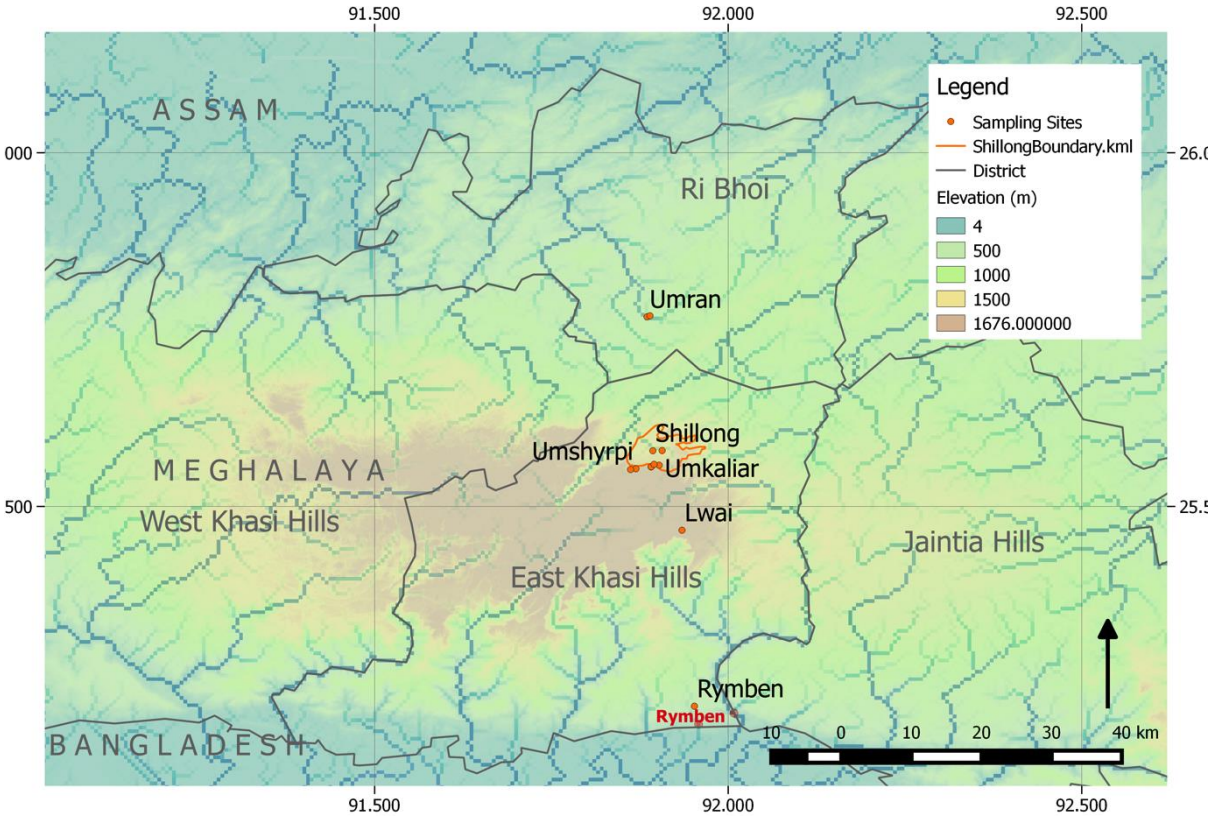
Project Update: July 2017

Conservation of Freshwater Ecosystems in Indian Northeast

1. Background: the need for environmental flows

Our work in the Indian Northeastern state of Meghalaya involves local communities to work with the scientists to establish a river monitoring program. Hydrological parameters (rainfall, water level and discharge) along with information on fish catch and diversity of river Rymben are collected to determine environmental flows required to maintain ecosystem services while supporting multiple uses. Rymben originates in the South facing slopes of Khasi Hills the catchment of which encompasses an area of ~ 30 km^2 as it drains the villages of Lapalang and Pomchutia before it enters Bangladesh and becomes part of the Meghna catchment (Fig. 1). The data collected over one year establishes a baseline relationship linking hydrology (river flow, depth) with fishing patterns (fish species and catch across seasons) as determined by interacting with local fishermen. This information is used to determine flow regime or Environmental Flows (EF) necessary for maintaining diverse fish communities.

