G.10 AQUATIC SURVEY REPORT

BASELINE SURVEY FOR AQUATIC INVERTEBRATES AND FISHES

REPORT

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ACRONYMS/ABBREVIATIONS

AVFM	Area Velocity Flow Meter
YSI	Yellow Springs Instruments (used in the context of water quality meters)
DSS	Digital Sampling System
TDS	Total Dissolved Solids
pH	Potential of Hydrogen (a measure of acidity or alkalinity)
DO	Dissolved Oxygen
GPS	Global Positioning System
H	Shannon Diversity Index (used in equations for biodiversity)

1 INTRODUCTION

1.1 Executive Summary

The aquatic biodiversity baseline survey for the Gelephu Mindfulness City pre-feasibility study aimed to evaluate the aquatic biodiversity, particularly focusing on fish and macroinvertebrate species, in the region identified for the construction of a new road and bridge connecting Gelephu and Taraythang along southern border of Bhutan. The study as a part of the pre-feasibility assessment, focused on the lowland riverine ecosystems characterized by varying flow regimes, substrate compositions, and aquatic vegetation. The primary objective was to assess the aquatic biodiversity at proposed infrastructure development, specifically fish and macroinvertebrate populations, and to understand the distribution patterns across different habitats to inform mitigation strategies that would minimize adverse effects on biodiversity.

The study followed a systematic sampling approach across multiple habitats within the five aquatic biodiversity plots provided to conduct the survey. Equipment such as D-frame kick nets were used for collecting macroinvertebrates, while electrofishing gear and cast nets were used for fish sampling. Water quality parameters including pH, dissolved oxygen, and turbidity were measured using the YSI ProDSS Multiparameter Water Quality Meter. The sampling methodology ensured comprehensive coverage of the area, capturing the spatial and temporal variability (to be conducted for two seasons monsoon and post-monsoon) in species presence and abundance.

For the monsoon season, a total of 282 fishes were encountered, representing 32 species from eight families across various sampling stretches. The most dominant species was *Garra birostris* (*N* = 53, Relative Abundance [*RA*] = 18.79%), followed by *Garra annandalei* (*N* = 41, *RA* = 14.54%). For macroinvertebrates, a total of 535 samples were recorded, belonging to 11 families under 9 orders. The most dominant species was *Baetis* sp. (*N*= 212) under the Baetidae family, accounting for 39.63% of the total abundance. The survey did not record any critically endangered or endangered species as per IUCN Red List during the monsoon season, which corroborates that the current aquatic biodiversity, while diverse, does not include species that are at immediate risk of extinction.

In summary, this study provides a detailed baseline assessment of the aquatic biodiversity within the Gelephu-Taraythang corridor. By evaluating the distribution patterns of fish and macroinvertebrates, the study lays the groundwork for understanding the ecological dynamics of the region.

1.2 Key Literature Review

1.2.1 Ichthyology and environmental challenges in Bhutan

Bhutan is located in the eastern Himalayas with a geographic size of 38,394 km^2 (Thinley et al., 2020). The country has more than 52% of forest under the protected system with about 70.41% of forest coverage. With its location in two out of eight geographical realms: Indo-Malayan and Palearctic realms, the country is blessed with rich forest and diverse ecosystem corroborating to one of the biodiversity hotspots in the world with over 11,248 species (National Biodiversity Centre, 2017). The country is endowed with rich natural water bodies in the form of rivers, streams and lakes portraying a rich diversity of aquatic life. Recently, study on Bhutan's aquatic biodiversity has gained momentum and with the growing pressure on our water bodies (NRCRLF, 2017b), it is crucial that the taxonomic studies have to be advanced cutting-edge technology to ascertain the biodiversity in the country.

Only recently, taxonomic studies on fishes found in the rivers and streams of Bhutan were studied. Historically, the first specimen of fish from Bhutan was collected in 1838 by Griffith (McClelland and Griffith, 1822). Three more species were recorded by Beavan in 1877. Day (1889) has recorded five species from Bhutan as reflected in the Fauna of British India. 41 fish species were recorded by T. Petr (1999). Bhattarai and Thinley (2005) recorded 11 species from Bumdeling Wildlife Sanctuary and listed 52 species for the country. Gurung et al. (2013) recorded 91 species after conducting a sporadic survey around the country. For the first time in the country, Gurung and Thoni (2015) prepared a preliminary checklist recording 109 species of fishes under 24 families, it is the most comprehensive study in the country whilst still remains preliminary, requiring confirmation of species through a combination of morphometric and molecular analysis (Dorji & Gurung, 2017). All the studies including the ongoing studies by the National Research Centre for Riverine and Lake Fisheries (NRCRLF) in Bhutan are based on conventional methods of morphometric studies. Bhutan has approximately 180 fish species (Gurung & Thoni, 2015a; NRCRLF, 2017a) .

