Co-funded by the European Union

INDIA-EU WATER PARTNERSHIP

Environmental Flows Assessments in Ramganga River Basin

Under the India-EU Water Partnership Action

Phase 2

Summary Report

First Field Mission- 16-19 May 2022

In Collaboration with

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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1. Background

The Government of India recognizes in its National Water Policy (2012) that "environmental needs of aquatic ecosystem, wetlands and embanked floodplains need to be recognized and taken into consideration while planning" (Clause 3.3: "a portion of river flows should be kept aside to meet ecological needs ensuring that the low and high releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water uses". The overall vision for the Ganga is for a healthy, clean (*nirmal*) river with an uninterrupted flow (*aviral*), which supports the needs of society and nature, while being resilient to future changes in water demands and climate. E-Flows assessment and implementation for the Ramganga River system is an element of the planned rejuvenation of the wider Ganga system, of which it is a key tributary.

Within its 32,493 km^2 catchment, the Ramganga River faces similar sustainable development and management challenges to those of the Ganga. Ramganga River system supports the local economy and diverse livelihoods of 18.2 million people, 73.4% of whom live rurally, in the basin's two states of Uttarakhand and Uttar Pradesh. Basin water resources are already used for multiple purposes and are under increasing pressure. In particular, the river supports extensive irrigated cropland, hydropower, domestic uses (especially from groundwater) and industry. The major reservoirs, of which Kalagarh Dam is the largest, and barrages and weirs located in the basin have significantly altered the pattern and timing of flows and fragmented the river system. Industrial and other pollution sources have led to some river reaches exhibiting poor water quality. The detrimental effects on ecological health, ecosystem services and biodiversity are serious, putting the future sustainability of the Ramganga River at risk.

In this context, there is a need to move from the E-Flows assessments of the previous IEWP Phase 1, which covered the upper Ramganga Basin and river mainstem till Moradabad, to a basin wide assessment of the flow-related needs of the Ramganga as a functionally interconnected river network. Enlarging the scope of the E-Flows assessment, as well as ensuring it is sufficiently inclusive and interdisciplinary, requires the participation of national, state and other basin stakeholders, including technical partners. Steered by the NMCG, and undertaken under Phase 2 of the IEWP Action together with CWC and the State water agencies, the E-Flows assessment is underway in the Ramganga Basin to continue to advance the Indian E-Flows approach and the associated guidance, and to ensure that the E-Flows are implementable through the Ramganga River Basin Management Plan.

In this context, the first field mission to collect the eco-hydrological and hydraulic data at selected sites in the Ramganga Basin and to carry a hands-on training regarding field assessments and data collection was organized during 16-19 May 2022. A multidisciplinary team about 25 experts/trainees/participants from NMCG, CWC, WII, CIFRI, CPCB, EU consultant team and GIZ India participated in the field mission. The list of participants has been annexed with this report (Annex 1). A team from IIT Kanpur also carried out the UAV survey work in the similar time frame.

In preparation for the first e-flows field mission to the Ramganga Basin, a preliminary desktop characterization of the basin's types of rivers was made, primarily using GIS-based catchment information and physiographic variables, including: river drainage network, topography, land use-land cover, geology, ecoregions, urban areas, locations of gauging stations and water infrastructure and administrative units. The characterization analysis yielded 13 different, spatially non-contiguous ecohydrological river types, of which 2 were excluded as they were small stream types (Figure 1; refer to basin characterization chapter of E-Flows Assessment Report in preparation). The identification of river reaches to be visited as potential E-Flows sites during the mission was informed by the basin characterization results and guided by pre-mission virtual planning meetings with the Indian team members familiar with the river system (WII, CWC and others). Care was taken to cover those river reaches/sections of reaches that were likely in a largely unaltered condition ecologically (e. g. the 3rd or 4th order tributaries) and reflected well the habitat features and other ecological components and features typical of an ecohydrologically healthy Ramganga system. Particularly, it was noted that the lowland section of the Ramganga River, from Bareilly downstream, is highly anthropogenically altered. It has relatively fewer mesohabitat and microhabitat features than other parts of the Ramganga mainstem, as well as a largely homogeneous sand-dominated bed. The habitat quality, water quality and fish community present in the lower reaches therefore will not be representative of the basin as a whole.

The GIS layers and classification results were pre-loaded into a GIS database, which was used to guide the site reconnaissance steps while in the field; the data will continue to be elaborated as needed, to refine the site locations and reach delineations. The 11 preliminary sites formed the basis of the schedule for the first field mission to capture the pre-monsoon river conditions, which took place in the Ramganga Basin from 16-19 May, 2022.

2. Objectives of the mission

The main objectives of the inception mission were:

- Reconnaissance and reach (site) selection for E-Flows primary data collection.
    - Reconnaissance visits to the Ramganga River Basin for the familiarization of all team members with the river system and catchment features.
    - Ground-truthing of multiple mainstem and tributary sites to confirm suitable and unsuitable reaches for field data collection.
    - Informal meetings with local stakeholders.
- Collection of a first set of field data for habitat-discharge modelling, for pre-monsoon discharge conditions.
    - Meeting of the E-Flows Technical Team (Indian and European members) in person for the first time.
    - Collection of eco-hydraulic data from the different reaches identified through desktop analysis.
- Capacity building through hands-on training during data collection.
    - Preceded by a self-paced work-through by all of those to be trained in the field, of a comprehensive set of online written and audiovisual materials (www.mesohabsim.org): narrated presentations, tutorials, movies, workshops and manuals.
    - Multidisciplinary interactive exercise for the first couple of sites, as an exercise to increase understanding of an integrative approach to E-Flows.
    - Training of team members regarding in field habitat data collection concepts, methods and tools.

3. Daily activities and key observations

The team became familiar with the local conditions of different representative and/or critical reach types identified (Figure 1) and the ground-truthing objectives were met during the course of the field mission.

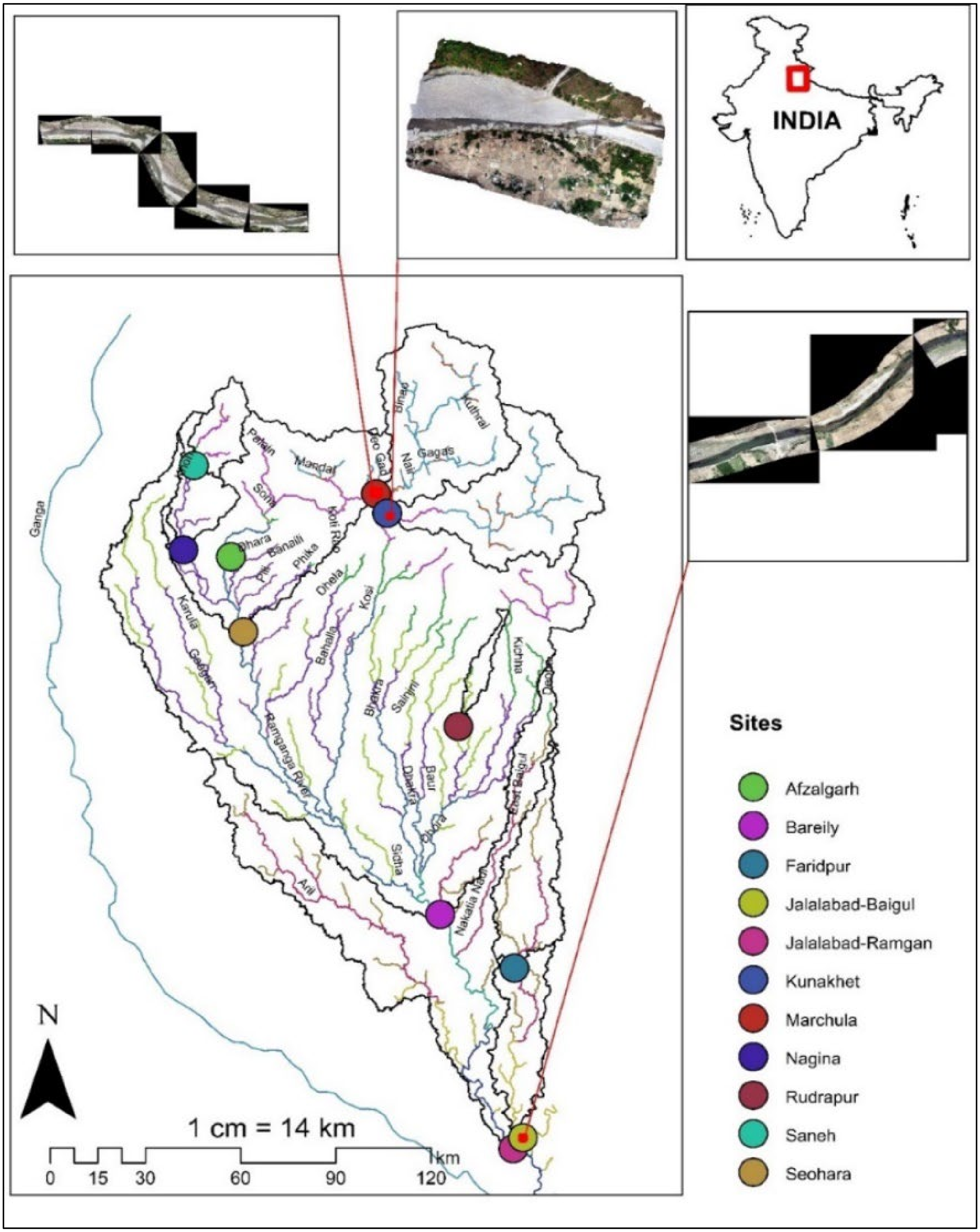


Figure 1. Locations of distinct river reaches of different types within the Ramganga River Basin, based primarily on physiographic features.

May 16, 2022- Bareilly-Ramganga River

While half of the day was used for travelling to Bareilly, second half of the day was used to collect the eco-hydrological samples at the Bareilly site. The drone survey team also took observations at the Bareilly site on this day.

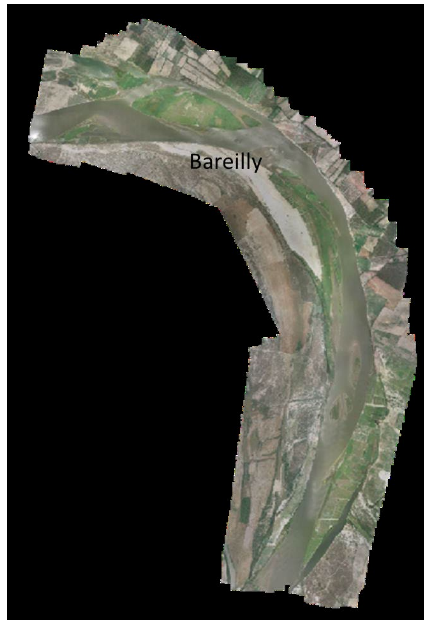



Figure 2. Observations at Bareilly site

May 17, 2022- Jalalabad-Ramganga River

It is a boatable section of the river, although large portions of the main channel were shallower than 50 cm on the day (instantaneous discharge data were unavailable for the site).

At this site, observations of river bathymetry and zig-zag flow profiles were made using a boat mounted ADCP. In shallow sections, manual observations of flow conditions (depth and velocity) were made. CWC team undertook this hands-on exercise together with the EU expert. Detailed ecological observations were undertaken by the CIFRI team. Fish ecology and fisheries data were collected at the site, and a general description made of reach ecological character using a standardized local protocol (Section 4).

Figure 3. Eco-hydraulic observations at Jalalabad Site on Ramganga River and local community members (stakeholders)

May 17, 2022- Jalalabad-Baigul River

Another Jalalabad site on the Baigul River, a tributary of the Ramganga just before its confluence with Ramganga, was visited. WII expert elaborated the approach and methodology for ecological data collection (including the data sheet filling) and a brief training on Mesohabitat mapping was provided to the WII and CWC team. The river here is a low gradient, wide shallow site, free-flowing, and well suited for wading survey. The substratum is sand and mud. A deeper subset of the reach was sampled by the boat team (Figure 3; Section 4) using ADCP for the bathymetric and flow profile data. Water quality and ecological samples were also collected by the WII and CIFRI teams. With the visual guess at site, the flows were expected to be in the range of 3-4 cumecs and locals informed the team that this is the usual summer flow condition (at least this much flow is always available in the river) and a few water pumps were installed to withdraw water from river to irrigate the farms around the floodplain. Fishing is limited to very small scale as it is not consumed widely locally. Floodplain farming in rabi season is very common and common rabi crops are wheat and mint.

Figure 4. Ecological, water quality sampling and Aerial imagery of Site: Baigul River at Jalalabad

In parallel, a cross-disciplinary discussion of the condition of the site took place, with an assessment of the general ecological characteristics of the reach, as well as of the extent of its alteration due to human activities in the vicinity.

May 18, 2022- Marchula-Ramganga River

The team visited the site: Ramganga River upstream of Marchula. It is a high gradient river, with a bedrock and cobble-boulder dominated alluvial bed (Figure 5). The site is located within Jim Corbett National Park. It was confirmed to be suitable and not difficult to survey. Aerial imagery documented a high reach morphological diversity. The site was in very good ecological condition and only slightly modified from natural (nearby village with some human disturbance evident associated with access along the river corridor). Risk of potential wildlife threats to team safety were a serious consideration at this site (elephant, tiger) and it was necessary to visit the site with local forest rangers. Ecological and water quality related samples were collected at this site by the WII and CIFRI teams. Hydraulic and Habitat survey had to be curtailed due to the serious threats of a man-eater tiger's presence in the locality and the location of site was adjacent to the dense forest.

Figure 5. Marchula Site -General character of the reach-eco-hydraulic observations etc.

May 19, 2022-Kunha khet-Kosi River

Training on habitat mapping was carried out using a readily accessible reach of the Kosi River in Ramnagar. Note that this practical training exercise was conducted in the river reach adjacent to the hotel for convenience; it was not the Kosi site designated for primary physical habitat data collection. In parallel, a part of the team went to Kunkhet (/Kuna khet) and ground-truthing of the site upstream of Kuna Khet was undertaken. Also, fish, benthic invertebrate and water quality data were collected site. The site was considered ecologically functionally intact. It was informed by the forest guard that there were some bank protection structures in place on the left bank which swept away in the very recent flood.




Figure 6. Kosi River at Kuna khet, showing the reach sampled by the E-Flows team for fish, benthic invertebrates and water quality

As the river flows through the protected area boundary of the National Park and due to the wildlife risk at the site, the Forest Department had to be notified in advance. Forest guards accompanied the team to the river and remained with them until the work was completed. Local fishers from the community assisted with fish data collection at this, and other sites, and standard ecological methods were employed (e.g. cast net sampling and snorkel observation).

Other sites and locations visited

1. *Dhara River at* Afzalgarh (Figure 7).
   The access to the site is limited (private agribusiness access roads through sugar cane fields). The river water level was very low and water surface and riparian zone were overgrown by non-native vegetation, including invasive macrophytes (e.g. *Eichhornia* spp.). It was agreed that the site was not feasible to survey, and that an alternative reach of the same type would need to be identified as an alternative, either prior to/during the next field mission.
2. Similar observations were made by the drone survey team about the site near Rudrapur (Figure 8). At this site river is in the form of Nallah where it is clear from the visual inspection that the water quality is badly affected also including some solid waste.

Figure 7. Dhara River at Afzalgarh.

Figure 8 Site neat Rudrapur- Badly affected water quality

3. Khoh River at Nagina (Figure 9) is a multi-thread, sandy bottom reach that is fully suitable for a wading survey. At times of higher flow levels, it can be surveyed using a boat with ADCP. The site was fairly homogeneous, low gradient and with a mix of native and non-native riparian and floodplain vegetation. There was clear evidence of human impact and use of the reach, including large areas of crop cultivation within the local floodplain (dependent on the dynamic natural flooding regime) use of the river for water, silt and nutrients, cf. irrigation.

Figure 9. Nagina Site on Khoh River

4. The Harewali Barrage (Figure 10), impounds the water released by Kalagarh Dam (located upstream) and diverts it to the Khoh River, from where it is taken to the Upper Ganga canal system for irrigation purposes.

Figure 10. Harewali Barrage

5. Kosi Barrage on the Kosi River at Ramnagar mainly serves for the irrigation and domestic water supply demands in the basin. Though there was no specific water release happening on purpose (e.g. environmental flows in the river), these was significant leakage in the barrage gate resulting into some river discharge.