Figure 1. Rymben originates in southern flanks of the Khasi Hills in Meghalaya. Map generated by drainage network delineation using QGIS upon ASTER 30 m Digital Elevation Model.



Free-flowing streams and rivers benefit mankind by providing fish, recreation and by maintaining water quality naturally. Yet, mounting human needs for water lead to increasing water abstractions from rivers, changing flow regimes with negative consequences for the aquatic ecosystem. The Brisbane declaration of 2007

(http://www.watercentre.org/news/declaration) defines EF as "the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems". EF assessments are now considered globally as important tools used for ecosystem restoration and management of water resources. Our monitoring data on hydrological parameters and fish abundance add to the data-poor but biodiversity-rich North-eastern India region that suffers from a lack of infrastructure and resources required to install and maintain monitoring stations across vast remote areas.

2. The study approach

The underlying assumption of our approach is that existing fish communities have been maintained by flows that currently occur. Native fish species have adapted their life cycles to seasonal variation in hydrology. We thus relate the existing river flow across seasons with fish abundance and diversity. The life cycle history of the fish species and their dependence upon water flow and depth are then determined from local community knowledge and researching the literature. The task of determining environmental flows is challenging because majority of rivers in India neither have publicly available monthly discharge data nor any estimates of fish abundances.

To close this data gap, we have initiated a study to monitor discharge and depth data for Rymben, and have involved local communities. Ours is the first study to obtain the hydrological information required to determine minimal flows. Here we report monthly data on river depth and discharge collected from December 2015 to March 2017 in conjunction with information on fish catch. Minimum flow guidelines are then provided based on discharge values for each month in a year, to provide water users (local communities and the government) a guideline, without which river flow alterations can irreparably harm ecosystems presence.

With the help of local school faculty and students, a height scale was painted on a bridge column at Lapalang that was used to measure water level on a periodic basis.

Fig. 2. Monitoring stream flow in Rymben with help of St. Xavier's High School students

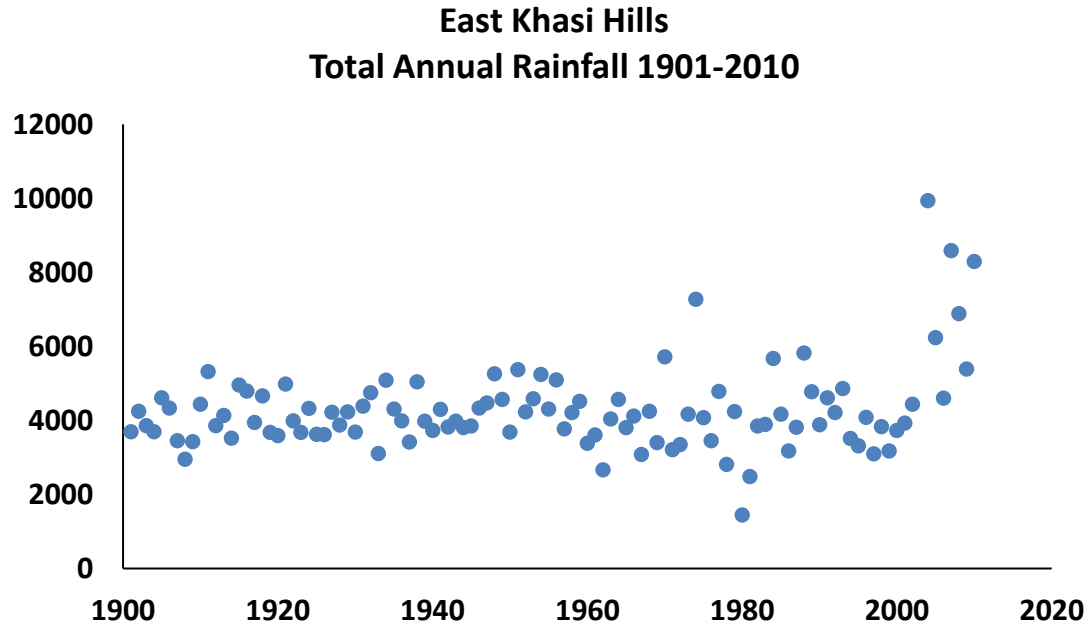
Discharge was collected monthly using two methods: a mechanical current meter (2030R, General Oceanics, FL, USA; Fig. 2) and by the float method. The data on fish catch and fishing methods were collected by interacting with local fishermen of Lapalang and neighboring villages (Pomshutia, Wahkdait, Sohlong, Umkrem, Nongthymmai, Nongtyngur, Dawki) and spending days with fishermen while they were fishing during both dry and wet seasons. In addition, data from Massar (2017) was referred to and used as baseline information.