1.2.2 Macroinvertebrates diversity and distribution

Aquatic macroinvertebrates are organisms that live in water, are visible to naked eye and lack an internal skeleton (Agouridis et al., 2015). Benthic macroinvertebrates have long been used as an indicator for biological assessment of streams. They have been used for both short- and long-term monitoring of stream environment due to their species diversity, long lifespan, bottom dwelling activity and their sensitivity to habitat disturbances (Min & Kong, 2021). Macro-invertebrates are important components for maintaining the integrity of urban river ecosystems and providing a basis for water quality monitoring. Urbanization development continues to risks river ecosystems due to point and non-point source pollution, which has resulted in a decrease in macro-invertebrates' diversity (Zhang et al., 2023). To understand long-term effects of multiple divers on riverine communities, macro-invertebrates is an efficient biological indicator of freshwater attributing to their sensitivity to pollution and disturbances (Nguyen et al., 2023). Macro-invertebrates are an important link in the food chain, primary processors of organic material and an important food source for fishes (Di, 2020).

The way macroinvertebrates respond to changes in their environment and how they have gathered over time can indicate whether an ecosystem is stressed or resilient to both natural and man-made disturbances. Taxonomic identification of invertebrates is required for techniques that uses species diversity as an indicator of pollution. Some of the organisms are highly sensitive to pollution whereas some are pollution tolerant which makes them the best biological indicator of water quality as the decline in assemblage of pollution sensitive organisms indicates introduction of pollution into the river ecosystem (Di, 2020). The sensitive macroinvertebrate taxa include Ephemeroptera, Plecoptera and Trichoptera (EPT) and the pollution tolerant organisms taxa includes Mollusca, Annelida and Crustaceans (Fergus et al., 2023 & Shilla & Shilla, 2012). As per the report of Kim et al. (2019), it is said that macroinvertebrates and their functional diversity regulates nutrients and algal dynamics in riverine ecosystems.

Dunsmoor-Connor & Dunsmoor, (2017), reported that due to their interaction with both water bodies and bottom sediments during their life cycle and their relative immobility compared to other organisms like fish, benthic macroinvertebrates are used as an indicator of water health. Due to their different sensitivity to pollution, macroinvertebrates also indicate the biological makeup of the ecosystem outside of water quality. Aquatic macroinvertebrates are an integral part of food chain and without them, a streams entire aquatic food web would collapse (Agouridis et al., 2015).

The study done by IUCN (2010), reports that eastern Himalaya claimed that region supports significant numbers of species dependent upon freshwater habitats. The study assessed the water quality of portions of Brahmaputra River drainage in Arunachal Pradesh, Meghalaya and northern Bengal and other parts of Assam and Himalayan foothills between Nepal and Bihar which exhibits diverse fish fauna and macroinvertebrates. The study reported 180 freshwater molluscs and 367 species of Odonata and predicts that Bhutan will also have similar composition of fauna as it belongs to Himalayan region. The study conducted by WCNP (2012) in Bumthang recorded 1107 insect specimens belonging to nine orders from 18 sampling sites to assess the water quality in Bumthang with the help of macroinvertebrates.

2 MATERIALS AND METHODS

2.1 Study area

The study area is located along the Gelephu, southern border of Bhutan under Sarpang District, specifically in the regions of Gelephu and Taraythang. The study area lies between the extent following geographic coordinates: 26°94'10.89"N; 90°51'84.85"E to 26°84'85.95"N; 90°53'39.23"E (North to South), and 26°94'10.89"N; 90°51'84.85"E to 26°86'45.36"N; 90°50'30.93"E (West to East). The region is characterized by a mixture of lowland subtropical forests, agricultural lands, and riverine ecosystems, with varying altitudes that provide diverse habitats for a wide range of fishes and invertebrate species. The proposed road and bridge will traverse these landscapes, connecting the communities of Gelephu and Taraythang.