Figure 11. Kosi Barrage, Ramnagar

4. Data and Results

4.1 Training activities

The mission included intensive hands-on training on eco-hydraulic and habitat surveying (Concept and Agenda in Annex-2). As training progressed, the level of technical detail increased and the group of participants was limited to those, who had sufficient interest and technical knowledge. MesoHABSIM training during the mission included a general presentation of equipment, such as a Laser Range Finder and dipping bar of Jens for velocity measurements, as well as the use of the TMap application on a tablet for mapping habitats. The trainees were presented with the habitat mapping concepts and general approach, which was explained with Q&A while the team was wading in the river.
This interactive training was accompanied by discussion of the approach. Trainees expressed their good understanding of the methodology.

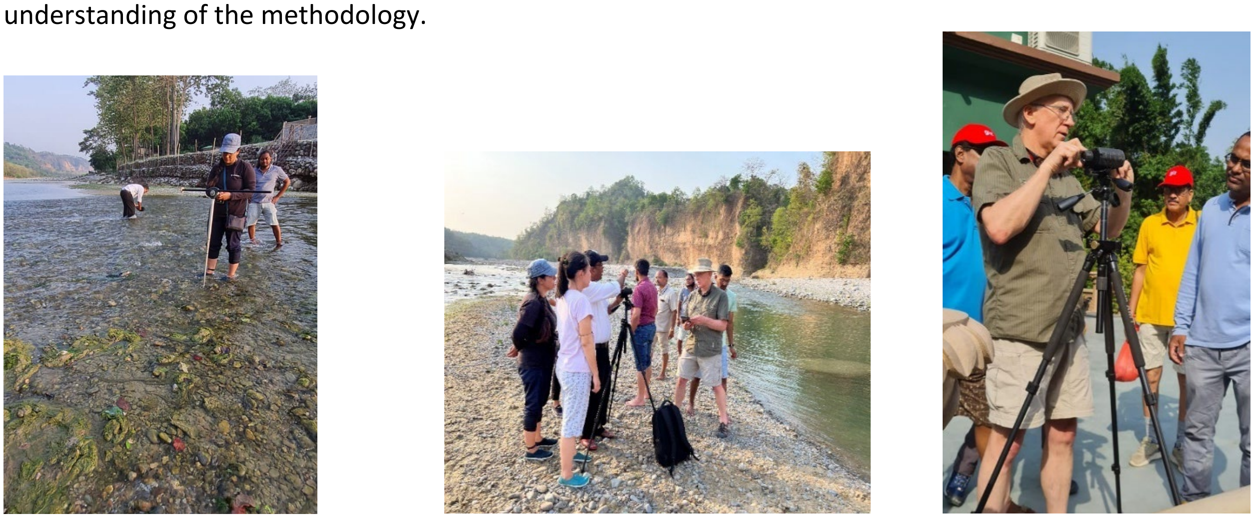


Figure 12. Hands-on training of various mapping tools and techniques, and habitat mapping in the field exercise reach of the Kosi River.

Figure 13 shows the *Hydromorphologic units (HMUs) and (Right) finer scale habitat features (choriotopes) of ecological relevance to fish and invertebrates, mapped by the team members during the hands-on training on the Kosi River.*

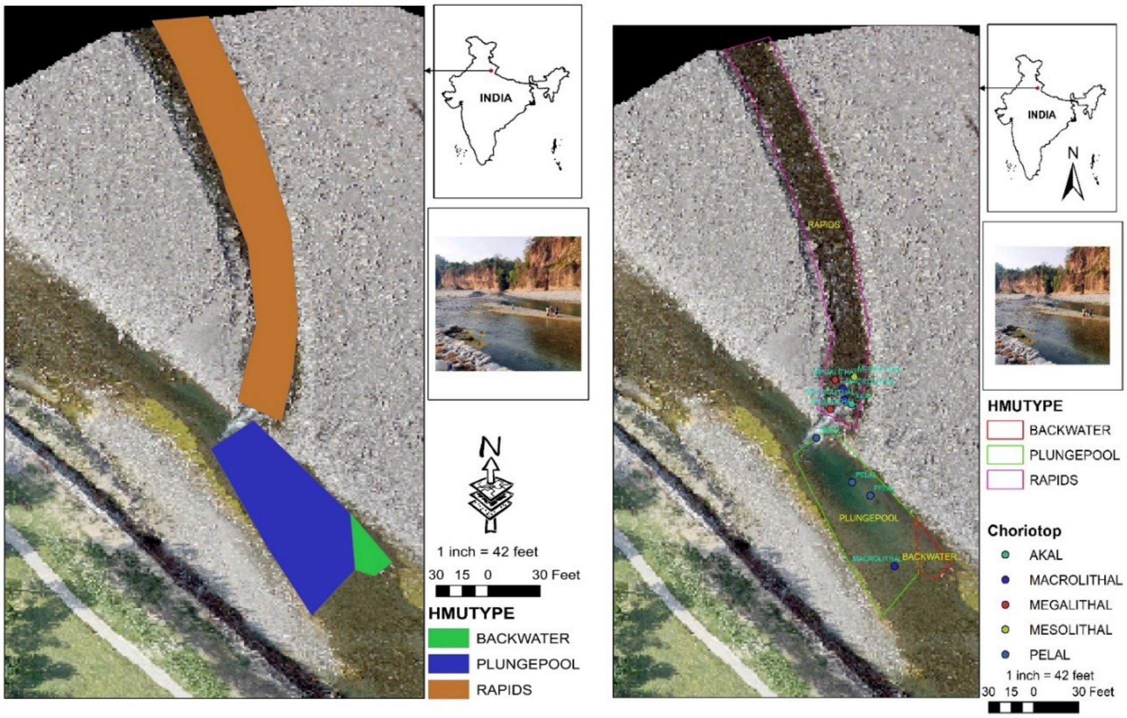


Figure 13.) Hydromorphologic units (HMUs) and (Right) finer scale habitat features (choriotopes) of ecological relevance to fish and invertebrates, mapped by the team members during the hands-on training on the Kosi River.

At each site, it was described what activities are planned and participants followed the trainers into the rivers in smaller groups. At the Marchula site, a large group of participants hiked with the survey team though the challenges associated with intensive habitat fieldwork, such as slippery boulder substrate, large distances to cover etc were faced.

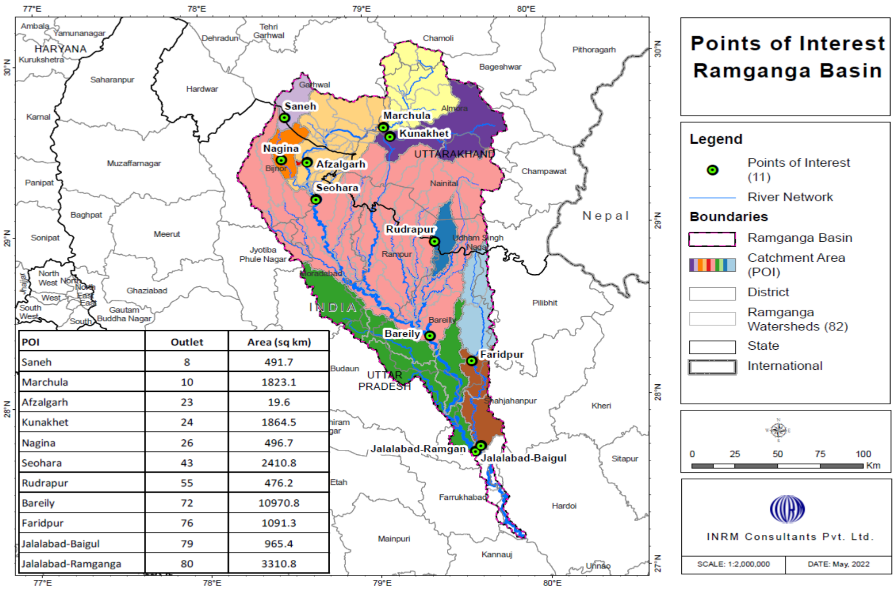
4.2 Hydrology

The INRM team provided desktop technical information on the catchment areas (and long-term modelled hydrology, based on previous studies) for the 11 sites, to assist in a general understanding of their hydrological regimes during the course of the field mission (Figure 14).

Information on the hydrological characteristics of the sites was limited during the individual sites visits. Information on the instantaneous discharges at the site (from survey information) or the average daily discharges at the nearest hydrological gauging station to each site were collated and are summarised in Table (1).

Table 1. On-day discharges ($m^3 s^{-1}$) recorded/estimated/modelled for the sites visited in the field.

Name of the Site	Flow (cumecs)	Observed/estimated/modelled
Bareilly	33.48 cumecs	Observed at HO Site at Bareill
Jalalabad (Ramganga)	35-40 cumecs	Estimated
Jalalabad (Baigul)	4-5 cumecs	Estimated
Marchula	8-9 cumecs	Observed at HO site just d/s of site
Kuna Khet	4-5 cumecs	Estimated



POI	Outlet	Area (sq km)
Saneh	8	491.7
Marchula	10	1823.1
Afzalgarh	23	19.6
Kunakhet	24	1864.5
Nagina	26	496.7
Seohara	43	2410.8
Rudrapur	55	476.2
Bareily	72	10970.8
Faridpur	76	1091.3
Jalalabad-Baigul	79	965.4
Jalalabad-Ramganga	80	3310.8

Figure 14. Catchment areas (km2) of the 11 Ramganga sites.

4.3 Aerial reach surveys of sites

Aerial surveys were made of the individual reaches representing the sites the day before the hydraulic and physical habitat data were collected, using an unmanned aerial vehicle (UAV, drone). Aerial imageries were gathered for 9 sites. For detailed report on the aerial surveys please refer to the annex.

4.4 Collection of habitat data

Hydraulic cross-section and bathymetric data collection

a) Bathymetry and Hydraulic data were collected at 2 of the sites (Figures 15, Figure 16, Figure 17) using a boat mounted ADCP.
b) Aerial imageries were gathered for 9 of 11 sites and along with aerial images, terrain profile of the rivers reaches along with adjacent floodplains were compiled using UAV. DEM and DSM have been developed using these UAV datasets (refer to annex).

Habitat mapping and MesoHABSIM data collection

a) Reconnaissance level data were collected at 7 of the 11 sites.
b) A sample of habitat data was collected for the Kosi River during the training exercise at the hotel site (Section 4.1).

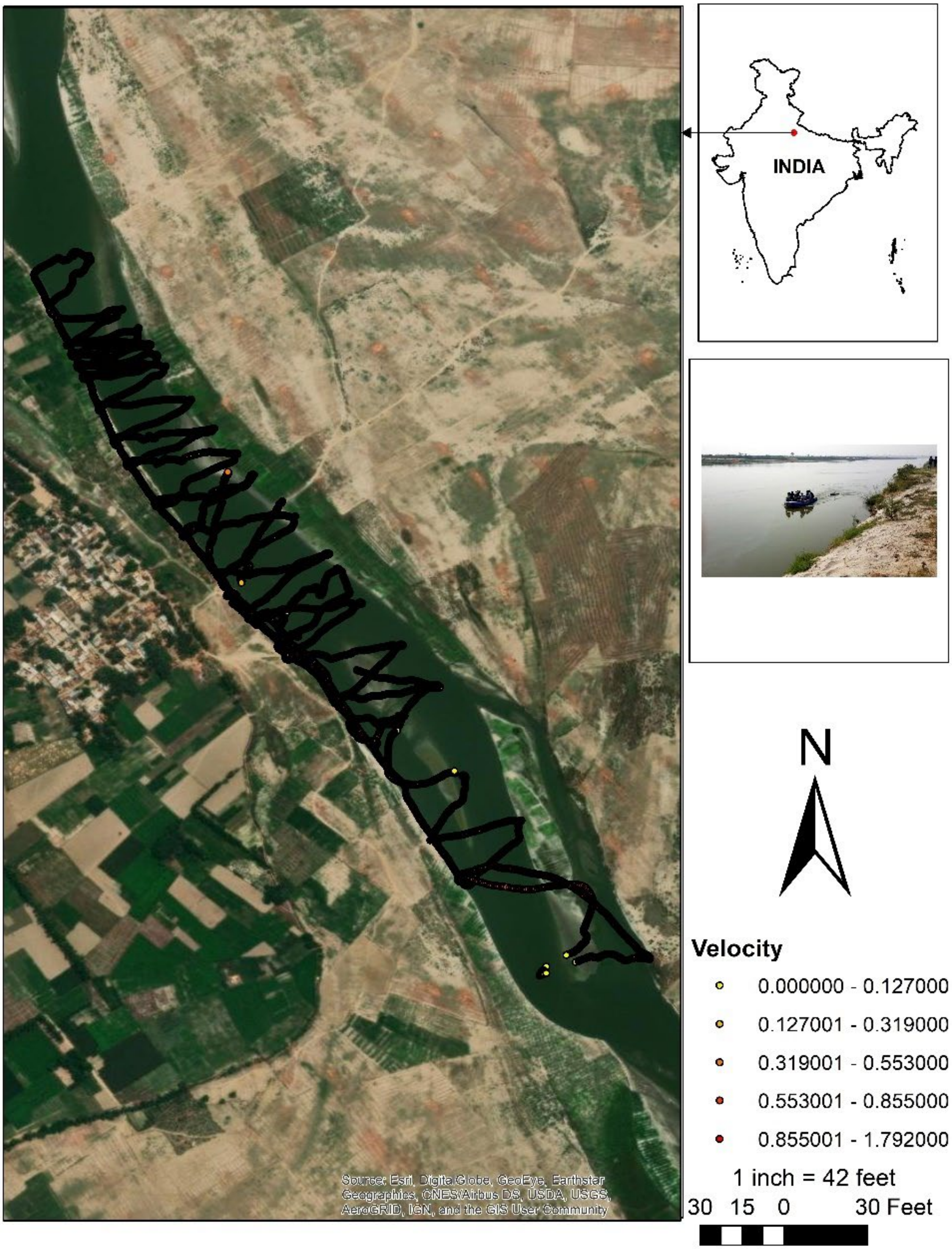


Figure 15. The ADCP velocity profile for Site (2): Ramganga River near Jalalabad.

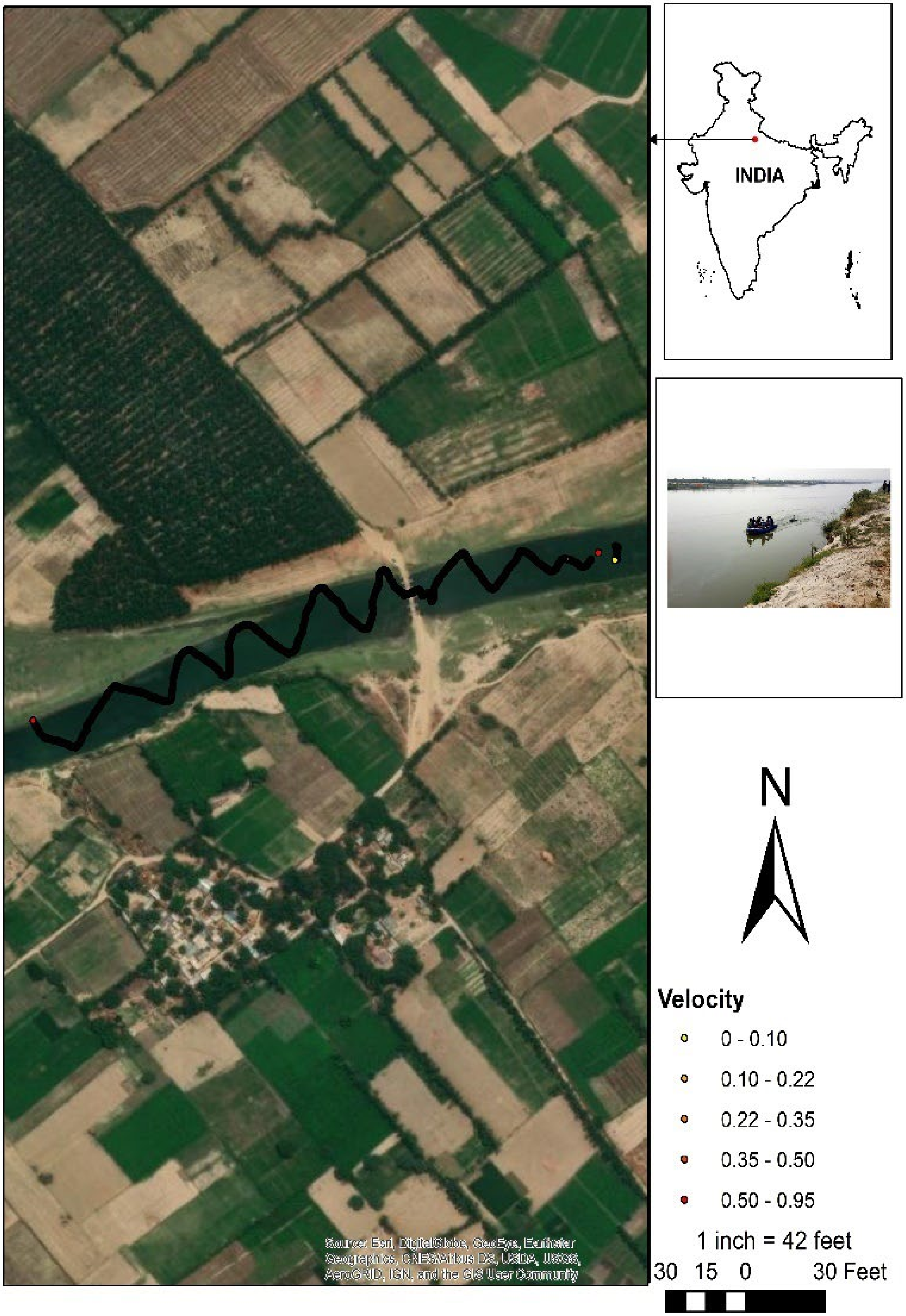


Figure 16. The ADCP velocity profile for Site (2): Baigul River near Jalalabad.