3. Results so far

3.1. Using Hydrology to determine environmental flows

We use river discharge, rainfall and depth data to provide flow guidelines. Historic data on low flows is desirable but hard to find. Here we use one-year data on discharge and depth and historical rainfall data from to determine if rainfall has shown change over time. While discharge is influenced by a suite of variables-rainfall, infiltration, groundwater discharge and evapotranspiration rates (influenced by the catchment land-use), abstractions; rainfall is the strongest predictor. Rainfall data across 1901-2010 (Fig. 3) suggest an increasing rainfall from year 2000, with mean greatest rainfall occurring in June; however, the spread of the rainfall across the months of the year are lower during 1901-1980, after which there is a rise in variance; predominantly driven by increase in rainfall during July. The amount and duration of high flows may not be a limiting factor for fish in Rymben River during, however the low flows are critical. Low flows are especially for sustenance of fish populations that breed during low flows, keeping the minimum flow is critical.

Fig. 3. Total annual rainfall in East Khasi Hills across 1901 to 2010 showing a recent increase in total rainfall in the decade starting 2000.



Over the dry season (November-April; Fig. 4a), the river flow slows and trickles to one-two narrow channels, while pools of water from across the outer edges of the river channel. These data indicate that the minimal water flows during the low flow season should be maintained between 0.1-0.24 cumecs, as these flows allow water to pool in

the sinkholes dotting the river channel bed, the habitats utilized by fish such as garra species, *Glyptothorax* species and *Balitora* sp. for breeding. High flows are observed during the wet season (April-October) when the river turns torrential (Fig. 4b)

Our discharge data shows peak values in June-July with low flows during December-February. The river hydrograph (Fig. 5) shows that several flow values exist for a water table height and that the discharge takes time to increase while the stage measurements are steadier.

Fig. 4a. Rymben in the dry season, the seasonal pools are habitats for several bottom dwelling species

Fig. 4b. Rymben during the rainy season, habitat for Chocolate Mahseer

These data have implication for watershed health suggesting that discharge is influenced by interflow (a shorter response time, a day to respond) and groundwater flow (takes longer to respond) as opposed to solely by overland flow (within minutes of a deluge) suggesting that dominant storage capacity of the landscape is not compromised and therefore it takes time before discharge shows dramatic change (Widodo and Noorwijk accessed 2017 March 30).

Figure 5. Rymben river hydrograph showing monthly discharge and stage from 2015-2016.