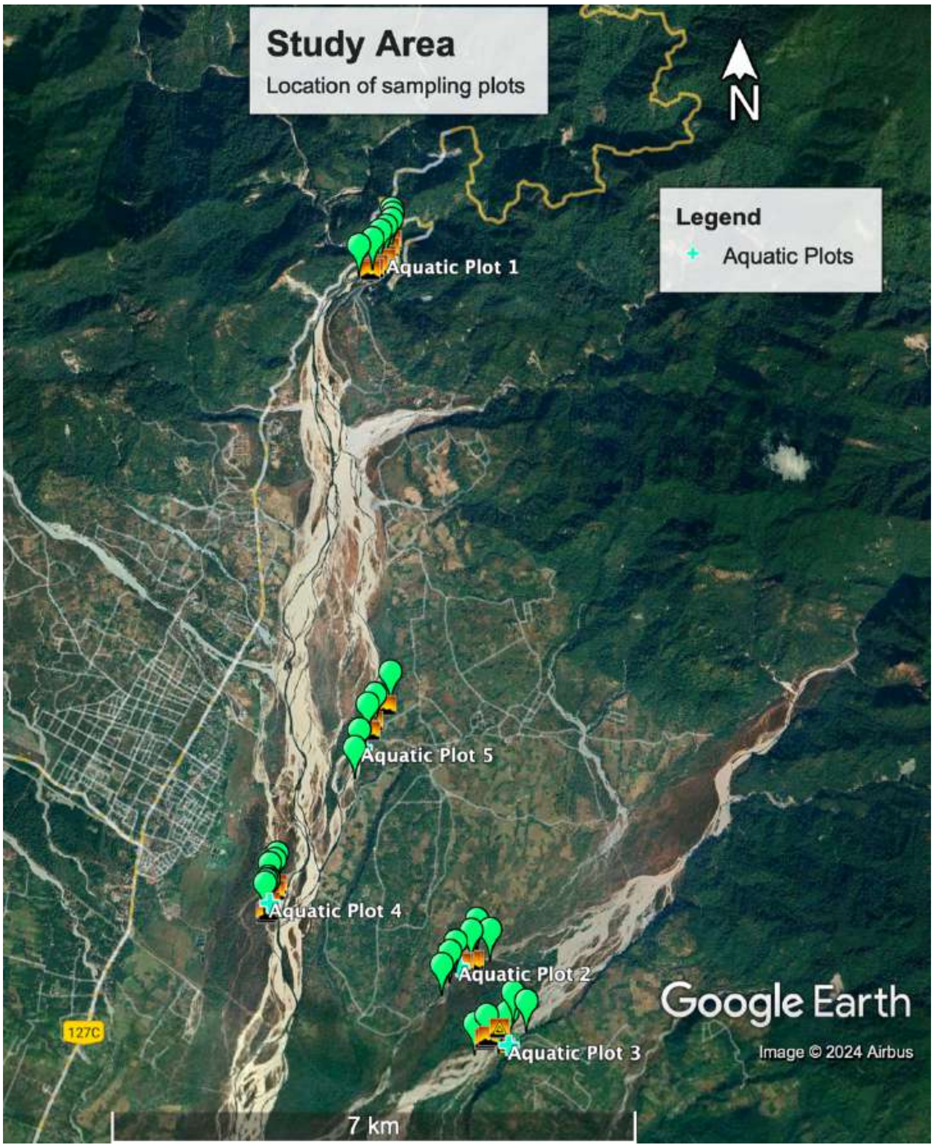


Figure 2. 1: Location of study sites and sampling plots

2.2 Materials required

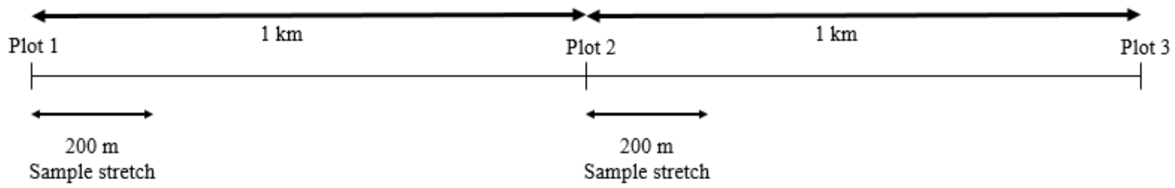
The materials required for data collection were fishing gears which included cast nets and electro-shocker, Global Positioning Systems user handheld device, portable water analysis kit PCS Testr and YSI ProDSS Multiparameter Water Quality Meter, specimen containers, formalin, ethanol, measuring tap, caliper and aquarium. The samples were photographed and specimens which could not be identified in the field were fixed in formalin and preserved in ethanol using specimen container. From the study sites, none of the fish samples were taken to the laboratory due to the lone fish species and the species sampled were identified on the project site. Portable water analysis testing kits was used to measure the physical parameters on site such as pH, dissolved oxygen, TDS, turbidity and temperature. For the macroinvertebrates, the materials used were A D-frame aquatic dip net with the mesh size of 600 µm, magnifying glass, forceps and tray. The advantages of using D-Frame dip net is because it is affordable and can be used in low gradient stream. Moreover, it is easy to handle and can be used to collect sample from more than one habitat (McIntosh et al., 2019).

Figure 2. 2: YSI ProDSS Multiparameter Water Quality Meter and PCS Testr used for water quality measurement

Figure 2. 3: The AVFM 6.1 Area Velocity Flow Meter used for velocity and depth.

2.3 Sampling design

Samples were collected following systematic random sampling technique. Sampling points were laid with a distance of 1 km between each sampling point (Gyeltshen, 2018). GPS coordinates were recorded in all sampling areas using GPS logger which provided the distribution pattern of species. A 200 m transect line which is also known as sample stretch was laid in 1 km sample distance for collection of data (Wangmo and Rai, 2019).



2.4 Data collection

2.4.1 Fish sampling

Figure 2. 4: Use of different techniques for fish sampling.