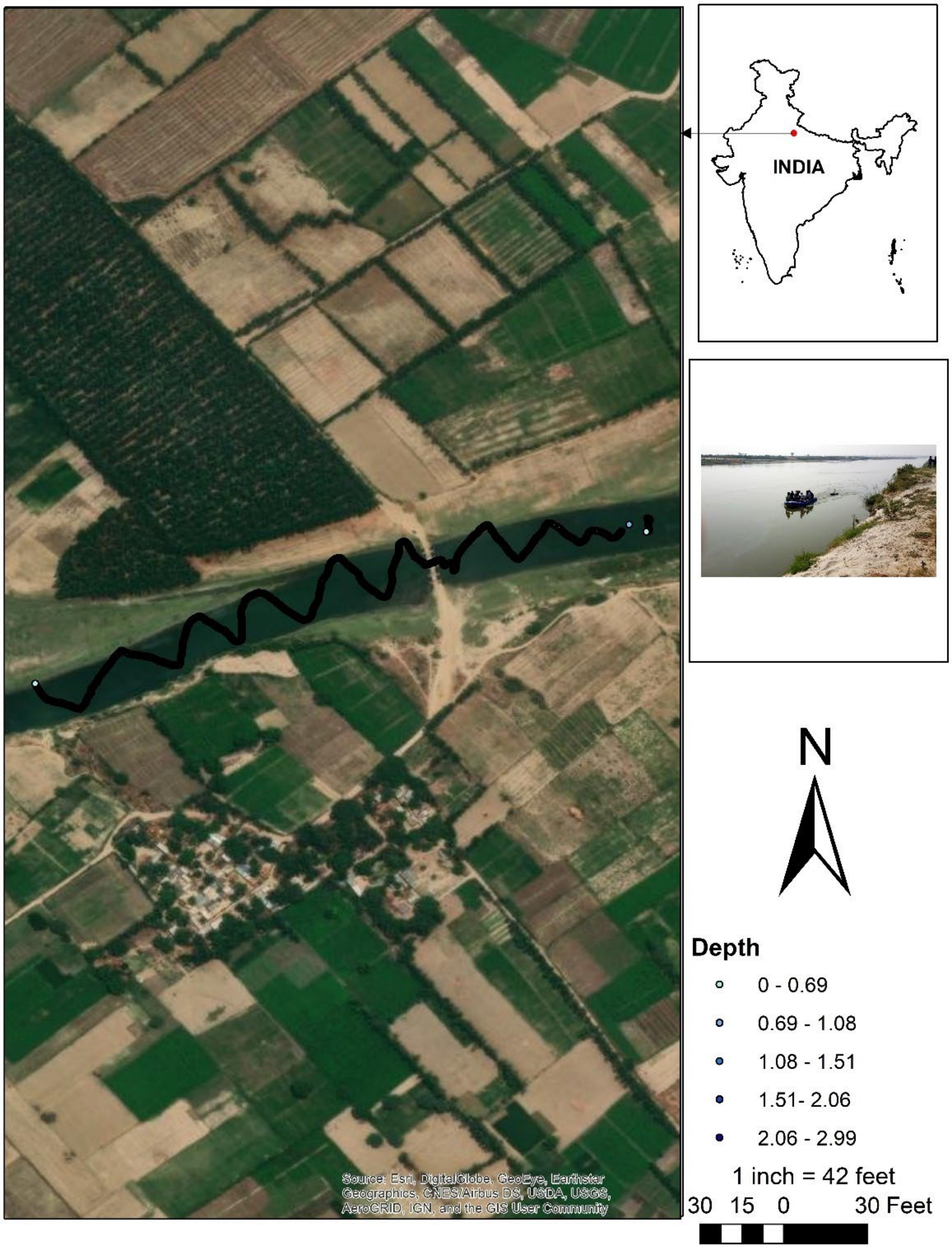


Figure 17. The ADCP depth profile for Site (2): Baigul River near Jalalabad.

4.5 River ecology and water quality

Ecological data were collected at all of the sites, including on fish assemblages and life cycles, macroinvertebrates, macrophytes, basic water chemistry, and point microhabitat conditions.

Example of data template for site description and general ecological data collection along with the results compiled at five sites are annexed.

5. Summary and conclusion for next steps

There was a concerted effort to undertake all of the preparatory desktop steps required in time, ahead of the first field mission, given the ambition of having a set of primary data collected for habitat modelling for all of the river reaches (field sites), before the onset of the monsoon season (late May to early June). The desktop nature of the initial characterization of the basin and the classification of different types of rivers representing possible E-Flow sites required ground-truthing of the reaches. It was decided that a drone technical survey be accordingly done ahead of time for each of the potential sites, to provide the base layer data for mapping. Additionally, field based, hands-on learning by doing technical training of partners was a parallel objective of the field visit.

1. The tight schedule in addition to the seasonal variations during the field days(harsh weather), as well as logistical constraints, meant that the achievement of all the mission objectives was highly ambitious.
2. Certain pre-selected sites were found to be unsuitable during the field visits and ground-truthing (e.g. Afzalgarh Site). Based on this, it is now foreseen that further desktop analysis will be required to identify alternate sites for the same river types prior to the next field mission.
3. An E-Flows data collection and assessment is most efficient when a fully multi-institutional, multidisciplinary E-Flows team is established and can work effectively as a cohesive unit. It is suggested that for further work, additional field officers (preferably from CWC/NMCG) with a specific technical interest in and with allocated time for field data collection, including habitat surveys joins the process. Additionally, the continuity of engagement of these nodal field officers will be of priority to minimize the risk of having any gaps in the data collection and in turn will ensure capacity building of these involved officers. Moreover, clarification of the kinds of resources available through NMCG, CWC and other multidisciplinary actors to support the future work of the E-Flows team will be helpful.
4. Some modelling data sets were collected, viz. reach ecohydrological characteristics, hydrology and aerial imagery. The training objective of learning-by-doing was only partially achieved as training of the habitat survey team needed to include a more structured and mentored pre-mission coaching effort, ending with an assessment of the level of preparedness for hands-on field data collection. However, a basic data collection training was conducted for the team.
5. It is suggested that the drone survey team carries out the survey mission in advance with further guidance from the team members and other team members are briefed on the drone survey results beforehand.
6. A more realistic timeframe for a consultative joint design of the second field programme, with the input of all e-flow team members, should be feasible - the second field survey will only be possible once the river is past the peak of the monsoon (flood) season.
7. The Ramganga Basin has multiple risks that will continue to need to be avoided and/or mitigated. Risk assessment and safety protocols will need to be explicitly built into the field programme. During the

field mission, for instance, there were a combination of unexpected and anticipated risks, including dangerous levels of heat exposure and dehydration, wildlife threats (elephants, tigers) that required the presence of armed rangers and affected the timing of access to certain sites, weather and equipment hazards, limited experience in working in aquatic environments for some of the wider group of participants, major travel distances, and delays due to problems with site access and permissions. An actual risk assessment for field work in the Ramganga Basin should be made before the second field visit. This will include the kinds of risks experienced in the field, from solar and heat exposure, physical hazards such as river currents, risk of drowning and flash flooding, to threats from wildlife and disease. A general informative field protocol/ brief regarding the possible risks and the safety measures will be available prior to field work will be done to ensure the E-Flows team's preparedness for all kinds of field risks that may be encountered during the data collection on the selected sites in the basin.

8. A clear assignment of roles and responsibilities, an assessment of the resources gap (what is needed vs. what is available) and guided training for data collection will ensure success of the next steps in the E-Flows assessment.
    - Planning meetings ahead of the second (post-monsoon) field mission, including a first discussion on the objectives, steps, resource needs, timeline and check-ins on progress will ensure this.
    - Wherever possible, the experiences from the first field visit will be incorporated to adapt and customize procedures for local data collection and analysis.

9. An additional time could be invested in future to engage with local stakeholders and understand their respective interests, as well as to explain to them the objectives of the work being done at the site.

Acknowledgements

The team gratefully acknowledge the field support provided by Forest Department rangers for sites in the upper basin. We also thank the field vehicle drivers for long distances safely travelled.

Annexure 1 - List of participants

No	Name	Organization
1	Amiya Sahoo	CIFRI
2	A K Chowdhary	CIFRI
3	S K Paul	CIFRI
4	Arghya Kunnui	CIFRI
5	J A Johnson	WII
6	Eliza Kh	WII
7	Bhavna Dhawan	WII
8	Mohit Mudliar	WII
9	Neeraj Bisht	Forest Dept UK
10	Tejpal	Forest Dept UK
11	Brajesh Srivastava	CPCB
12	Abad Alam	CWC
13	Surendra	CWC
14	Akshat Jain	CWC
15	Rebecca Tharme	Riverfutures, UK
16	Ashish Singh Kushwah	CWC
17	Alok Srivastava	NMCG
18	Harish Kumar Mahavar	NMCG
19	Piotr Parasiewicz	Rushing Rivers, Poland
20	Shubham Wagh	Inland Fisheries Institute, Poland
21	Avnish Gangwar	CWC
22	Anuj Sharma	CWC
23	Saurabh Kapasiya	CWC
24	Jyoti Nale	GIZ
25	Chhavi Sharda	GIZ

Annexure 2 – Training Concept and Agenda

Concept

Interactive Trainings on Environmental Flows Assessments

under the India-EU Water Partnership Action-Phase 2

The assessment of Environmental Flows (E-Flows) is a highly interdisciplinary process that requires direct and indirect contributions from basin stakeholders from various backgrounds, including water and natural resource planners and managers, ecologists, hydrologists, geomorphologists and other technical specialists, and other local knowledge holders. In the previous phase of the India-EU Water Partnership (IEWP) Action, E-Flows assessments were carried out by an interdisciplinary team of Indian and EU experts to evaluate the performance of various methodologies in three river pilots representing different hydro-climatological regions in India. An IEWP Guidance Document (Nale et al. 2020) was developed to support the advancement of the E-Flows assessment methodologies in India towards EU and international good practices. The IEWP Guidance Document also provides an overview of the current status of the India approach for E-Flows, as well as the requirements in terms of data, knowledge and expertise to improve E-Flows assessments locally.

In the current Phase 2 of the IEWP Action, an additional E-Flows assessment will be undertaken for the Ramganga River system, making use of the IEWP E-Flows Guidance Document, to strengthen and advance E-Flows recommendations and the methods of assessment. The work is closely linked to the *Support to Ganga Rejuvenation II* (SGR II) *Project* under the Indo-German Development Cooperation. As part of this project, a comprehensive stakeholder consultation process will take place, with the ultimate aim of identifying three measures to ensure adequate E-Flows are implemented in the Ramganga River Basin.

In addition, and to directly support the above activities, the IEWP Action will organise hands-on training activities on various aspects of E-Flows assessment. Trainings will be organised by the IEWP Action/GIZ Project Team, together with the National Mission for Clean Ganga (NMCG), the Central Water Commission (CWC), the National Water Academy (NWA), the SGR II Project and other stakeholders involved in E-Flows assessment in India. The experts from the EU, CWC, NMCG, Central Inland Fisheries Research Institute (ICAR-CIFRI), Wildlife Institute of India (WII) and the IEWP Action/GIZ Project Team will be responsible for carrying out the trainings. As a training and capacity building agency, NWA will host the trainings.

The E-Flows training plan comprises the following three Parts:

Part 1: Introduction on E-Flows Assessment in India and the EU (held 05 – 07 April 2022)

Part 2: Hands-on interdisciplinary training on field assessment and data collection for assessing E-Flows in the Ramganga Basin (being held during 16-19 May 2022)

Part 3: E-Flows assessments with different methods, analyses, results and further incorporation of E-Flows in river basin planning and management (schedule to be discussed).

The draft programme for Part 2 of the trainings is attached as follows.

Programme

Part 2: Hands-on interdisciplinary training on field assessment and data collection

16 – 19 May 2022, in Ramganga River Basin (Bareilly and Ramnagar)

In this part of the training, participants will be introduced to the hands-on field activities for field data collection for an interdisciplinary E-Flows Assessment, including: site selection; methods, tools and equipment for a multidisciplinary field survey (e.g. hydrology, hydraulic habitat, fish ecology); data collection steps; and the integration of knowledge across disciplines.- Both wadeable shallow water reaches and boatable deep water reaches of the river mainstem and tributaries will be surveyed, from mountain/foothill zones to plains/floodplain zones, covering a wide range of biophysical characteristic of many Indian river systems and the methodological conditions.

A preparatory meeting between the field data collection experts and the trainee participants will be arranged on 12 May/ 13 May 2022. In this meeting, the participants will be briefed about the outline and structure of field activities.

Date	Time (IST)	Topic	Expert
Travel and recce of boatable and wadeable river sites in plains			
16/05/2022	08.00- 14.00	**Travel to Jalalabad with on the way stopovers at river and catchment viewpoints**	
	15.00- 19.00	**Visit to deep and shallow water sites** **Site Recce, outline of the data collection plan for the site** • Identification of the survey reach, general features and habitat types • Identification of locations for ecohydrological sampling • Identification of types of substrate and cover conditions • Demonstration on use of ADCP and outline of the parameters to be measured	Piotr Parasiewicz Rushing Rivers Institute, Poland Rebecca Tharme, Riverfutures Jyoti Nale, IEWP/GIZ A.K. Sahoo, ICAR-CIFRI J. A. Johnson, WII

Date	Time (IST)	Topic	Expert
		• Introduction to tools/Equipments and methods for data collection in wadeable rivers • Discussion on morphological features of ecological importance • Characteristics of adjacent floodplain, and local resource users in this part of the basin, and implications for the ecology and E-flows • Interaction with local community, fishing/agriculture, water managers etc	Michael McClain, IHE Delft
Data collection at both sites at Jalalabad			
17/05/2022	07.00-13.00	**Data Collection and compilation**	
		River physical profile (topographical points), discharges, velocities, depths, habitat mapping Demonstration on software use for data collection Discussion on the range of observations at various locations in the river	Piotr Parasiewicz Rushing Rivers Institute, Poland Jyoti Nale, IEWP Action/GIZ
		Ecological Sampling Demonstration of observed fish, macroinvertebrates, plankton etc., and their habitat preferences	A.K. Sahoo, ICAR-CIFRI J. A. Johnson, WII Rebecca Tharme, Riverfutures Michael McClain, IHE Delft
	13.00-19.00	Travel to mountain site (stay at Ramnagar)	
Recce and data collection in wadeable river site in mountain range			
18/05/22	07.00-12.00	Recce and data collection at the mountain site 1 with guided hands-on experiences on above points	As above
	12.00-14.00	Travel to mountain site 2	
	14.00-17.00	Recce and data collection at the mountain site 2 with guided hands-on experiences on above points	
	17.00-18.00	Travel back to stay in Ramnagar	
Recce and data collection in wadeable river site in Terai region			
19/05/22	07.00-13.00	Recce and data collection at the site near Rudrapur with guided hands-on experiences on above points	As above
	13.00-20.00	Return journey	

Annexure 3 –Ecological and other data collection by CIFRI

Study area

The field visit was carried out during May 16-19th, 2022 to record fish fauna, and ecological diversity in the Ramganga River Basin. During the period, five sampling sites were selected as shown in Table 1. Sites covered about 400 km. long stretch of river Ramganga. The positional coordinates ranged from N 28° 22.648' E 079° 19.400' to N 29° 28.831', E 079° 08.959' at an elevation between 125 to 561 m. above msl (Table 1).