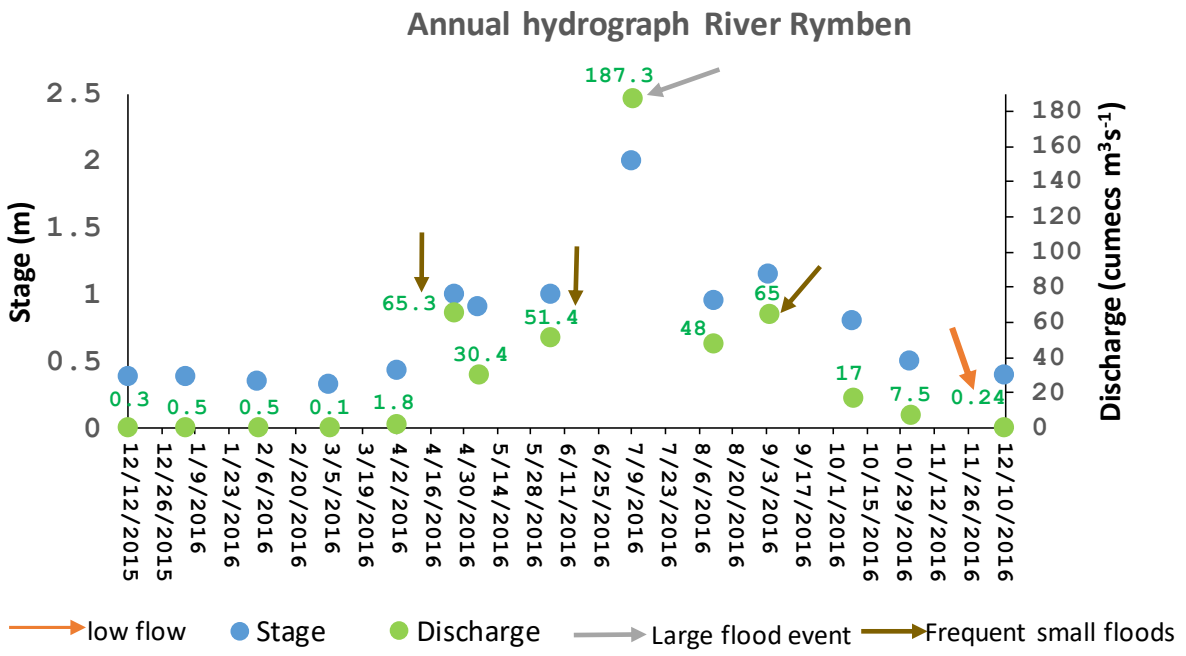


Table 1. Showing the depth, width, velocity and discharge rate of river Rymben. These are the discharge values recommended to maintain diverse fish communities.

Date	River Depth (m)	River Width (m)	Discharge (m^3 /sec)
12.12.15	0.38	3.7	0.3
01.05.16	0.38	4.1	0.5
02.04.16	0.35	3.9	0.5
03.05.16	0.33	3.8	0.1
04.02.16	0.43	7.6	1.8
04.24.16	1.0	45.0	65.3
05.06.16	0.9	38.0	30.4
06.05.16	1.0	39.5	51.4
07.09.16	2.0	49.3	187.3
08.12.16	0.95	39.0	48.0
09.04.16	1.15	47.0	65.0
10.0916	0.8	35.0	17.0
11.02.16	0.5	30.0	7.5
12.11.16	0.4	1.3	0.24

3.2. Diversity of fish catch in Rymben

In Rymben the following fish species are found throughout the year though species such as - Chocolate mahseer (*Neolissochilus hexagonolepis*), the near threatened mahseer that inhabits high gradient and low gradient riffles and pools, Gray's stone loach (*Balitora brucei*Fig. 6), a rare species found underneath rocks in fast flowing waterfalls and high gradient riffles are declining in numbers and getting harder to catch. Other species occurring and commonly fished are the members of catfish families (*Glyptothorax striatus* and *G. trilineatus*), the benthic inhabitants of torrential rivers and streams attaching to rocky bottom against strong currents, two species of true suckers (*Garra gotyla gotyla and Garra lissorhynchus*, Fig. 7*),* which adhere to the rocks of fast flowing waters of hill streams and rivers, multi-banded loach *(Schistura multifasciata),*a benthopelagic species of shallow streams and rivulets, Blue perch*, (Badis badis)*that inhabits shallow slow moving pools of water amidst of submerged vegetation are commonly fished by children as well, and an indicator of water quality of hill streams, Giant Danio (Devario aequipinnatus) is common in Rymben and fished regularly. The snakehead Channa gachua is the generalist species with tolerance to a variety of habitat and water quality conditions among all the species occurring in Rymben.