Fishes were sampled using fishing gears like cast net, spinner hook, temporary river diversion, siene net and electro-shocker. Catch and release method was strictly adopted. A cast net of 3 metres radius was used for the sampling and the distance of two sample points was 50 metres, each stretch covered up to one-kilometer. Coupled with the cast net, wherever possible, seine net was used via rock flip and kick sampling method. The coordinates, water depth and mean water velocity of the site where the fishes were caught were recorded using AVFM 6.1 Area Velocity Flow Meter.

2.4.2 Macroinvertebrate sampling

Kick-sampling technique with D-frame net (1x1 feet; 600 µm net mesh) was used to collect macroinvertebrates (Gretchen, 2007). Simultaneously, mosquito nets from the local market were also used to maximize the collection and effort. To guarantee that the majority of macro-invertebrates were collected, the substrate was disturbed and scooped with the net for multiple times. Three replicates of samples were collected from the sampling sites covering all representative habitat types: pool, riffle and run within the project sites. Identification followed Bouchard (2004), Janecek (2006) and Hartmann (2007), Wangchuk and Eby (2013) and Steveninck, Attermeyer, and Venneker (2019). Macroinvertebrates that could be identified on the spot were photographed and documented, while unidentified macroinvertebrates were collected in labelled ethanol-filled containers to be identified in the laboratory.

2.4.3 Water Quality

A total of six water quality parameters were analysed for the water samples collected from the 2 sampling plots. The details of methods to be used are as follows:

Table 2. 1: Details of methods used to analyse different water quality parameters.

Sl.	Parameter	Maximum Hold Time	Preservation	Methods	Equipment Use
1.	pH	Immediately	Immediately	Electrometric method	PCS Testr 35 (Multi-Paramater)
2.	Temperature	Immediately	Immediately	Electrometric method	PCS Testr 35 (Multi-Paramater)
3.	Conductivity	48 hours	At 4°C	Electrometric method	PCS Testr 35 (Multi-Paramater)
4.	TDS	Immediately	Immediately	Electrometric method	PCS Testr 35 (Multi-Paramater)
5.	Turbidity	24 hours	At 4°C	Instrumental method	YSI ProDSS Multiparameter Water Quality Meter
6.	Dissolve Oxygen	Immediately in field	Immediately	Winkler method with azide modification	YSI ProDSS Multiparameter Water Quality Meter

2.4.4 Data analysis

Data were computed in Microsoft Excel and R software. Descriptive statistics were obtained to compare the results of different sites. Species diversity was calculated using the Shannon-biodiversity index (Shannon and weaver, 1949). This diversity index gives biotic density of the study site and also the differences in species richness and evenness across the study site. The value of Shannon Diversity Index indicates the level of species diversity in such a way that the greater in value of Shannon Diversity Index shows greater in species diversity. It usually ranges between 1.5 to 3.5 in most ecological studies and the index can be lesser than 1.5 in some cases and is rarely greater than 4 (Kessler *et al*., 2005).

Shannon diversity Index (H)= $-\sum (N=Pi * Ln (N=Pi)$……………………….equation 1

Evenness (E) = $S/Ln(N=s)$…………………………………….equation 2

Species richness formula (S_R)= $(S - 1) / Ln N$ ………………………equation 3

Where Pi = relative abundance of each species and Ln = logarithm to base e. S = Total number of species encountered, $\sum$ = sum from species 1 to species S and s = number of species .

Relative abundance for different species were also calculated using the following formula:

Relative abundance (RA) = n/N X 100

Where n = the number of particular species

N = the total observation detected for all species.

3 RESULT AND DISCUSSION

3.1 Fishes

3.1.1 Species composition and dominance

For the monsoon season, a total of 282 fishes were encountered, representing 32 species from eight families across various sampling stretches in Gelephu. The most dominant species was *Garra birostris* (*N* = 53, Relative Abundance [*RA*] = 18.79%), followed by *Garra annandalei* (*N* = 41, *RA* = 14.54%). The least dominant species included *Macrognathus pancalus*, *Olyra longicaudata*, *Pseudolagovia shawi*, and *Xenentodon cancila*, each with only a single individual encountered (*N* = 1, *RA* = 0.35%).

The overall species diversity of the study site during the monsoon was *H'* = 2.87, with species evenness E_H = 0.83 and species richness S_R = 12.65.