Table 1: State wise distribution of sampling stations in river Ramganga

Station	River	State	Coordinates	Elevation (m. above msl)
Site-I (Bareilly)	Ramganga	Uttar Pradesh	N 28° 22.648' E 079° 19.400'	146
Site-II (Jalalabad)	Ramganga	Uttar Pradesh	N 27° 41.714' E 079° 34.633'	125
Site-III (Jalalabad)	Baigul	Uttar Pradesh	N 27° 43.427' E 079° 36.526'	134
Site-IV (Marchula)	Ramganga	Uttarakhand	N 29° 36.381' E 079° 05.737'	561
Site-V (Ramnagar)	Kosi	Uttarakhand	N 29° 28.831' E 079° 08.959'	411

River Ramganga

The Ramganga River originates from the river "Diwali Khal" located in Gairsain tehsil at 30°05′00″N 79°18′00″E in the southern slopes of Dudhatauli Hill in Chamoli district of the Indian state of Uttarakhand. The river enters the Almora district of Kumaon via town of Gairsen. Emerging from there, it turns southwest and receives the Tadagatal River, wandering widely around the southeastern boundary of Lohabagarhi. During its course the river passes through Ganai where it receives the Khargad and Khetasargad rivers. Coming out of Ganai, it flows towards the Talla Giwar region, where there is an open valley with alluvial land along and around the river, which is extensively cultivated and irrigated by the waters of the river. After passes through hilly region the river Ramganga receives numerous streams and ultimately enters into the plain at Kalagarh in Bijnor district of Uttar Pradesh where a dam has been constructed on the river for the purpose of irrigation and hydroelectric production. About 15 miles from here it is joined by the Khoh, after which it enters the Moradabad district, where on the alluvial lowlands it flows in a southeastern direction with a very rapid flow, and forms the boundary between Thakurdwara and Kanth tehsils. The Ramganga receives several tributaries in Moradabad, almost all on its left bank, most of which are Tarai streams flowing towards south or south-west.

The Ramganga flows through the Bareilly district mainly in the southeastern direction. It receives the combined stream of Bhakra and Kichha (also called Baigul) from its left and the Gagan River from its right, after which it reaches near Bareilly city, which is located at a distance of about 10 km on its left side. Here it receives the Deoranian and Nakatiya rivers from its left – both rivers flow through Bareilly Flowing further through Badaun and Shahjahanpur and Hardoi districts, it finally outfall in the Ganga river at village Katri Chandapur in the Hardoi district of U.P., after covering a total distance of about 600 km.

Fish Diversity:

Sampling methodology:

Sampling for fish was done from the main channel as well as the adjacent areas such as backwater, secondary channel etc. Fish were collected from the river using cast nets and gill nets of assorted mesh sizes from all possible habitat niches along the sampling sites assuming that the existing species and their abundance would be reflected in the sample. The fish samples were collected mainly through experimental fishing within a stretch of 2 km. A sampling effort of 2 hours for the gill net and cast net was carried out. Further, the abundance of species indicative in the observations is the total number of fishes of the individual species collected. Fish catch data and samples were also collected from fish landing stations from all the sampling sites. Representative specimens (n=10) of all fish species were identified and preserved in 10% formalin and brought to the laboratory for analysis.

The identification of the fish specimen from various sites of river Ramganga was conducted using the keys per Francis Day (1889), Mishra (1962), Talwar and Jhingran (1991), Jayaram (1981 & 2006), Nath and Dey (2000).

Results

A total of 193 individual fish samples were recorded from all the selected locations at Site I, Site II and III,. Fish sample were also collected from Marchula and Ramnagar of Uttarakhand state which are in hilly terrain. The fishes belong to 5 orders, 6 families, 16 genera, and 21 species (Table. 2). Cyprinid was the dominant group (66.66%) followed by Ambassidae (9.52%), Bagridae (9.52%), Channidae (4.76%), Cobitidae (4.76%) and Belonidae (4.76%) respectively. *Cirrhinus reba* (Relative Abundance (RA) 12.95%) was the dominant species followed by *Puntius sophore* (RA 9.32%) in site-I, *Salmophasia bacaila* (RA 7.77%), *Barilius bendelisis* (RA 7.25%) recorded from site II and IV respectively. Maximum species occurrence (n=10) was recorded from Site-I followed by site-II and III (n=7) (Table 3.). Cyprinidae was the dominant group in all the sampling sites at (site-I, 42.85%), (site-II, 19.04%), (site-III, 14.28%), Marchula (site-IV, 19.04%) and Ramnagar (site-V, 9.52%). The maximum occurrence of individual fishes (n=95) was recorded from site-I followed by site-II (n=35), site-IV (n=32), site-III (n=21) and site-V (n= 10) respectively. Significantly 52.38 % of species are considered as important food fishes and 33.33% fish species are categorized as indigenous potential ornamental fishes. This shows the potential economic value added to the socio-economic status of the region by the fish composition.

Sperata aor, S. seenghala, C. reba, S. bacaila, Puntius sophore, X. cancila and *C. punctatus* were the most important species recorded from site-I,II and II of river Ramganga which is flowing in low elevation. Significantly the spectrum of fish diversity varied according to elevation and habitat structure. In the stretch at Marchula the most dominant species found were *Tor putirora, Labeo dyocheilus, Garra gotyla, Barilus bendelisis* which are predominantly cold water fish species. Similarly, in Ramnagar stretch the important species found were *B. bendelisis* and *Garra gotyla.*

The overall fish catch composition as obtained from the present study is categorized into six major groups (Table 2). The carps included major and minor; the catfishes included large and small catfishes, miscellaneous which included fish species of lesser economic importance, and lastly the exotics. Significantly, the only exotic species *Cyprinus carpio* (n=10) was recorded from site- I, II and

III. It is established that the invasion of alien species into natural water bodies is a serious concern for native fish species.

Less abundant fish species:

Quantitatively less abundant species in the low elevation zone of river Ramganga were as follows: *Labeo catla, Cirrhinus mrigala, Puntius ticto, Rasbora daniconius, Corica soborna, Ompok bimaculatus, Bagarius bagarius, Mystus bleekeri, Notopterus notopterus, Channa marulius, Colisa fasciatus, Heteropneustes fossilis, Macrognathus pancalus, Bagarius yarrellii, Wallago attu, Gonialosa manmina.*Similarly, in hilly terrain fish species like *Bengana dero, Barilius vagra, Botia almorhae, Schistura rupecula, Glyptothorax plectinopterus, Pseudecheneis sucatus, Schizothorax* sp.were not encountered during the sampling period.

Remarks:

In the stretches of river Ramganga at lower stretches (site-I,II & III), the most important species contributing to the fishery were *C. reba, Chanda nama, S. bacaila, Puntius sophore.* The dominant species in higher elevation of river Ramganga were *Tor putitora, Garra gotyla, Labeo dyocheilus, Barilius bendelisis.* Less abundance of fish diversity was recoded with the increase of elevation.

Table 2. Fish species representation identified from river Ramganga during sampling

Sl. No.	Fish species	Family	Cons. Status (IUCN)	Commercial importance	Sampling sites				
					Site-I (RA %)	Site-II (RA %)	Site-III (RA %)	Site-IV (RA %)	Site-V (RA %)
1	*Aspidoparia jaya*	Cyprinidae	LC	OFD	5 (2.59%)	0	0	0	0
2	*Aspidoparia morar*	Cyprinidae	LC	OFD	10 (5.18%)	6 (3.1%)	0	0	0
3	*Barilius bendelisis*	Cyprinidae	LC	OR	0	0	0	14 (7.25%)	7 (3.62%)
4	*Chanda nama*	Ambassidae	LC	OR	0	0	5 (2.59%)	0	0
5	*Channa punctatus*	Channidae	LC	OFD	0	4 (2.07%)	2 (1.03%)	0	0
6	*Cirrhinus mrigala*	Cyprinidae	LC	F	0	1 (0.51%)	0	0	0
7	*Cirrhinus reba*	Cyprinidae	LC	OFD	25 (12.95%)	0	0	0	0
8	*Crossocheilus latius*	Cyprinidae	LC	FG	5 (2.59%)	0	0	0	0
9	*Cyprinus carpio*	Cyprinidae	VU	F	7 (3.62%)	2 (1.03%)	1 (0.51%)	0	0
10	*Garra gotyla*	Cyprinidae	LC	OR	0	0	0	7 (3.62%)	3 (1.55%)
11	*Labeo dyocheilus*	Cyprinidae	LC	F	0	0	0	6 (3.1%)	0
12	*Lepidocephalus guntea*	Cobitidae	LC	OR	0	0	0	0	0
13	*Parambassis ranga*	Ambassidae	LC	OR	0	5 (2.59%)	3 (1.55%)	0	0
14	*Puntius conchonius*	Cyprinidae	LC	OR	7 (3.62%)	0	4 (2.07)	0	0
15	*Puntius sophore*	Cyprinidae	LC	OR	18 (9.32%)	0	0	0	0
16	*Puntius ticto*	Cyprinidae	LC	OR	4 (2.07%)	0	0	0	0
17	*Salmophasia bacaila*	Cyprinidae	LC	OFD	3 (1.55%)	15 (7.77%)	2 (1.03%)	0	0
18	*Sperata aor*	Bagridae	LC	F	11 (5.69%)	0	0	0	0
19	*Sperata seenghala*	Bagridae	LC	F	0	2 (1.03%)	0	0	0
20	*Tor putitora*	Cyprinidae	EN	F	0	0	0	5 (2.59%)	0
21	*Xenentodon cancila*	Belonidae	LC	FG	0	0	4 (2.07%)	0	0

LC= Least Concern; VU= Vulnerable; EN= Endangered;
OFD= Other food fish; F= Food fish; OR= Ornamental fish; FG= Forage fish, RA = Relative Abundance
Site-I (**Roop pur ghat, Bareily, U.P.), Site-II (Paharpur, Sahajanpur, U.P.), Site-III (Nangla kishan, U.P.), Site-IV (Morchula (U.K.), Site-V (Ramnagar (U.K).**

Table 3. Occurrence of fish species identified from different stretches of river Ramganga and its tributaries

Sl. No.	Fish species	Family	Site-I	Site-II	Site-III	Site-IV	Site-V
1	*Aspidoparia jaya*	Cyprinidae	+	-	-	-	-
2	*Aspidoparia morar*	Cyprinidae	+	+	-	-	-
3	*Barilius bendelisis*	Cyprinidae	-	-	-	+	+
4	*Chanda nama*	Ambassidae	-	-	+	-	-
5	*Channa punctatus*	Channidae	-	+	+	-	-
6	*Cirrhinus mrigala*	Cyprinidae	-	+	-	-	-
7	*Cirrhinus reba*	Cyprinidae	+	-	-	-	-
8	*Crossocheilus latius*	Cyprinidae	+	-	-	-	-
9	*Cyprinus carpio*	Cyprinidae	+	+	+	-	-
10	*Garra gotyla*	Cyprinidae	-	-	-	+	+
11	*Labeo dyocheilus*	Cyprinidae	-	-	-	+	-
12	*Lepidocephalus guntea*	Cobitidae	-	-	-	-	-
13	*Parambassis ranga*	Ambassidae	-	+	+	-	-
14	*Puntius conchonius*	Cyprinidae	+	-	+	-	-
15	*Puntius sophore*	Cyprinidae	+	-	-	-	-
16	*Puntius ticto*	Cyprinidae	+	-	-	-	-
17	*Salmophasia bacaila*	Cyprinidae	+	+	+	-	-
18	*Sperata aor*	Bagridae	+	-	-	-	-
19	*Sperata seenghala*	Bagridae	-	+	-	-	-
20	*Tor putitora*	Cyprinidae	-	-	-	+	-
21	*Xenentodon cancila*	Belonidae	-	-	+	-	-

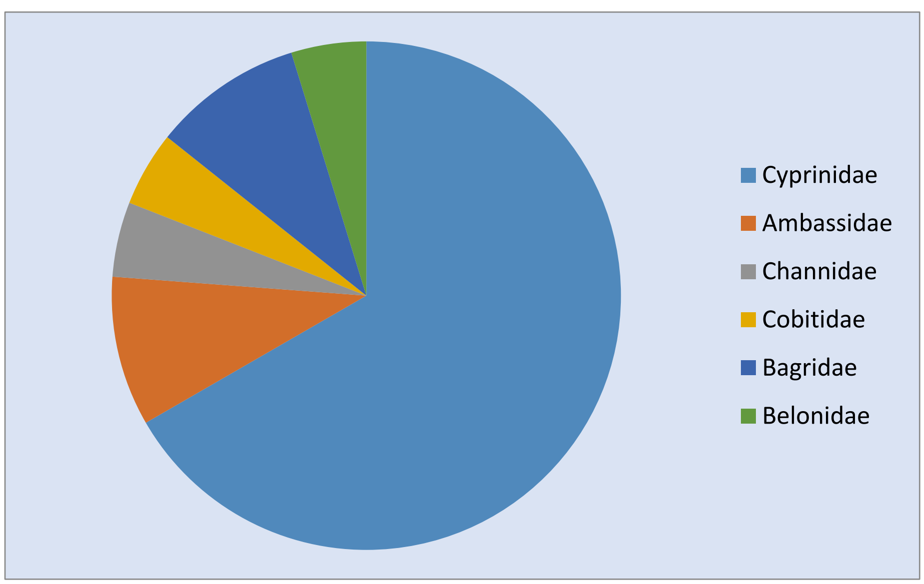


Fig. 1. Graphical representation of distribution of families

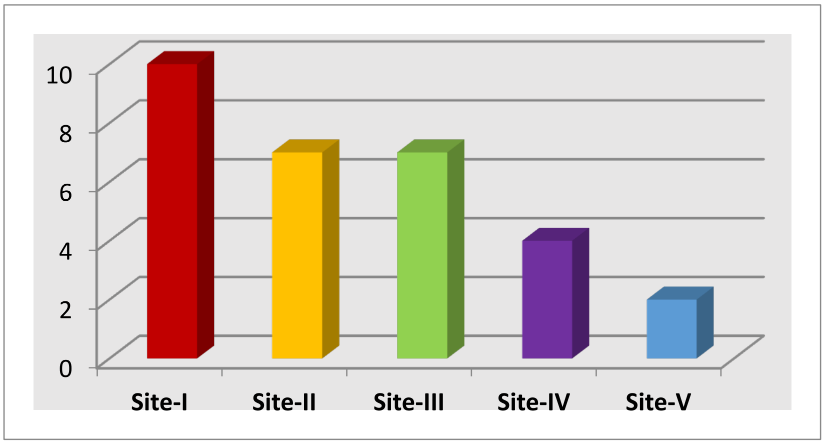


Fig. 2 Occurrence of fish diversity in sampling sites

Habitat profile of river Ramganga at Bareilly, Jalalabad, Ramnagar and Marchula.

Aquatic habitat plays a significant role in the successful colonization of fishes and other aquatic organisms. It is well established that water alone will not ensure the survival of fish. Fishes need an ideal and suitable aquatic habitat for their growth, breeding, migration, etc. In general, freshwater can be categorized into lentic (standing) and lotic (flowing) water habitats. Habitat diversity can vary tremendously within these two broad categories and few fish taxa can be found in both the habitat. The habitat factors that influenced fishes to complete their lifecycle are substrate type, deep pools, riparian vegetation, water depth, water flow, the width of the wetted channel, flood plains, etc. Some indigenous fishes also have to move between different habitats as they mature and breed. Different fish species have different habitat requirements and these may change as they grow older.

Methodology

The habitat factors that influenced fishes to complete their lifecycle are substrate type, deep pools, scur pools, riparian vegetation, water depth, water flow, width of wetted channel, flood plains etc. Hill stream ecosystem includes a variety of bed rock habitats with sand, cobbles, gravels, boulders etc. Bed materials have a major influence on the type of organism found in the stream. Boulders (More than 25 cm. across) are defined as rock occupies moderate space around their bases within which insects and indigenous fish can live. Similarly cobbles (12-25cm.), gravels (up to 6 cm.) provide a good ecological habitat to hill stream life as they together provide ideal hiding space for invertebrates and native fishes.

In the present investigation habitat profile of each site recorded based on types of bedrocks, riparian vegetations, deep pools, refill, etc. water velocity of the stream was measured using a flow meter. However, average depth and deep pools were measured using echo sounder at the shoreline and mid-channel. Agriculture practices on the river banks were recorded based on interaction with local people and observations at sampling site. The width of the river channel was measured using survey tape (m).

Results

Habitat profile of each sampling site of river Ramganga has been portrayed (Table.4) and data was recorded in printed proforma prepared for this purpose. Some significant habitat variations were recorded in each sampling sites. The mean depth of the studied stretches varied from 0.8 to 1.2 m. Depth was recorded from the shoreline (L and R banks) and mid-channel. The substrate type was dominated by sandy clay and sandy in low elevation zone and boulders and pebbles, gravels in hilly terrain which are considered to be ideal habitats for the river ecosystem (Fig. 3). Water velocity recorded ranged from 0.08 to 0.75 m/sec. which is acceptable for freshwater rivers. Comparatively higher water velocity (0.70-0.75 m/sec) was observed in the hilly region and this velocity range is acceptable for the fish diversity in hilly region. Deep pools were recorded in all the sampling sites except site-III which are significant for aquatic fauna for their shelter and breeding ground, especially in the lean period. Agriculture practices were observed in catchment and island areas in the sampling sites of I to III which are a serious concern as the pesticides used for agriculture practice may be deposited into the river through runoff. Good riparian vegetation on the catchment area and riverbanks is considered to be an important part of the river habitat.