Fig. 6. *Balitora brucei* dorsal view (Photo courtesy, Massar 2017)

Fig. 7. *Garra lissorhynchus,* dorsal view (Photo courtesy, Massar 2017)

Overall, the species occurring in Rymben experience dramatic transition from a flowing to static water system across the seasons. Temperature increases and dissolved oxygen decreases in the winter and dry season. Fish associated with swift flowing currents, and hence requiring highly oxygenated waters, such as mahseer, are not seen in the dry season. Fish such as *badis* can live in these pools, indicating that these fish can survive in lower oxygen environments.

3.3. Fish stock assessment based on interactions with Fishermen of Rymben.

We summarize list of species targeted by the local communities and estimates of their fish catch based on interviews with local fishermen during 2016-2017. There are 10 species of fish known and collected from Rymben (Massar 2017). Each of the species is fished with help of nets or fishing lines and poles (8a). Fish are either used by the fishermen family, or are sold in the local market of Lapalang. Species commonly caught during the low flow season are *Badis* and *Schistura*, which occur in pools in the river. In a village of ~ 300 households, a person can catch 15-30 of them per species during the day. Young Chocolate mahseers and Danio are caught during the high flow season after the rains (Fig. 8b, however their abundance is on decline. Chocolate mahseers can attain the size of 60-70 cm or more, but individuals of this size are rarely caught which fish 10-20 cm are caught and retained.

Local fishermen mention that all fish that are caught are kept irrespective of their life history stage. While there might be equipment limitation for catching big fish, indiscriminate fishing is rampant where people remove immature and juvenile fish; for species such as Chocolate mahseer and Snakehead (Channa spp) people catch very young and juveniles.

Based on the number of fish caught per household across several villages it can be inferred that River Rymben supports moderate stocks of the fish. However, individuals that are yet to attain sexual maturity are caught which impairs population growth. While the fishermen acknowledge decline in fish, they continue their fishing practices.

Our data suggests that from the perspective of fish abundances the hydrological parameters are not what is driving the fish to a skewed distribution, but it is the overfishing and people harvesting immature fish. Overfishing may be contributing to declines in fish population and not the discharge deficits.

Fig. 8a. Left: A fisherman with a traditional bamboo fishing pole. 8b. right: Young chocolate mahseer caught during a regular fishing day in the rainy season.

Table 2. A list of fish species of the river targeted by local fishermen

Species name and adult size	season	Size of the catch
***Neolissochilus hexagonolepis* Chocolate mahseer, 70 cm**	June-September	7-20 cm
***Glyptothorax striatus* (20-25 cm) *Glyptothorax trilineatus* (10-15 cm)**	October-March (dry season)	Possible to catch adult size
***Garra gotyla gotyla* (15-20 cm) *Garra lissorhynchus* (10-15)**	October-March	Possible to catch adult size
***Balitora brucei*. 10 cm**	October-March	Possible to catch adult size
***Schistura multifasciata*, 10 cm**	October-March	Possible to catch adult size
***Badis badis*, 9 cm**	October-March	Possible to catch adult size
***Channa gachua*, 20 cm**	June-September	Possible to catch adult size

4. References

Brisbane Declaration. 2007. http://www.watercentre.org/news/declaration Accessed June 20, 2017

Massar, B 2017. Documentation and Classification of Animal species of River Rymben in Meghalaya, India, and Scanning Electron Microscopy of Mouth parts of Sucker Fishes inhabiting the river. Final Report submitted to UGC.

Widodo R H van Noordwijk M. 2008. Rainfall & Discharge Relationship: A Simple technique to diagnose the health of a watershed - Bogor, Indonesia World Agroforestry Centre (ICRAF). SEA Regional Office.