Table 3. 1: Species diversity and relative abundance of fishes for monsoon

SN	Order	Family	Species	Count	RA
1.	Cypriniformes	Cyprinidae	*Garra birostris* (Hora, 1921)	53	18.79%
2.	Cypriniformes	Cyprinidae	*Garra annandalei* (Hora, 1921)	41	14.54%
3.	Cypriniformes	Cyprinidae	*Barilius barna* (Hamilton, 1822)	31	10.99%
4.	Siluriformes	Amblycipitidae	*Amblyceps apangi* (Vishwanath & Shanta, 2004)	19	6.74%
5.	Cypriniformes	Nemacheilidae	*Schistura reticulofasciata* (Kottelat, 1990)	18	6.38%
6.	Cypriniformes	Psilorhynchidae	*Psilorhynchus balitora* (Hamilton, 1822)	12	4.26%
7.	Anabantiformes	Channidae	*Channa striata* (Bloch, 1793)	10	3.55%
8.	Cypriniformes	Cyprinidae	*Barilius bendelisis* (Hamilton, 1807)	10	3.55%
9.	Cypriniformes	Cyprinidae	*Neolissochilus hexagonolepis* (McClelland, 1839)	9	3.19%
10.	Cypriniformes	Cyprinidae	*Devario aequipinnatus* (McClelland, 1839)	7	2.48%
11.	Cypriniformes	Cyprinidae	*Cyprinion semiplotus* (McClelland, 1839)	6	2.13%
12.	Cypriniformes	Cyprinidae	*Bangana dero* (Hamilton, 1822)	6	2.13%
13.	Siluriformes	Sisoridae	*Pseudecheneis sulcata* (McClelland, 1842)	6	2.13%
14.	Cypriniformes	Balitoridae	*Balitora brucei* (Gray, 1830)	5	1.77%
15.	Cypriniformes	Cyprinidae	*Danio dangila* (Hamilton, 1822)	5	1.77%
16.	Cypriniformes	Cyprinidae	*Oreichthys crenucoides* (Chu, 1981)	5	1.77%

17.	Cypriniformes	Nemacheilidae	*Schistura devdevi* (Hora, 1935)	5	1.77%
18.	Cypriniformes	Nemacheilidae	*Aborichthys elongatus* (Hora, 1921)	4	1.42%
19.	Synbranchiformes	Mastacembelidae	*Mastacembelus armatus* (Lacepède, 1800)	4	1.42%
20.	Cypriniformes	Cyprinidae	*Puntius sophore* (Hamilton, 1822)	4	1.42%
21.	Cypriniformes	Cyprinidae	*Crossocheilus latius* (Hamilton, 1822)	3	1.06%
22.	Siluriformes	Sisoridae	*Glyptothorax striatus* (McClelland, 1842)	3	1.06%
23.	Perciformes	Badidae	*Badis badis* (Hamilton, 1822)	2	0.71%
24.	Cypriniformes	Cyprinidae	*Barilius vagra* (Hamilton, 1822)	2	0.71%
25.	Siluriformes	Bagridae	*Batasio merianiensis* (Chaudhuri, 1913)	2	0.71%
26.	Cypriniformes	Botiidae	*Botia almorhae* (Gray, 1831)	2	0.71%
27.	Cypriniformes	Cyprinidae	*Cirrhinus cirrhosus* (Bloch, 1795)	2	0.71%
28.	Cypriniformes	Cyprinidae	*Pethia conchonius* (Hamilton, 1822)	2	0.71%
29.	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* (Hamilton, 1822)	1	0.35%
30.	Siluriformes	Bagridae	*Olyra longicaudata* (McClelland, 1842)	1	0.35%
31.	Siluriformes	Erethistidae	*Pseudolagovia shawi* (Hora, 1921)	1	0.35%
32.	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	1	0.35%
			Total	**282**	**100%**

Table 3. 2: Fishes found in all the aquatic plots

SN	Species	Site
1.	*Amblyceps apangi*	Aquatic Plot 1
2.	*Balitora brucei*	
3.	*Bangana dero*	
4.	*Barilius barna*	
5.	*Barilius vagra*	
6.	*Botia almorhae*	
7.	*Crossocheilus latius*	
8.	*Devario aequipinnatus*	
9.	*Garra annandalei*	
10.	*Garra birostris*	
11.	*Glyptothorax striatus*	
12.	*Neolissochilus hexagonolepis*	
13.	*Pseudecheneis sulcata*	
14.	*Schistura devdevi*	
15.	*Amblyceps apangi*	Aquatic Plot 2
16.	*Badis badis*	
17.	*Balitora brucei*	
18.	*Bangana dero*	

19.	*Barilius barna*	
20.	*Cirrhinus cirrhosus*	
21.	*Garra annandalei*	
22.	*Garra birostris*	
23.	*Neolissochilus hexagonolepis*	
24.	*Pseudolagovia shawi*	
25.	*Psilorhynchus balitora*	
26.	*Schistura devdevi*	
27.	*Glyptothorax striatus*	Aquatic Plot 3
28.	*Neolissochilus hexagonolepis*	
29.	*Pseudecheneis sulcata*	
30.	*Schistura devdevi*	
31.	*Schizothorax richardsonii*	
32.	*Amblyceps apangi*	Aquatic Plot 4
33.	*Barilius barna*	
34.	*Garra annandalei*	
35.	*Garra birostris*	
36.	*Neolissochilus hexagonolepis*	
37.	*Pseudecheneis sulcata*	
38.	*Psilorhynchus balitora*	
39.	*Schistura devdevi*	
40.	*Schizothorax richardsonii*	
41.	*Amblyceps apangi*	Aquatic Plot 5
42.	*Barilius barna*	
43.	*Garra annandalei*	
44.	*Garra birostris*	
45.	*Neolissochilus hexagonolepis*	
46.	*Pseudecheneis sulcata*	
47.	*Psilorhynchus balitora*	
48.	*Schistura devdevi*	
49.	*Schizothorax richardsonii*	