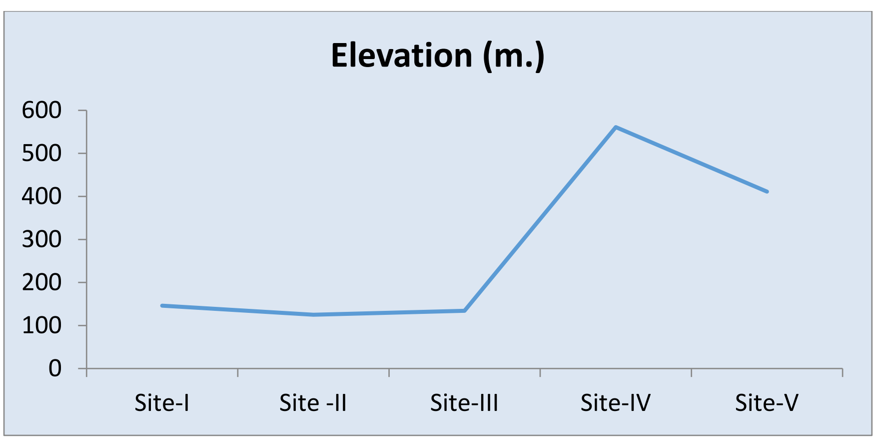


Fig. 3 Diagrammatic representation showing habitat variation at different elevation of sampling sites

Table. 4 Habitat profile of river Ramganga at Bareily, Sahajanpur, Morchula and Ramnagar

Parameters	Sampling sites				
	Site-I (U.P)	Site-II (U.P.)	Site-III (U.P.)	Site-IV (U.K.)	Site-V (U.K.)
Width of wetted channel (m.)	300	200	70	70	70
Width of the bank to bank of the river (m.)	900	800	110	150	90
Av. Depth (m.)	1.2	1.1	0.9	1.13	0.8
Deep pools	Present (2 nos. Av. Depth 5.6 m.) *	present	Not recorded	1 no. recorded av. depth 5.4 m.	Present
Scour pools	Not recorded	Present	present	present	Present
Substrate type	Sandy clay (Sand-65%, clay- and others- 35%)	Sand-75%, clay-20%, others-5%	Sandy clay (Sand-65%, clay and others 35%)	Dominated by boulders-55%, gravels-20%, pebbles-15%, course sand and others-10%	Dominated by boulders-45%, gravels-20%, pebbles-15%, course sand and others-20%
Refill	Not recorded	Not recorded	Not recorded	Recorded	Present
Elevation (m.)	146	125	134	561	411
Riparian vegetation	Trees (30%) & shrubs (45%), and grazing land (25%)	Trees (35%) & shrubs (20%), grazing land and rural house (45%)	Trees (25%) & shrubs (20%), grazing land and residential house (55%)	Dominated by trees 35%, shrubs and herbs 65% grown on hilly terrain.	Dominated by trees 30%, shrubs and herbs 70% grown on hilly terrain.
Water velocity (m/sec.)	0.04	0.06	0.08	0.70	0.75
In-stream cover	Present in the form of small ditches	Not recorded	Not found	Present	Present
Meandering nature	Meandered	Meandered	Recorded	Slight meandered	Recorded
Source of pollution	Funeral and ritual activities observed	Domestic sewage discharge point identified.	Discharge of domestic sewages.	Not observed	Not observed
Agriculture practices	Visualized in the riparian zone	Observed in the riparian zone	Recorded in riparian zone	Not observed	Not observed
Other observations	Heavy erosion of soil in the riverbank observed, Agriculture practices observed in riparian zone.	Soil erosion was observed	Floating bridge constructed across the river		Resort, hotels and business shop constructed on the river banks.

* As per fishermen's perception

Water quality at different sampling sites

The water sample was collected across the river as well as from the two banks and also from the sub-surface layer of the middle of the river to obtain composite water from each center. Water quality parameters were measured within 2 km. of the fishing sites.

Results:

In the present study as is evident from table 4, in general terms water quality of river Ramganga at all the sites (site I-V) were alkaline in nature as the observed pH value ranged from 7.9 – 8.95 which is suitable for fish survival (Fig. 4). The concentration of dissolved oxygen (DO) varied from 2.8 to 6.8 ppm which is moderately acceptable for fish survival (Fig. 4). The site-III is having comparatively lower DO (2.8 ppm) value in comparison to other sampling sites, however, the maximum value of DO (6.8 ppm) was recorded from site-V which is located at mountain terrain. Conductivity ranged between 146.3 to 320 µs/cm showing significant variation among the sampling sites. The higher conductivity value in the stretch signifies the increased pollution as well as organic load in the riverine system. In the present study comparatively higher conductivity value (318 to 344 µs/cm) recorded from lower stretches of river Ramganga located in lower elevation (site I – III). Similarly, other parameters like salinity (0.15 to 0.17 ppt), TDS (87.6 to 246 ppm), total alkalinity (101.6 to 178 ppm) and total hardness (90 to 188 ppm) showed downstream variation among the sampling sites except salinity which showed not significant variation. Water temperature showed downstream variation and is probably a major environmental factor influencing the distribution of fish communities in the river as indicated in the observation, the temperature ranged from 23.4 – 33.8 °C (Fig. 5). Mean depth ranged between 0.8 to 1.2 m. which is not considered to be favorable for aquatic life. Similarly, mean water velocity ranges from 0.004 to 0.75 cm/sec recorded from sampling sites.

Table.5 **Physico-Chemical Parameters of Water Quality**

Parameters	**S-I**	**S-II**	**S-III**	**S-IV**	**S-V**
Air Temp. (°C)	42.6	35.9	41.2	34.3	29.6
Water Temp. (°C)	33.8	29.8	33.9	26.2	23.4
pH	8.95	7.9	8.27	8.1	7.93
DO (ppm)	6	3.2	2.8	6.8	5.2
Conductivity (µs/cm.)	320	344	318	168.9	146.3
TDS (ppm)	227	244	226	108	87.6
Salinity (ppt)	0.16	0.17	0.16	0.08	0.05
Total Alkalinity (ppm)	178	160	169.6	101.6	106
Total Hardness (ppm)	188	168	150	90	132

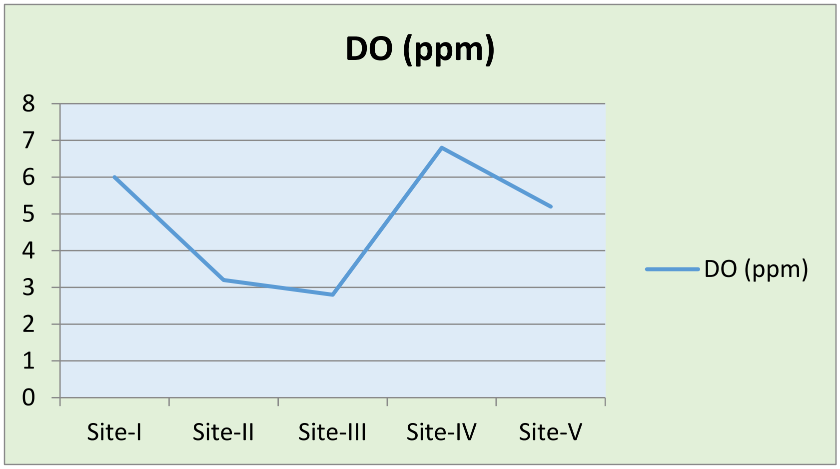


Fig. 4 Graphical representation of Dissolved Oxygen (DO) level at sampling sites

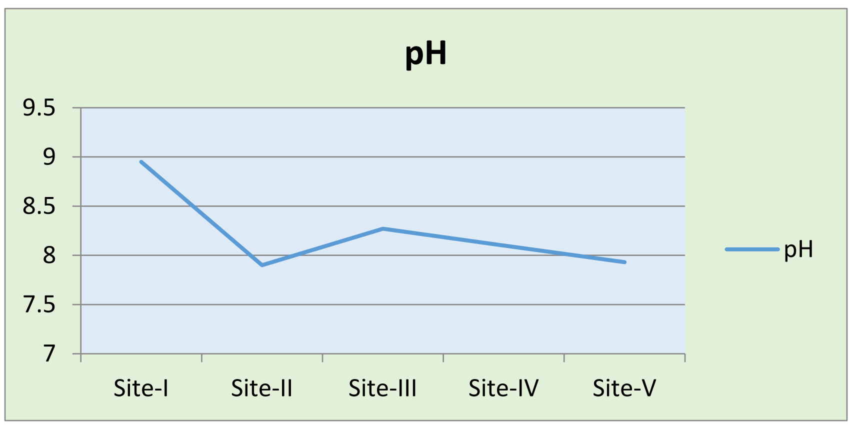


Fig. 5 Graphical representation of pH level at sampling sites

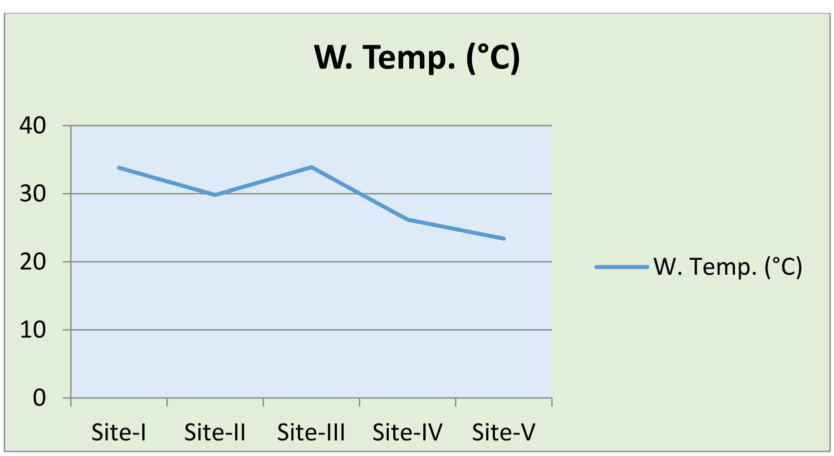


Fig. 6 Water temperature in different sampling sites of river Ramganga

Plankton diversity

Site-II exhibits most abundance. Total plankton diversity, Site-II (268 unit/l)>Site-I (173.6 unit/l)> Site-IV (146.4 unit/l) (Fig. 7). In the lower stretches of Ramganga river which denote as a Site-I (Ruppur) & Site-II (Paharpur). In Site-I, Trebouxiophyceae (66.4 unit/l) was most dominating group among the all eight class followed by Bacillariophyceae (48 unit/l) and Cyanophyceae (30.4 unit/l). In site-II Chlorophyceae (186.4 unit/l) was the most dominant group followed by Bacillariophyceae (24 unit/l). In case of upper stretch of Ram ganga river in Site-IV Bacillariophyceae (62.4 unit/l) exhibits highest abundance followed by Chlorophyceae (34.4 unit/l). Among the three sites of Ramganga river Chlorophyceae was found maximum (237.6 unit/l) followed by Bacillariophyceae (134.4 unit/l), Trebouxiophyceae (92.8 unit/l) and Cyanophyceae (58.4 unit/l) (Fig. 8).

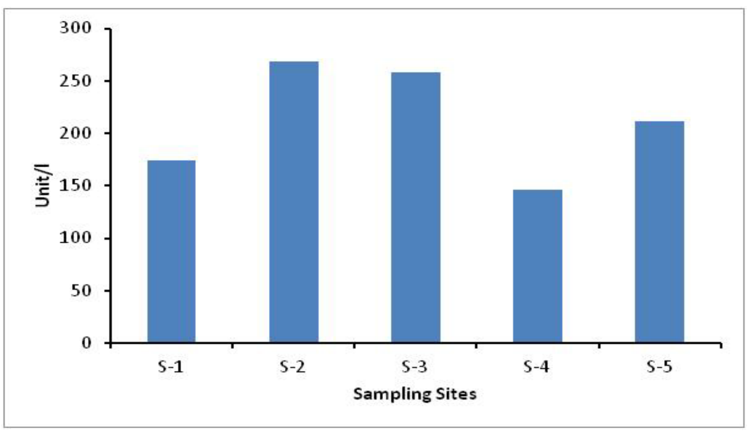


Fig. 7: Graphical represntation of Total Plankton (unit/lt) in different sites

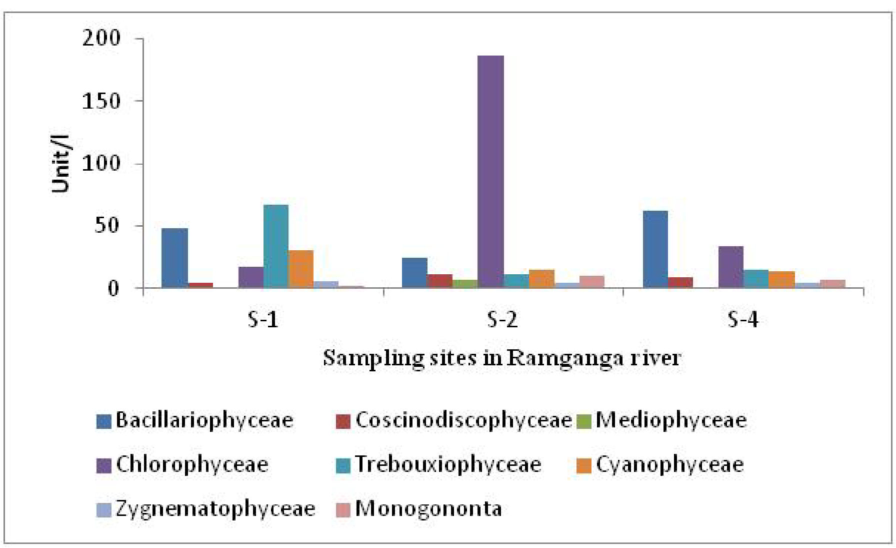


Fig. 8: Graphical represntation of Total Plankton (unit/lt) in Ramganga river

In terms of plankton Baigul (Site III) shows more abundance (258.4 unit/l) than Kosi (211.4 unit/l) River (Site V). Chlorophyceae (96.8 unit/l) is the most abundant group followed by Bacillariophyceae (58.4 unit/l) and Trebouxiophyceae (51.2 unit/l) in Baigul river. In Kosi river Bacillariophyceae (85 unit/l) was the most dominating group followed by Chlorophyceae (53.6 unit/l)and Trebouxiophyceae (27.2 unit/l) (Fig. 9). Photographs of the most abundant plankton is presented i

