability curves (HSCs) for *Bangana dero* (mature) and *Wallago attu* (mature) fish species, respectively. The HSCs indicate that *B. dero* prefers velocities varying from 0.6 to 1.2 m/s, while the optimal range of velocity of *W. attu* varies from 0.6 to 0.9 m/s. The HSCs also indicate that *B. dero* uses depth varying from 0.6 to 1.5 m while *W. attu* prefers depth extending from 0.6 to 1 m. Thus, it can be concluded that both of the fish species prefer higher flow (velocity) and shallow depth. Finally, habtae was set to run and WUA was obtained as output from the habitat model. WUA depicts the index of suitable habitat available in units of square meters per km.

RESULTS AND DISCUSSION

Fig 4 shows the variation of WUA for *Bangana dero* and *Wallago attu* fish species for the different amounts of discharge covering from the lean season to the rainy season. The highest WUA for *B. dero* and *W. attu* are estimated to be 22,041.80 sq m/1,000 m and 13,856.29 sq m/1,000 m at 21 cumecs. There is a steep increase of suitable habitat from 5 cumecs to 21 cumecs discharge. Any increase in discharge above 100 cumecs is not beneficial for the target species. *B. dero* is found to be unsuitable when the discharge is above 380 cumecs, while *W. attu* shows unsuitability when the amount of discharge is greater than 328 cumecs. The WUA versus discharge relationship for the selected target species specifies that there is a steep increase in usable habitat area from 5 cumecs to 21 cumecs. *B. dero* lives in a broader range of depths and velocities and their high occurrence in the Iril River is contributed by the wide range of suitable habitat conditions available in the Iril River. However, *W. attu* is an economically significant fish species, and its availability is comparatively lesser. This might be attributed to overexploitation for food and commercial purposes. The usable habitat area of *B. dero* is found to be broader than the usable area of *W. attu*.

Further, the results depict that the optimal flow requirement of the selected species is estimated at 21 cumecs. The average mean flow of the Iril River was about 29.5, 29.76 and 24.06 during 2000, 2001 and 2002, respectively. As compared to the optimal flow requirement, the flow requirement should be 6.7 cumecs less than the mean flow. The stakeholders may take into account the optimal discharge and

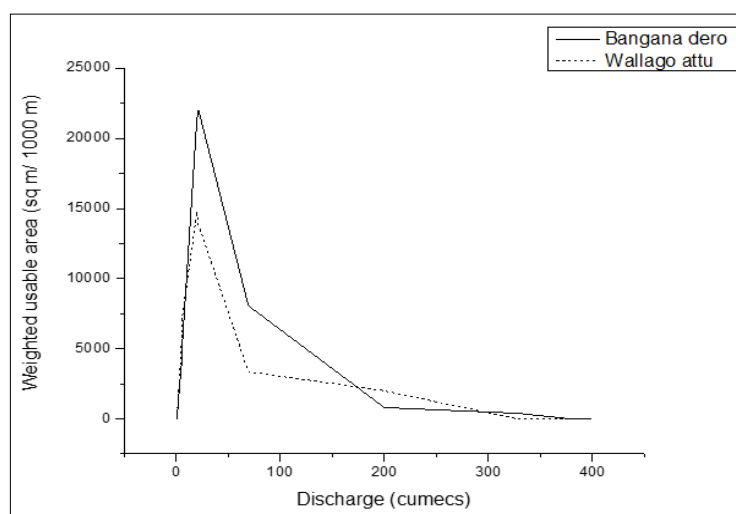


Fig 4: WUA versus discharge for *Bangana dero* and *Wallago attu* fish species.

preferable depth and velocity while developing management and conservation plans.

CONCLUSION

The present study estimates the minimum ecological flow requirement for the selected target fish species *Bangana dero* and *Wallago attu* in a river stretch extending about 6,000 m in Iril River. Hydrodynamic habitat suitability modeling has been performed using PHABSIM. The WUA has been estimated for the two target species. The highest WUA for *B. dero* is found to be 22,041.80 sq m/1,000 m at 21 cumecs of discharge. At the same time, the highest WUA for *W. attu* is estimated to be 13,856.29 sq m/1,000 m at 21 cumecs. The WUA for both species increases from 5 cumecs to 21 cumecs of discharge. *B. dero* is estimated to be unsuitable when the discharge is above 380 cumecs, while *W. attu* is found to be unsuitable when the discharge is above 328 cumecs. The study also revealed that the optimal flow requirement of the selected target species in the river stretch of Iril River is about 21 cumecs. Meanwhile, the mean flow of the Iril River is 27.7 cumecs. So, it is observed that the mean flow can be decreased by 6.7 cumecs to get optimal ecological flow requirements. It provides a better understanding of the minimum ecological flow requirement of the two target species. Habitat suitability modeling of selected target fish species can be regarded as a crucial step towards framing conservation and management strategy.

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Conflict of interest

There was no conflict of interest in this study.

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