3.1.2. Description of fishes in different plots

Aquatic Plot 1

Table 3. 3: Details of the fishes found in Aquatic Plot 1 During the monsoon

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1.	*Amblyceps apangi*	Very coarse gravel (32-64 mm)	1	34	0.2	26.94321469	90.51939142
2.	*Balitora brucei*	Big stones (256-384 mm)	1	50	0.4	26.94059246	90.51783546
3.	*Bangana dero*	Big stones (256-384 mm)	2	50	0.4	26.94059246	90.51783546
4.	*Bangana dero*	Small stones (64-128 mm)	2	46	0.3	26.94197444	90.51935342

5.	*Barilius barna*	Big stones (256-384 mm)	6	27-50	0.2-0.4	26.93885201	90.5149557
6.	*Barilius vagra*	Big stones (256-384 mm)	1	50	0.4	26.94059246	90.51783546
7.	*Botia almorhae*	Small stones (64-128 mm)	1	48	0.4	26.94114862	90.51860634
8.	*Crossocheilus latius*	Big stones (256-384 mm)	1	50	0.4	26.94059246	90.51783546
9.	*Devario aequipinnatus*	Very coarse gravel (32-64 mm)	2	34	0.2	26.94321469	90.51939142
10.	*Garra annandalei*	Big stones (256-384 mm)	3	40-50	0.2-0.4	26.93885201	90.5149557
11.	*Garra birostris*	Big stones (256-384 mm)	5	34-50	0.2-0.4	26.94321469	90.51939142
12.	*Glyptothorax striatus*	Big boulders (>512 mm)	1	85	0.5	26.94261811	90.5195077
13.	*Neolissochilus hexagonolepis*	Small stones (64-128 mm)	4	34-46	0.2-0.3	26.94197444	90.51935342
14.	*Pseudecheneis sulcata*	Big boulders (>512 mm)	4	46-85	0.3-0.5	26.94261811	90.5195077
15.	*Schistura devdevi*	Big stones (256-384 mm)	1	40	0.2	26.93885201	90.5149557

Figure 3. 1: Location and habitat of Aquatic Plot 1 with water spread across the cross section of the river bed.

Figure 3. 3: Fishes found in aquatic plot 1: *Neolissochilus hexagonolepis* (Left) and *Bangana dero* (Right)

Aquatic Plot 1 during the monsoon season recorded an a ssemblage of 15 different fish species. The most commonly observed species were *Barilius barna* and *Garra birostris*, exhibiting preferences for larger stone substrates and moderate flow velocities. Notably, species like *Pseudecheneis sulcata* and *Glyptothorax striatus* were found in deeper waters with higher velocities, particularly associated with large boulders, indicating their adaptation to more turbulent conditions. The plot was characterized by wide floodplain containing the main river flow on one side and tributaries formed towards the other bank from the same main river. There was a waterfall about 100 meters upstream of the bridge which was well oxygenated and provided a cooler water temperature to the flowing water nearby. The range of depths and

Figure 3. 2: *Glyptothorax striatus* recorded from plot 1

flow velocities suggests a suitable environment that supports a variety of ecological niches, potentially making this site a crucial habitat for maintaining fish diversity in the area.

Aquatic Plot 2

Aquatic Plot 2 recorded ten species. *Garra birostris* was the most abundant, followed by *Barilius barna* and *Garra annandalei*. The river stretch also had a confluence for the two streams joining together near the plot.The depth of the water varied from 35 cm to 65 cm, while the flow velocity ranged between 0.3 m/s and 1.3 m/s, with most fish preferring larger stones as their substratum. The habitat diversity, with a mix of big boulders and stones, likely contributed to the high species richness observed. The presence of diverse substrata, including big stones and boulders, along with varying depths and velocities, likely supports a more complex habitat structure, encouraging higher species richness.