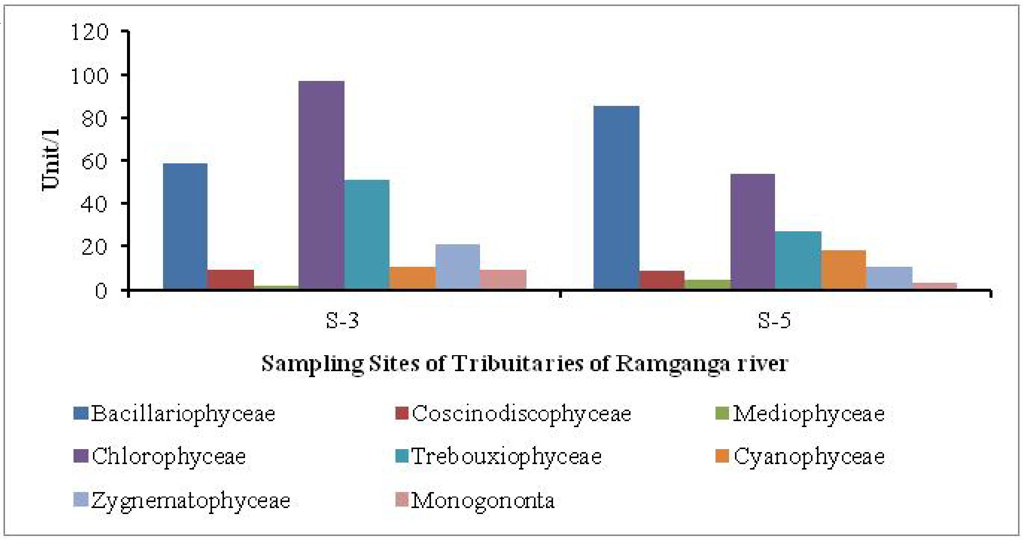
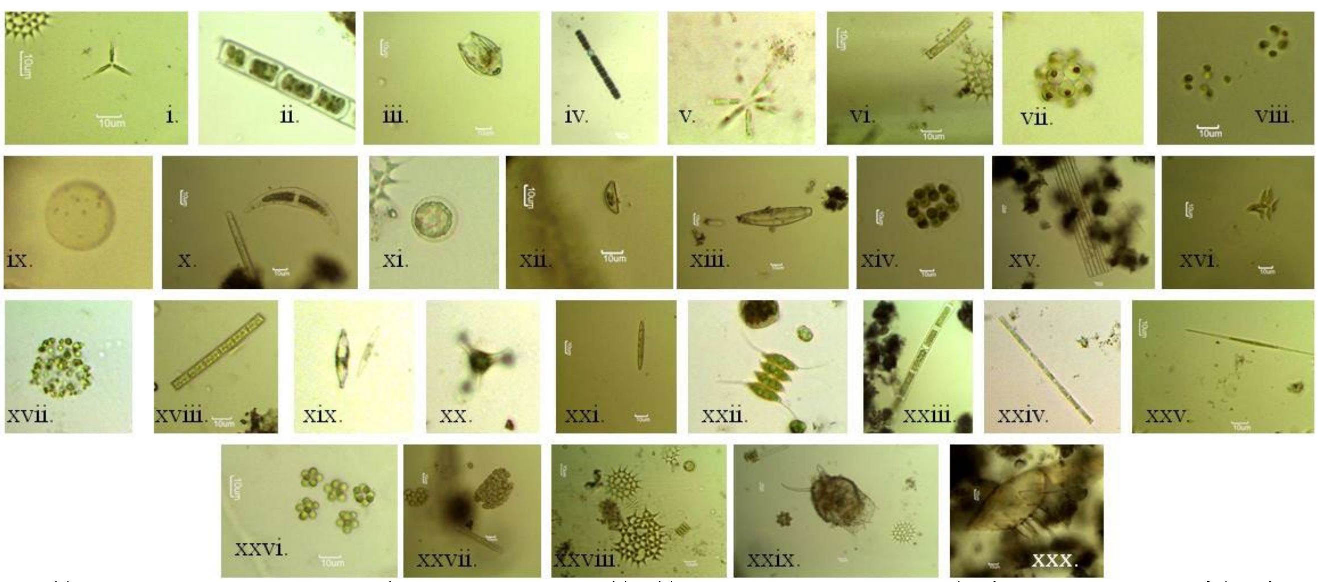


Fig. 9: Graphical represntation of Total Plankton (unit/lt) in two tribuitaries of Ramganga River



Aulacoseria sp, iii) *Amphora* sp, iv) *Anabenna* sp., v) *Asterionella* sp., vi) *Bacillaria* sp, vii) *Coelastrum* sp, viii) *Chlorella* sp, ix) *Cosinodiscus* sp, x) *Closterium* sp. xi) *Cyclotella* sp, xii) *Cymbella* sp, xiii) *Diatoma* sp, xiv) *Eudorina* sp, xv) *Fragilaria* sp xvi) *Gyrosigma* sp, xvii) *Microcystis* sp, xviii) *Monoraphidium* sp xix) *Navicula* sp. xx) *Staurastrum* sp., xxi) *Synedra* sp.,

xxii) *Scenedesmus* sp xxiii) *Spyrogyra* sp., xxiv) *Microsphora* sp., xxv) *Nitzschia* sp., xxvi) *Protococcus* sp., xxvii) *Pandorina* sp., xxviii) *Pediastrum* sp., xxix) *Brachionus* sp., xxx) Cladoceran.

Macro Benthic Faunal Diversity

Benthos plays an important role in maintaining natural energy flow and nutrient balance. When benthos dies, they decompose and release nutrients that are reabsorbed by plants and other animals. Benthos refers to some aquatic organisms that live above, inside or near the bottom of a body of water. It is one of the important components of food chain especially for fish. Many fish consume algae and bacteria, some fishes eat benthos.

In the present study, the aquatic insects and other bottom fauna were collected from selected sites of the river Ramganga. One square meter of riverbed was selected at each sampling sites and the bottom stones, gavels and sand were upturned to dislodge the aquatic life. The organism was handpicked and also by using dredge. The collected specimens were preserved in 5% formalin and analyzed quantitatively and qualitatively. The details distribution of benthic fauna is presented in table 6.

Table 6. Site wise occurrence of macro benthic fauna

Sampling sites	**Date**	**Name of benthic organisms.**	**Quantity/efforts**	**Total nos. (u/m^2)**
Site-I	16.5.2022	Chironomus larvae	4	174
		Earth worm	2	87
Site-II	17.5.2022	*Bellamya bengalensis*	4+2	261
		Thiara tuberculata	5	217
		Corbicula striatella	2	87
		Lymnaea luteola	2	87
Site-III	17.5.2022	*Bellamya bengalensis*	5	217
		Parreysia (P) favidens	4	174
		Brotia costula	1	43
Site-IV	18.5.2022	Insecta	1	43
		Fish seed	4	174
Site-V	19.5.2022	Insecta i. Water penny (Coleoptera group) ii. Trichoptera iii. Ephemeroptera iv. Plecoptera	4	174

Results

There are distinct variations of benthic fauna observed from low elevation zone to higher elevation zone of River Ramganga. In site-I, only 2 benthic sp. were recorded. Chironomus larvae were observed maximum with relative abundance (RA%) of 66.66%, followed by earth worm which contributed only 33.33% (RA). No other benthic fauna were recorded from site-I. However, rich occurrence of chironomus larvae is an important food source of fishes. In site-II, quiet rich diversity of benthic fauna were recorded. A total of 4 species of benthic fauna were observed in site-II. *Bellamya bengalensis* contributed maximum occurrence (RA 40.03%) followed by *Thiara tuberculata* (RA 33.28%), *Corbicula striatella* (RA 13.34%) and *Lymnaea luteola* (RA 13.34%) respectively. As it is evident that rich presence of macro benthic fauna is a good indicator of aquatic ecological integrity. In site-III, a total individual of 434 benthic fauna comprising of 3 species were recorded. These are *Bellamya bengalensis* (RA 50%), *Parreysia (P) favidens* (RA 40.09%) and *Brotia costula* (RA 9.90%). In site IV and V the river passes through hilly terrain with gravellier substrate and torrential water flow. Only insects were collected from site-IV and V. In site IV, only one sp. of insect was recorded contributing 43 nos. in a m^2 along with fish seed of *Tor putitora* and others (n=174). In site- V, 4 species of insects were identified contributing total nos. of 174 in a m^2 area. The species were Water penny (Cleoptera group), Trichoptera, Ephemeroptera and Plecoptera. These aquatic insects are considered to be ideal food for carnivorous fish species (Fig. 11).

Bellamya bengalensis

Thiara (M) tuberculata

Brotia costula

Lymnaea luteola

Parreysia favidens

Corbicula striatella

Insect

Chironomus larvae

Fig. 11 Macro benthic invertebrate diversity in River Ramganga and tributaries

Conclusion

- The water quality parameters at majority of the stretches except at selected stretches of Site-II and III were optimal water quality for fish in the river Ramganga and its tributaries The DO level considerably low ranging from 2.8 to 3.2 ppm at site-III and II respectively.
- A total of 21 fish species belonging to 6 families from 5 orders were recorded from the main channel of river Ramganga and its tributaries. The relative contribution of major groups of fishes viz., carps (major, medium and minor), catfishes, miscellaneous and exotic fishes was 19.04%, 20%, 71.42% and 4.76% respectively.
- Macro benthic fauna and plankton diversity showed existence of rich diversity of plankton recorded from river Ramganga and its tributaries. Maximum plankton species (n=25) were recorded from site-II followed by Site-IV (n=21) and site-I (n=20) in river Ramganga whereas maximum species (n=25) were recorded from site-III of River Baigul and 23 species of plankton recorded from site-V of River Kosi.


Parambassis ranga


Channa punctatus


Puntius sophore


Chanda nama


Salmophasia bacaila


Cirrhinus mrigala

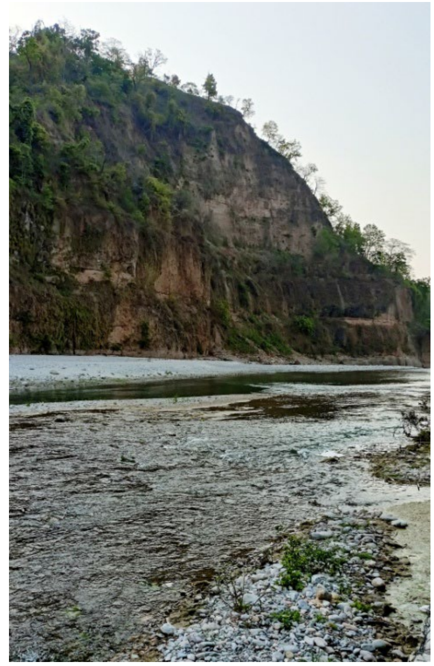

Sperata aor

Fig.12 Some important fishes recorded from river Ramganga (Bareilly and Jalalabad region)

Fig.13 Sampling activities in river Ramganga at Marchula & in River Kosi at Ramnagar

River habitat characteristics

(a)



(b)

(a+b) River Ramganga and Kosi in hilly region (Marchula and Ramnagar) - gravel substrate and riparian vegetation

River Ramganga at Bareilly area

River showing agriculture practice in floodplain

(a)

(b)

Fishing in Ramganga at Bareilly

Annexure 4 – Ecological and other data collection by WII

Data sheet for fish habitat quantification

Habitat Assessment (Site I/ Bareilly)

Site Name	Bareilly
Date	16/5/2022
Name of the Recorder	Dr. J.A. Johnson
Weather	Sunny
Stream Name:	Ramganga
Location & River Basin:	Rampur Ghat, Ramganga basin
GPS Co-ordinate:	28° 22' 41.7"N 79° 19' 29.7"E
Altitude:	147 m
Air Temper.	34°C
Water Temper.	33 °C
Bank Stability:	Unstable bank
Mean Flow/Velocity:	0.638 m/s
Substrate:	Sand (S)
Riparian Type and Cover:	No riparian cover
Land Use Pattern:	Modified agricultural bed
Human Dependency:	River bed is used for agriculture, fishing, some extent of sand mining

Habitat inventory and microhabitat measurements

Habitat type	Run

Flow and depth at every 2 m

Depth (right to Left) (cm)	**25**	**45**	**55**	**40**	**20**
Flow/ velocity (m/s)	**0.35**	**0.33**	**0.26**	**0.24**	**0.20**

Flow at every 2m

Depth (right to Left) (m)	**1**	**1.2**	**1.5**	**1.8**	**1**

Flow where cash net was put

Flow (m/s)	0.51	0.67	0.41	0.48	0.35	0.61	0.42	0.42	0.38	0.63

Sl. No.	Fish species recorded	No. of count
1	*Cyprinus carpio*	7
2	*Puntius sophore*	18
3	*Pethia conchonius*	7
4	*Crossocheilus latius*	5
5	*Aspidoporia morar*	10
6	*Cirrhinus reba*	25
7	*Salmophasia becaila*	3
8	*Puntius ticto*	1
9	*Sperata aor*	11

Water quality Parameters

Fish species	Sampling A	Sampling B	Sampling C	Average
Water temperature (°C)	33.2	33.2	33.4	33.27
Dissolved Oxygen (mg/L)	9.1	9.56	9.5	9.39
pH	9.05	9.1	9.2	9.12
Conductivity (uS)	367	365	365	365.67
TDS (ppm)	263	260	261	261.33

Figure 1.1: Bareilly site

Figure 1.2: Bareilly site

Data sheet for fish habitat quantification

Habitat Assessment (Site II/ Jalalabad-Baigul)

Site Name	Jalalabad-Baigul
Date	17/5/2022
Name of the Recorder	Dr. J.A. Johnson
Weather	Sunny
Stream Name:	Baigul River
Location & River Basin:	Rampur Dhaka, Ramganga basin
GPS Co-ordinate:	27° 43' 26"N 79° 36' 31.6"E
Altitude:	103
Air Temper.	33°C
Water Temper.	32.2 °C
Bank Stability:	70 per cent disturbed with agricultural area, bridge, nearby village
Mean Flow Velocity:	0.13 m/s
Substrate:	Sand (S)
Riparian Type and Cover:	No riparian cover
Land Use Pattern:	Agriculture (mostly subsistence)
Human Dependency:	River bed is used for fishing, water is used for irrigation and household purposes

Habitat inventory and microhabitat measurements

Habitat	Pool
Width	40 m

Depth at every 1m (cross section)

Lateral Distance from left bank (m)	Depth (cm)
1	10
2	45
3	53
4	75
5	93
6	108
7	118
8	127
9	140
10	132
11	130
12	131
13	130
14	129
15	131
16	129
17	129
18	128
19	129
20	128
21	125
22	119
23	114
24	117
25	113
26	108
27	100
28	91
29	90
30	86
31	79
32	70
33	71
34	76
35	71
36	61
37	60
38	57
39	40
40	10

Flow Velocity and depth where cash net was put

Depth (cm)	Flow Velocity (m/s)
30	0
45	0
48	0.02
59	0
66	0
65	0.02
71	0.02
75	0
60	0.18
60	0.13
57	0.09
50	0
44	0
58	0.17
55	0.04
52	0.19
46	0.11
49	0.2
25	0.43
72 (Labeo was found)	0.41
68	0.45
50	0.44

Sl. No.	Fish species recorded	No. of count
1	*Pethia conchonius*	5
2	*Pethia ticto*	3
3	*Paracanthocobitis gobius*	1
4	*Parambassis lala*	2
5	*Trichogaster pectoralis*	1
6	*Glossogobius giuris*	1
7	*Bangana dero*	1

Water quality Parameters

Fish species	Site II
Water temperature (°C)	32.2
Dissolved Oxygen (mg/L)	9.66
pH	8.3
Conductivity (uS)	368
TDS (ppm)	249

Figure 2.1: Jalalabad-Baigul site

Figure 2.2: Jalalabad-Baigul site

Data sheet for fish habitat quantification

Habitat Assessment (Site III/ Marchula)

Site Name	Marchula
Date	18/5/2022
Name of the Recorder	Dr. Eliza, Ms. Bhawna
Weather	Sunny
Stream Name:	Ramganga River
Location & River Basin:	Marchula, Ramganga basin
GPS Co-ordinate:	29° 36' 19.2"N 79° 05' 52.2"E
Altitude:	568
Air Temper.	31°C
Water Temper.	26°C
Bank Stability:	Stable with 10-15 % man made
Mean Flow Velocity:	0.83 m/s
Substrate:	Sand (S) + Bedrock + Gravel
Riparian Type and Cover:	No riparian cover
Land Use Pattern:	Forest area
Human Dependency:	River bed is used for fishing, some extent of mining

Habitat inventory and microhabitat measurements

Habitat : Run and Riffle

Lateral distance from right bank at every 1 m

Depth (cm)	Flow Velocity (m/s)
9	0
31	0.28
38	0.42
47	0.68
52	0.46
56	1.14
53	1.27
48	1.12
56	0.74
60	1.21
54	1.07
54	0.45
60	0.53
50	0.76
54	0.80
49	0.53
32	1.55
35	1.47
30	1.12
34	1.43
34	1.13
34	1.24
33	1.64
43	1.09
20	1.30
17	0.61

Flow where cash net was put

Depth (cm)	Flow Velocity (m/s)
24	0.44
27	0.39
43	0.36
38	0.59
41	0.78
41	0.74
41	0.72
42	0.64
41	0.53
41	0.52

Sl. No.	Fish species	No. of count
1	*Gara gotyla*	2

2	*Golden Mahseer*	9
3	*Labeo pengusia*	1
4	*Barillius bendalensis*	2

Water quality Parameters

Fish species	**Site 1**
Water temperature (°C)	26
Dissolved Oxygen (mg/L)	8.51
pH	8.8
Conductivity (uS)	201
TDS (ppm)	142

Figure 3.1: Marchula site

Data sheet for fish habitat quantification

Habitat Assessment (Site IV/ Kunkhet)

Site Name	Kunkhet
Date	19/5/2022
Name of the Recorder	Dr. Eliza, Ms. Bhawna
Weather	Sunny
Stream Name:	Kosi River
Location & River Basin:	Kunkhet, Ramganga basin
GPS Co-ordinate:	29° 21' 42.84"N 79° 10' 7.788"E
Altitude:	488
Air Temper.	30°C
Water Temper.	26°C
Bank Stability:	Unstable eroded bank on one side
Substrate:	Sand (S) + Bedrock + Co
Riparian Type and Cover:	No riparian cover
Land Use Pattern:	Forest area
Human Dependency:	River bed is used for fishing, high extent of mining

Habitat inventory and microhabitat measurements

Habitat type- Run, Riffle and Pool

Cross section at every 1m

Cross section/ Lateral Distance from right bank (m)	Depth (cm)
0	30
1	50
2	61
3	67
4	68
5	66
6	72
7	71
8	62
9	54
10	59
11	52
12	40
13	13

Flow depths where cash net was put

Depth
30
34
50

Sl. No.	Fish species recorded	No. of count
1	*Gara gotyla*	1
2	*Tor putitora*	4
3	*Mastacembalus armatus*	1
4	*Paracanthocobitis botia*	1

Water quality Parameters

Fish species	Site 1
Water temperature(°C)	24
Dissolved Oxygen (mg/L)	8.4
pH	8.7
Conductivity (uS)	270
TDS (ppm)	191

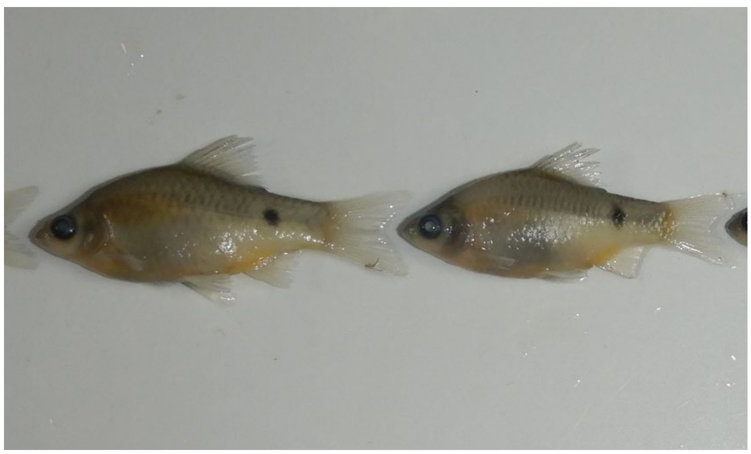
Figure 4.1: Kunkhet site

Tor putitora

Mastacembalaus armatus

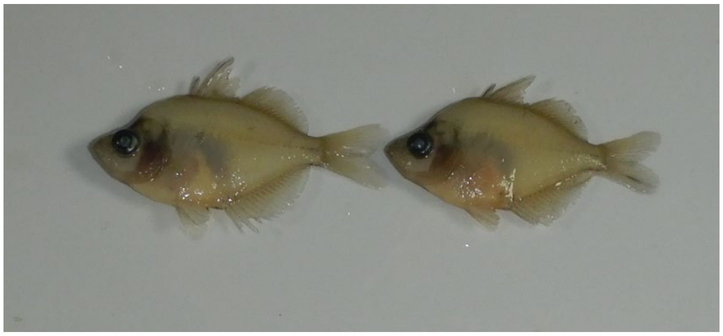
Opsarius bendelisis

Barilius vagra



Pethia Ticto

Trichogaster pectoralis



Parambassis lala

Pethia conchonius

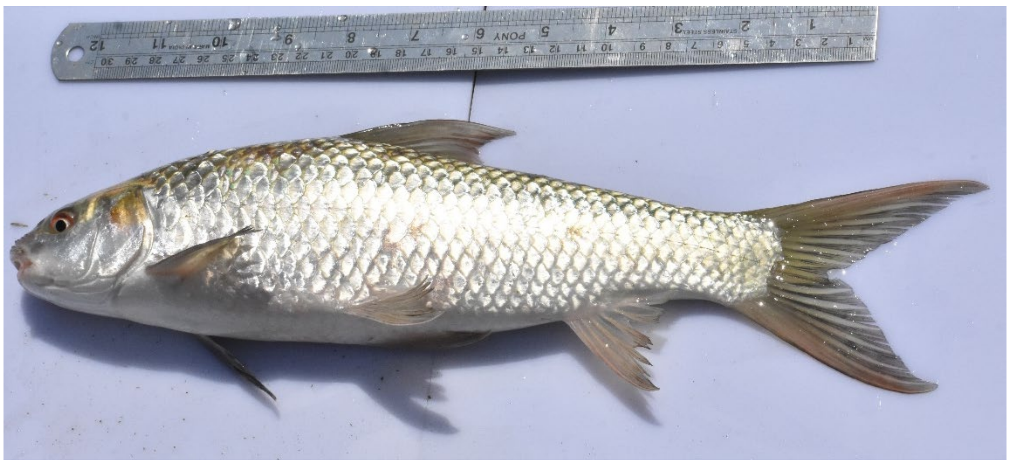
Glossogobius giuris

Paracanthocobitis botia

Cyprinius carpio

Bangana dero

Puntius sophore



Labeo pangusia

Garra gotyla

Annex 5 – Report on Aerial Survey by IIT Kanpur

UAV survey for selected sites in Ramganga Basin towards E-Flows Assessment – Lean

Submitted by

Rajiv Sinha

Professor, Department of Earth Sciences

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Attribution

Shobhit Singh, Research scholar, IIT Kanpur

Dr Dipro Sarkar, Project scientist, IIT Kanpur

July 2022

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1 BACKGROUND AND MOTIVATION

Unmanned aerial vehicle (UAV) platforms are nowadays a valuable source of data for inspection, surveillance, mapping, and 3D modeling. UAV photogrammetry has opened various new applications in the close-range aerial domain, introducing a low-cost alternative to the classical manned aerial photogrammetry for large-scale and high-resolution topographic mapping or detailed 3D recording of ground information and being a valid complementary solution to terrestrial acquisitions. In hydrological research UAVs are applied mainly for the acquisition of accurate and up-to date spatial information on the river environment and monitoring of fluvial process with high precision and high sampling frequency. In particular, UAV can provide precise up to date georeferenced information about the location of a river shorelines, channel geometry, vegetation cover mapping and other ecological indices. Fast development of UAV technology creates opportunity for quantitative estimation of hydraulic data.

The National Mission for Clean Ganga (NMCG) is undertaking the process of Environmental Flows (E-Flows) assessment in the Ramganga Basin which is being implemented by GIZ India through the India-EU Water Partnership (IEWP) Action Phase 2 together with Central Water Commission (CWC), and other relevant partners. The E-Flows Assessments in Ramganga Basin will focus on eco-hydrological and eco-hydraulic analysis of the Ramganga River and its tributaries. For this, aerial high-resolution imageries of the selected critical sites in the basin are to be collected in various flow seasons (pre-monsoon, post-monsoon). In addition, to undertake hydrodynamic modelling, 3D topographic survey of the identified sites will have to be done to develop DEMs. For generation of high resolution ortho images and DEMs, the UAV survey for the selected sites was conducted by IIT Kanpur.

2 STUDY SITES

The river Ramganga originates from Doodhatoli ranges in the district of Pauri Garhwal, Uttarakhand state of India. It rises at an altitude of about 3,100 m in the lower Himalayas near the Lohba village in the Garhwal district of Uttaranchal. It is the first major tributary joining Ganga on its left bank near Kannauj in Fatehgarh district. The total length of River in 596 Km and having a catchment of 32,493 sq km. This River flows from Almora and Pauri district in Uttarakhand and Kalagarh, Bijnore, Moradabad, Rampur, Bareilly, Shahjahanpur in Uttar Pradesh. Khoh, Gagan, Aril, Kosi are major tributaries of Ramganga (CWC, India - www.cwc.gov.in/ugbo/gangabasin/ramganga).

For this project, we planned to carry out UAV surveys at 11 locations in the Ramganga basin and the locations of the UAV survey sites are shown in the figure 1 and table 1.

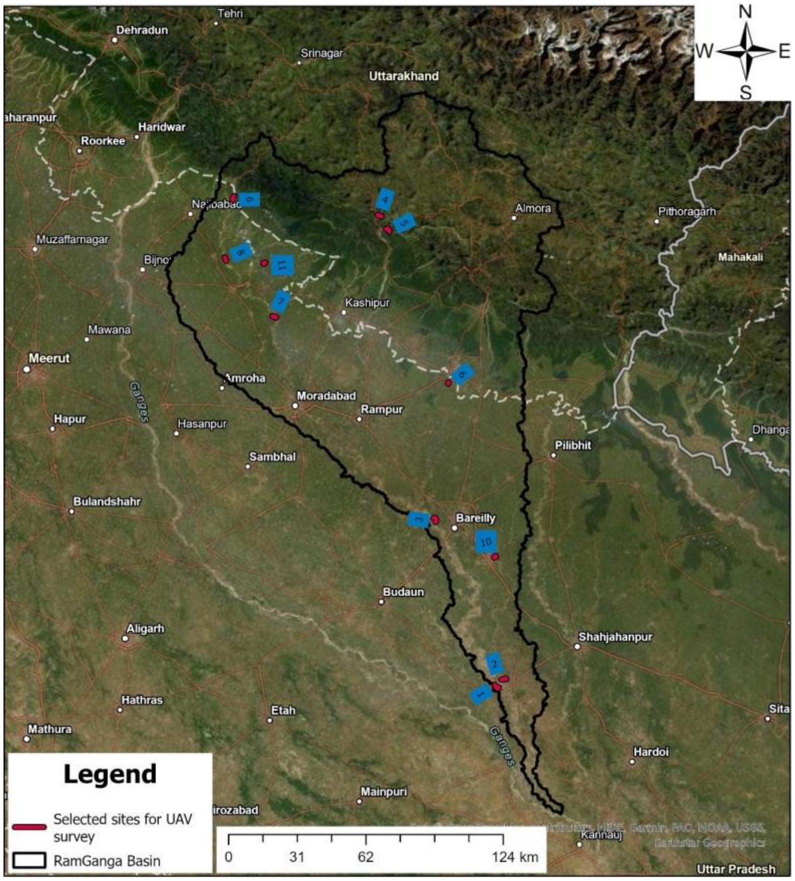


Figure 1. Location of Ramganga basin and selected sites for UAV survey. Number corresponds to the location of the sites given in table 1.

Table 1. Selected sites for UAV survey along with their central coordinate and corresponding districts.

S.No.	Site	Central Coordinate		District
		Latitude	Longitude	
1	Jalalabad_RamGanga	27.689828^0	79.581520^0	Shahjahanpur
2	Jalalabad_Baigul	27.724666^0	76.615242^0	Shahjahanpur
3	Bareilly	28.372143^0	79.337440^0	Bareilly
4	Marchula	29.601740^0	79.107448^0	Almora
5	Kunakhet	29.545748^0	79.144945^0	Almora-Nainital
6	Rudrapur	28.924559^0	79.385103^0	Rampur
7	Seohara	29.192065^0	78.680412^0	Moradabad
8	Nagina	29.427023^0	78.482653^0	Bijnor
9	Saneh	29.674328^0	78.5117829^0	Bijnor
10	Faridpur	28.217996^0	79.577767^0	Bareilly
11	Afzalgarh	29.411035^0	78.639718^0	Bijnor

3 FIELD PLAN AND SURVEY

Out of 11 originally selected sites, UAV survey was done for 9 sites. Afzalgarh site was discarded after the discussion with the team while Faridpur site could not be surveyed due to extreme weather conditions. The field campaign started on 14^{th} May 2022 and finished on 22 May 2022 (Table 2).

For each site, we planned to survey to cover 3-4 km long stretch along the river and also included the active floodplain of the river on both sides.

Table 2. Date wise survey plan, number of flight and GCP detail.

S.No.	Site	Survey date	No. of flights and images	No. of GCPs
1	Jalalabad_Ramganga	14-05-2022	3/446	8
2	Jalalabad_Baigul	15-05-2022	4/972	8
3	Bareilly	16-05-2022	5/1151	7
4	Marchula	17-05-2022	4/927	8
5	Kunakhet	18-05-2022	1/266	3
6	Rudrapur	19-05-2022	3/273	8
7	Seohara	20-05-2022	3/968	7
8	Nagina	21-05-2022	4/1003	9
9	Saneh	22-05-2022	4/1138	8
10	Faridpur	Left	NA	NA
11	Afzalgarh	Discarded	NA	NA

3.1 FLIGHT PLANNING AND DETAILS

Total 31 flights were made to cover all the sites (Table 2). Altogether, 7144 images were captured, each site required 3-4 flights on average depending on river configurations. The flight was planned to fly at a height of 150 meter from the launching base to achieve the required Ground Sampling Distance (GSD) of 3-4 cm (Figure 2). A GSD is the distance covered by a pixel on the actual ground. As a thumb rule the digital elevation model would have a resolution of 4 times the base GSD.

The survey was conducted using quadcopter (DJI Phantom 4Pro), the choice of landing sites was done in-situ, since a quadcopter provides more flexibility in maneuvering, launching and landing. Front overlap was kept at 85% and side overlap was kept at 75%.

Figure 2. An example of flight plan to cover the river and floodplains.

3.2 GROUND CONTROL POINTS (GCPS)

Standard drones without GPS correctional processing provide images which are not accurately geotagged, so you don't get reliable positional data from the drone hardware alone. The level of accuracy is achieved through ground control. Ground control points (GCPs) are known points marked and measured with a base and rover, or moveable (Figure 3).

Figure 3. Left figure shows the marker used as GCPs in the river floodplain and the figure on the right shows the distribution of GCPs in a site.

Precise coordinates of these markers\GCPs were measured using the RTK (Real Time Kinematic) survey. Real Time Kinematic (RTK) satellite navigation is a technique used to enhance the precision of position data derived from satellite-based positioning systems (global navigation satellite systems, GNSS) such as GPS, GLONASS, Galileo, BeiDou, and GAGAN. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to cm-level accuracy.

On an average 8-9 GCPS were taken at each site. Generally, the locations of GCPs are preplanned by generating random points in the area of interest to reduce human error in GCP selection in the field. However, since the riverine system is very dynamic, some of the inaccessible locations had to be changed onsite while ensuring that they are well distributed. Figure 3 shows an example of well-distributed GCPs at a site plotted on the UAV image.

4 UAV DATA PROCESSING

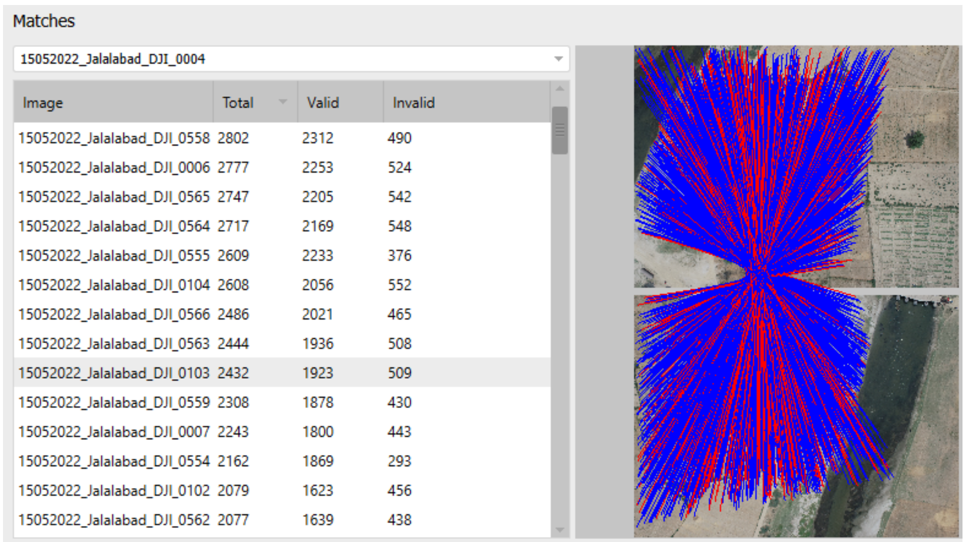
The raw data was processed using Agisoft Metashape software. The process of creation of orthophoto and DEM has multiple steps as follow:

4.1 ALIGNMENT

All images are first aligned with each other (Figure 4). The input data for alignment consists of images and their flight data (position and orientation). Using SIFT (Scale-invariant feature transform) algorithm, edges are calculated in each image. The edges are compared and matched by altering the scale of the images. This ensures digital placement of the images so that in the next steps they can be considered as one big image.

4.2 TRANSFERRING THE GCPS

The process of alignment creates an imagery which is the mosaic of all the provided images. This mosaic image has very low accuracy. The ground control points (GCPs) are then transferred on the mosaic image. These GCPs or benchmarks are measured with high precision Real Time Kinematics (RTK) system. Each GCP must be manually adjusted to the corresponding point on the images. Normally a GCP is visible in multiple images. Each of the images must be manually repositioned to adjust the position of the GCP (Figure 3). The GCPs and the image co-ordinates are used to create tie points- where the images are scaled up to match each other and create a near seamless image. This process is analogues to stitching pieces of fabrics to create a complete suit.