Table 3. 4: Details of the fishes found in Aquatic Plot 2 during the monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	*Amblyceps apangi*	Big boulders (>512 mm)	2	35	1.3	26.85789806	90.53082691
2	*Amblyceps apangi*	Small stones (64-128 mm)	3	35	1.3	26.85789806	90.53082691
3	*Amblyceps apangi*	Big stones (256-384 mm)	7	35-56	0.3-0.9	26.85245184	90.52611044
4	*Badis badis*	Big stones (256-384 mm)	1	55	0.9	26.85665455	90.53261006
5	*Balitora brucei*	Big stones (256-384 mm)	4	56	0.9	26.85245184	90.52611044
6	*Bangana dero*	Big stones (256-384 mm)	1	55	0.9	26.85665455	90.53261006

Figure 3. 4: Aquatic plot 2: confluence near the plot (Left) and river stretch (Right)

7	*Barilius barna*	Big stones (256-384 mm)	11	35-56	0.4-0.9	26.85789806	90.53082691
8	*Cirrhinus cirrhosus*	Big stones (256-384 mm)	1	55	0.9	26.85665455	90.53261006
9	*Garra annandalei*	Big stones (256-384 mm)	10	55-65	0.6-0.9	26.8540198	90.52721055
10	*Garra birostris*	Big stones (256-384 mm)	13	35-55	0.4-1.3	26.85789806	90.53082691

Figure 3. 5: *Barilius barna* recorded in abundant from most of the sites including plot 2

Aquatic Plot 3

Details of the fishes found in Aquatic Plot 3 in monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	*Aborichthys elongatus*	Sand	3	40-53	0.3-0.6	26.84810974	90.53748917
2	*Amblyceps apangi*	Sand	2	24-53	0.1-0.6	26.84678828	90.53491772
3	*Badis badis*	Sand	1	19	0.1	26.84642829	90.5321491
4	*Barilius barna*	Medium gravel	5	22-40	0.1-0.4	26.84810974	90.53748917
5	*Barilius bendelisis*	Medium to coarse gravel	9	22-40	0.1-0.4	26.84810974	90.53748917
6	*Channa striata*	Coarse gravel	7	19-24	0.1	26.84678828	90.53491772
7	*Cyprinion semiplotus*	Coarse gravel	3	21	0.4	26.84540269	90.53054138

8	*Danio dangila*	Coarse gravel	6	22-40	0.3-0.4	26.84810974	90.53748917
9	*Devario aequipinnatus*	Coarse gravel	1	40	0.3	26.84810974	90.53748917
10	*Garra annandalei*	Coarse gravel	6	22-53	0.1-0.6	26.84563625	90.53375204
11	*Garra birostris*	Coarse gravel	3	24-53	0.1-0.6	26.84678828	90.53491772
12	*Mastacembelus armatus*	Coarse gravel	2	40-53	0.3-0.6	26.84810974	90.53748917
13	*Neolissochilus hexagonolepis*	Coarse gravel	2	40	0.3	26.84810974	90.53748917
14	*Olyra longicaudata*	Coarse gravel	1	53	0.6	26.84919889	90.53565462
15	*Oreichthys crenucoides*	Coarse gravel	6	21-40	0.1-0.4	26.84810974	90.53748917
16	*Psilorhynchus balitora*	Coarse gravel	3	24	0.1	26.84678828	90.53491772

Figure 3. 6: Stretch where the Aquatic plot 3 was sampled (Left) and the fishes caught (Right)

Aquatic Plot 3 was located near Umling *gewog.* A total of 60 fish distributed across 16 species was recorded from the plot. The most common species were *Barilius bendelisis* and *Garra annandalei*, each showing a broad range of depth preferences from 22 to 53 cm. The habitat substratum primarily consisted of coarse gravel, supporting various species like *Channa striata* and *Neolissochilus hexagonolepis*. The main river in the region was divided into smaller tributaries due to the floodplain and the wide cross-section of the riverbed. The stretch where the sampling was conducted was in the smaller section of the river as the main river was not accessible due to higher currents and depth. The velocity of the river stretch where fishes were sampled ranged from 0.1 to 0.6 m/s, with deeper sections associated with faster currents.

The diverse species assemblage indicates a stable habitat with sufficient resources to support multiple species.

Figure 3. 8: The longest *Mastacembelus armatus* was caught from the stretch

Figure 3. 7: *Neolissochilus hexagonolepis* recorded in plot 3.

Aquatic Plot 4

Table 3. 5: Details of the fishes found in Aquatic Plot 4 in monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1.	*Amblyceps apangi*	Big stones (256-384 mm)	1	42	1.1	26.862907	90.502803
2.	*Bangana dero*	Small stones (64-128 mm)	1	39	0.2	26.865019	90.503679
3.	*Barilius barna*	Sand	1	53	0.3	26.865780	90.503976
4.	*Barilius barna*	Small stones (64-128 mm)	1	39	0.2	26.865019	90.503679
5.	*Barilius bendelisis*	Sand	1	53	0.3	26.865780	90.503976