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15052022_Jalalabad_DJI_0006	2777	2253	524
15052022_Jalalabad_DJI_0565	2747	2205	542
15052022_Jalalabad_DJI_0564	2717	2169	548
15052022_Jalalabad_DJI_0555	2609	2233	376
15052022_Jalalabad_DJI_0104	2608	2056	552
15052022_Jalalabad_DJI_0566	2486	2021	465
15052022_Jalalabad_DJI_0563	2444	1936	508
15052022_Jalalabad_DJI_0103	2432	1923	509
15052022_Jalalabad_DJI_0559	2308	1878	430
15052022_Jalalabad_DJI_0007	2243	1800	443
15052022_Jalalabad_DJI_0554	2162	1869	293
15052022_Jalalabad_DJI_0102	2079	1623	456
15052022_Jalalabad_DJI_0562	2077	1639	438

Figure 4. The lines represent the matching points between the Images 15052022_Jalalabad_DJI_004 and 15052022_Jalalabad_DJI_103. Blue lines are the correctly marked points whereas the red line represents the wrongly marked pair of points.

4.3 CREATING POINT CLOUD

A Point Cloud (PC) is a set of 3- dimensional points having x, y and z values on a coordinate system. Figure 5 shows that the known parameters are flight height, position of the images, amount of overlap between images and the orientation of the image (same as that of the UAV). With the help of trigonometry, all the ground points can be calculated from the data. Precise correction is made using the GCPs which act as tie points.

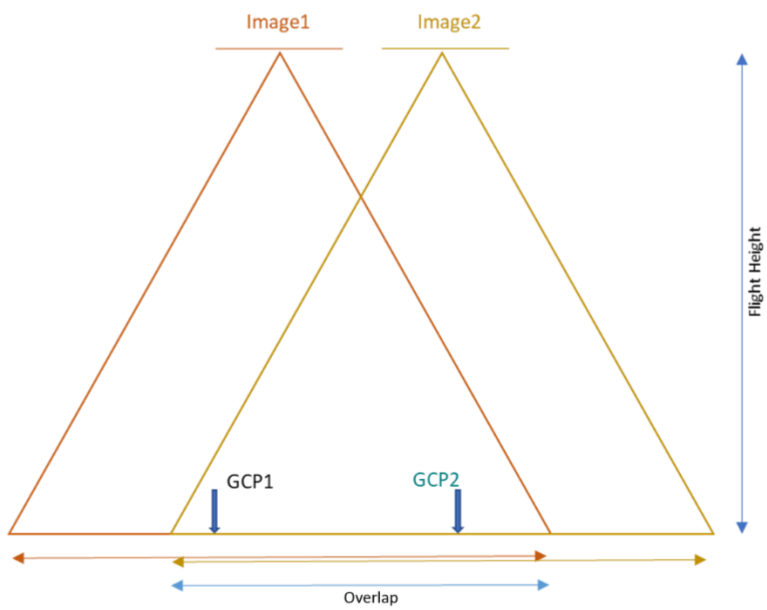

Figure 5. 3D calculation from 2D flight.

Creating the PC is the most time-consuming part as it involves calculation of billions of points (Figure 6). Typically, in a system with 256 GB of RAM and 40 cores, 15-16 hours of continuous processing is needed for computing point cloud for an area covering 5 square kilometers.

Figure 6. PC generated from the UAV images- high density.

4.4 FILTERING AND NOISE REMOVAL

Noise in a PC is an unwanted point which may be generated by the presence of unwanted items like a moving bird, whirls of dust, falling leaf or any such temporary incidents. Even reflection from sun on water bodies generate noises. With multiple statistical models, each point in the PC is evaluated as noise or non-noise points. The noises are then filtered out to provide with a PC which is practically noise free. This is a semi-automatic process where in visual comparison and authentication is made unless a satisfactory level is reached.

The noise free PC then undergoes multiple semi - automatic statistical iterations to classify the clusters of points as ground or non - ground. Non-ground points comprise of the trees, buildings, cars, or any such item which is not part of the terrain. Filtering them leaves us with the ground points.

The noise free PC is used to generate the Digital Surface model (DSM) while the Ground PC is used to generate the Digital Terrain Model (DTM).

5 FINAL DATA PREPARATION

As discussed, the digital elevation model (DEM) and orthomosaic were exported in WGS 84/Pseudo-Mercator (EPSG:3857) format.

DSM and DTM generation: Digital surface model (DSM) capture both the natural and built/artificial features in the ground i.e., it is the representation of the surface of an area as perceived from Nadir, while digital terrain model (DTM) represents the terrain only (bare earth) (Figure 7). DSM and DTM were exported at 10-11 cm resolution.

Orthomosaic: An orthomosaic is a geometrically correct aerial image that is composed of several still images that are stitched together. Figure 8 shows the orthophoto generated at 5cm resolution for the Jalalabad site.

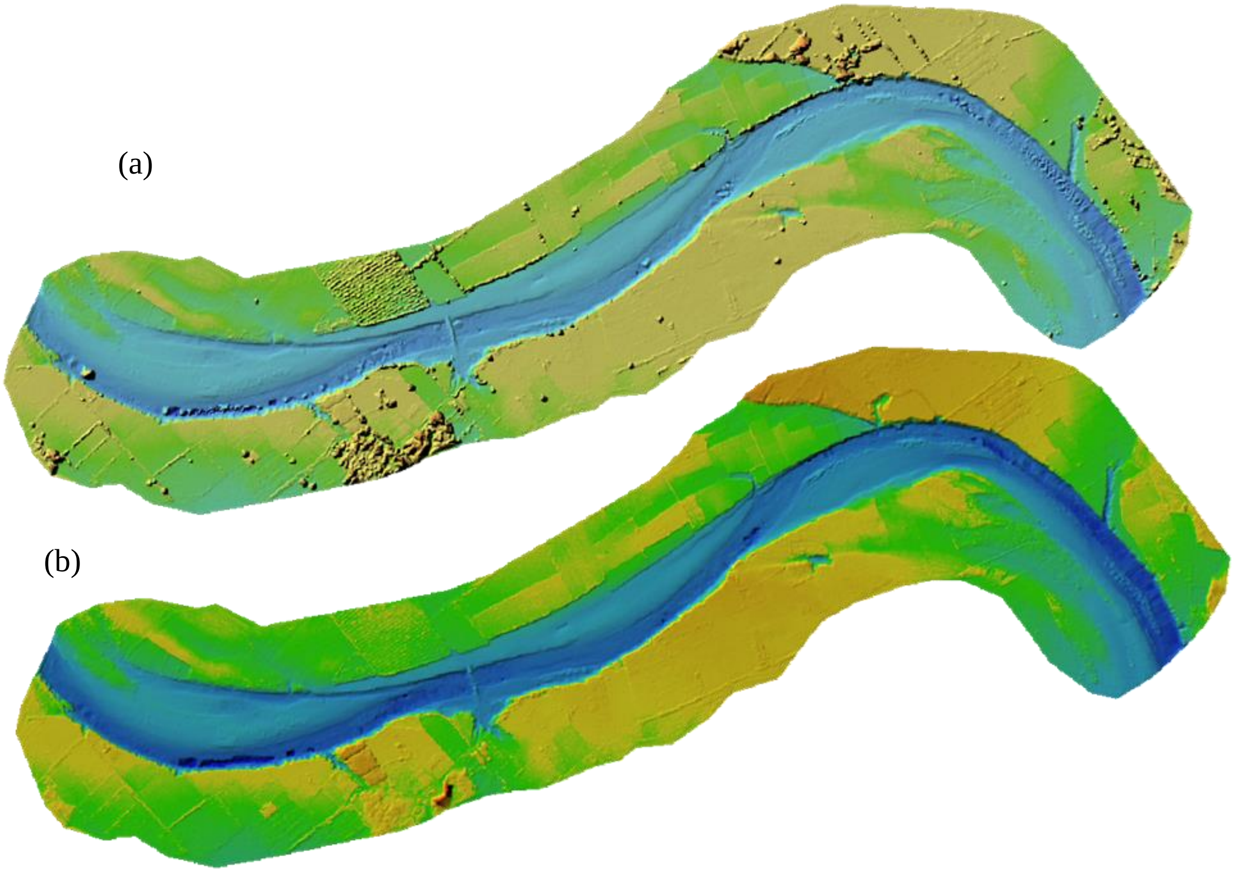

Figure 7. (a) DSM and (b) DTM of Jalalabad site (Baigul river).

Figure 8. Orthomosaic of the Jalalabad site exported at 5 Cm resolution.

6 CONCLUDING REMARKS

High resolution Orthophoto and DEM produced in this work can be used for multiple purposes such as hydraulic modelling, and ecological assessment. Information about rugosity, sinuosity, bed material, vegetation and other hydraulic factors are stored in the orthorectified images and information about wetted perimeter, width, depth, can be extracted from DEMs. Repeated survey of the same site will also provide the opportunity to perform the temporal assessment of the riverine system.

7 APPENDIX

Table A 1. All the GCPs along with their location and altitude data.

GCP name	Lat	Long	Height
140522_Jalalabad	27.69526	79.577	79.771
140522-1	27.69532	79.57692	79.62
140522-2	27.69823	79.57497	81.842
140522-3	27.70085	79.57354	82.173
140522-4	27.6977	79.57695	80.032
140522-5	27.70069	79.57561	78.871
140522-6	27.69286	79.58122	81.651
140522-7	27.68989	79.58302	81.711
140522-8	27.69243	79.57907	80.672
150522-Jalalabad	27.72292	79.60857	85.329
150522-1	27.72285	79.60848	85.33
150522-2	27.72175	79.60323	85.672
150522-3	27.72337	79.60237	83.073
150522-4	27.727	79.61281	83.796
150522-5	27.72799	79.61768	83.693
150522-6	27.72825	79.61785	85.581
150522-7	27.72698	79.61942	81.216
150522-8	27.72475	79.61308	85.782
160522-Bareilly	28.37489	79.33766	104.846
160522-1	28.37496	79.33767	104.837
160522-2	28.37006	79.33908	104.617
160522-3	28.36506	79.3393	101.162
160522-4	28.36877	79.33925	102.032
160522-5	28.3783	79.32495	103.113
160522-6	28.37952	79.32698	102.061
160522-7	28.37848	79.33373	105.078
170522-Marchula	29.60445	79.10735	527.24
170522-1	29.60444	79.1073	526.798
170522-2	29.60477	79.10567	496.867
170522-3	29.60615	79.10063	518.156
170522-4	29.60533	79.09847	492.156
170522-5	29.60536	79.09846	491.998
170522-6	29.60584	79.10352	528.471
170522-7	29.6019	79.11338	552.644
170522-8	29.60236	79.10809	504.241
180522-Kunakhet	29.53753	79.15702	486.619

180522-1	29.53752	79.15703	486.64
180522-2	29.53627	79.16052	489.497
180522-3	29.53526	79.16541	490.213
180522-4	29.53469	79.1682	492.303
180522-5	29.53793	79.15411	483.876
180522-6	29.53798	79.15168	481.797
190522-Rudrapur	28.92431	79.38459	146.111
190522-1	28.92434	79.38462	146.45
190522-2	28.9242	79.38576	141.9
190522-3	28.92347	79.3862	141.736
190522-4	28.92215	79.38618	141.131
190522-5	28.92571	79.38429	141.828
190522-6	28.92699	79.38523	142.198
190522-7	28.92701	79.38722	143.195
190522-8	28.925	79.38375	146.374
200522-Seohara	29.19303	78.67784	157.792
200522-1	29.19306	78.6779	157.732
200522-2	29.19265	78.68103	157.298
200522-3	29.19276	78.68417	156.27
200522-4	29.19177	78.68778	156.083
200522-5	29.18838	78.68562	157.23
200522-6	29.19392	78.67531	157.775
200522-7	29.1954	78.67279	157.762
210522-Nagina	29.42903	78.48347	186.411
210522-1	29.429	78.48351	186.402
210522-2	29.42729	78.48328	186.222
210522-3	29.42606	78.48241	184.253
210522-4	29.42304	78.48383	183.969
210522-5	29.42038	78.48625	184.533
210522-6	29.43165	78.48233	186.181
210522-7	29.43312	78.48095	186.657
210522-8	29.43408	78.47949	185.093
210522-9	29.42867	78.48234	185.777
220522-Kotdwar	29.67196	78.51068	245.974
220522-1	29.672	78.51071	245.907
220522-2	29.66887	78.5114	244.348
220522-3	29.66569	78.51282	242.567
220522-4	29.66759	78.51265	243.198
220522-5	29.67356	78.51217	246.721
220522-6	29.67614	78.5131	248.085
220522-7	29.68003	78.51469	250.328
220522-8	29.68185	78.51648	250.857

Figure A 1. Orthomosaic of Marchula, Kunakhet, Jalalabad_baigul and Jalalbad_RamGanga sites.

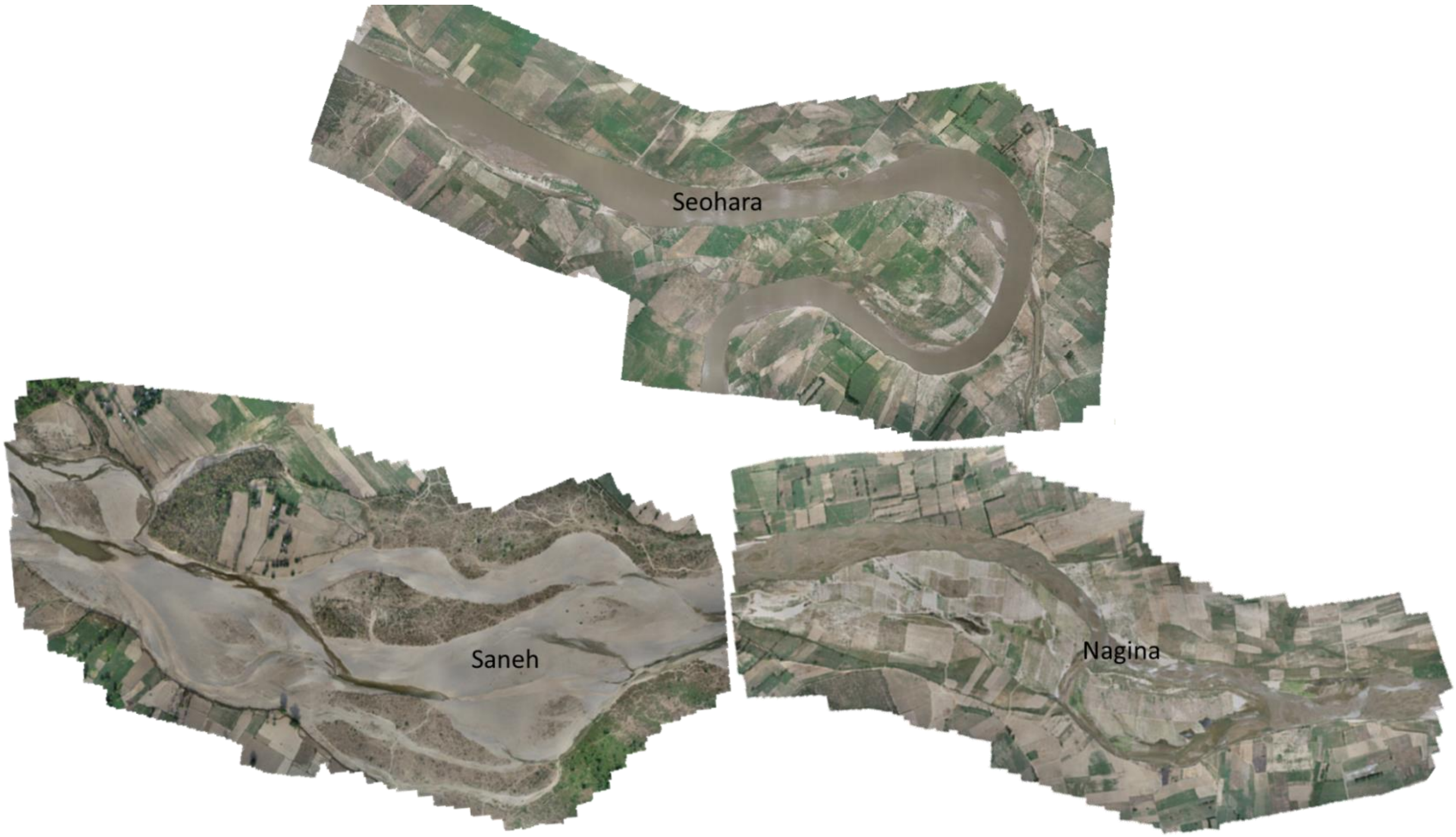

Figure A 2. Orthomosaic of Seohara, Saneh and Nagina site.

Figure A 3. Orthomosaic of Rudrapur and Bareilly site.