6.	*Batasio merianiensis*	Sand	1	53	0.3	26.865780	90.503976
7.	*Channa striata*	Big stones (256-384 mm)	1	42	1.1	26.862907	90.502803
8.	*Channa striata*	Sand	1	53	0.3	26.865780	90.503976
9.	*Crossocheilus latius*	Small stones (64-128 mm)	1	38	0.6	26.862247	90.502361
10.	*Devario aequipinnatus*	Sand	1	53	0.3	26.865780	90.503976
11.	*Devario aequipinnatus*	Sand	1	53	0.3	26.865780	90.503976
12.	*Garra annandalei*	Big stones (256-384 mm)	8	42	1.1	26.862907	90.502803
13.	*Garra annandalei*	Small stones (64-128 mm)	6	38	0.6	26.862247	90.502361
14.	*Garra birostris*	Big stones (256-384 mm)	2	39	1.0	26.862907	90.502803
15.	*Garra birostris*	Coarse gravel (16-32 mm)	1	46	0.9	26.864587	90.503015
16.	*Garra birostris*	Sand	1	53	0.3	26.865780	90.503976
17.	*Glyptothorax trilineatus*	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
18.	*Mastacembelus armatus*	Small stones (64-128 mm)	2	39	0.2	26.865019	90.503679
19.	*Neolissochilus hexagonolepis*	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
20.	*Neolissochilus hexagonolepis*	Sand	1	53	0.3	26.865780	90.503976
21.	*Pseudolaguvia shawi*	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
22.	*Psilorhynchus balitora*	Small stones (64-128 mm)	1	38	0.6	26.862247	90.502361
23.	*Schistura reticulofasciata*	Big stones (256-384 mm)	4	39	1.0	26.862907	90.502803
24.	*Schistura reticulofasciata*	Small stones (64-128 mm)	6	39	0.2	26.865019	90.503679

Aquatic Plot 4 is located downstream of the Gelephu toward just above the border to India and it is specifically located about 500 meters downstream of a dredging site. The plot is not on the main river, however, towards the tributary formed by the main river towards the Gelephu town. The plot recorded a high diversity of fish species, with a total of 24 individuals representing 17 species. The most abundant species was *Garra annandalei*, followed by *Schistura reticulofasciata*. The site exhibited varying depths and velocities, with substrates ranging from sand to large stones. This diversity indicates a well-structured habitat that supports a range of ecological niches, suggesting a relatively healthy aquatic environment.

Figure 3. 9: ***Mastacembelus armatus*** **recorded from the plot 4**

Figure 3. 10: The plot 4 is a river diverted from the main Mau Khola river.

Aquatic Plot 5

Table 3. 6: Details of the fishes found in aquatic plot 5 in monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	*Aborichthys elongatus*	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073

2	*Amblyceps apangi*	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
3	*Amblyceps apangi*	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
4	*Barilius barna*	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
5	*Barilius barna*	Stones (128-256 mm)	2	57	1.2	26.88753646	90.51923073
6	*Batasio merianiensis*	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
7	*Botia almorhae*	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
8	*Channa striata*	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
9	*Cirrhinus cirrhosus*	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
10	*Crossocheilus latius*	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
11	*Cyprinion semiplotus*	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
12	*Cyprinion semiplotus*	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
13	*Devario aequipinnatus*	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
14	*Garra annandalei*	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
15	*Garra annandalei*	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
16	*Garra birostris*	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
17	*Garra birostris*	Medium gravel (8-16 mm)	2	28	0.2	26.88753646	90.51923073
18	*Garra birostris*	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
19	*Macrognathus pancalus*	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
20	*Pethia conchonius*	Medium gravel (8-16 mm)	2	28	0.2	26.88753646	90.51923073
21	*Puntius sophore*	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
22	*Schistura devdevi*	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
23	*Schistura devdevi*	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
24	*Schistura reticulofasciata*	Big stones (256-384 mm)	2	54	0.1	26.88486816	90.51717986

25	*Xenentodon cancila*	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073

Aquatic Plot 5 is located in Chuzagang *gewog* and the river stretch is locally known as Kalikhola and it is characterized by different habitat such as pool, run, riffle and cascade, which makes the river suitable for wide range of species. The river stretch recorded 25 fishes from 18 species. The substrates vary from small to big stones and medium gravel, with velocities ranging from 0.1 to 1.2 m/s and depths from 28 to 57 cm. The dominance of species like *Barilius barna* and *Garra birostris* in stones and gravel suggests these substrates provide preferred habitats. Variability in water velocity and depth indicates a heterogenous environment supporting various species. Species like *Xenentodon cancila* and *Macrognathus pancalus* are usually found in this stretch and the team also recorded the fishes.

Figure 3. 12: Diverse range of habitat in Aquatic plot 5

Figure 3. 11: *Cyprinion semiplotus* recorded from plot 5

3.1.2 Distribution pattern of fishes across sites and habitats

The distribution of fish species across the five aquatic plots shows pattern in relation to habitat substratum, depth, and velocity. Plot 1, near Serzhong bridge, located in a habitat dominated by large stones and big boulders, had the highest species count, particularly for species like Barilius barna and Garra birostris. This plot has varied depths and velocities, primarily ranging between 34 to 50 cm in depth and 0.2 to 0.4 m/s in velocity. The substrate composition of big stones (256-384 mm) was predominant and the water fall next to the bridge leading to well oxygenated contributed to the high diversity observed.

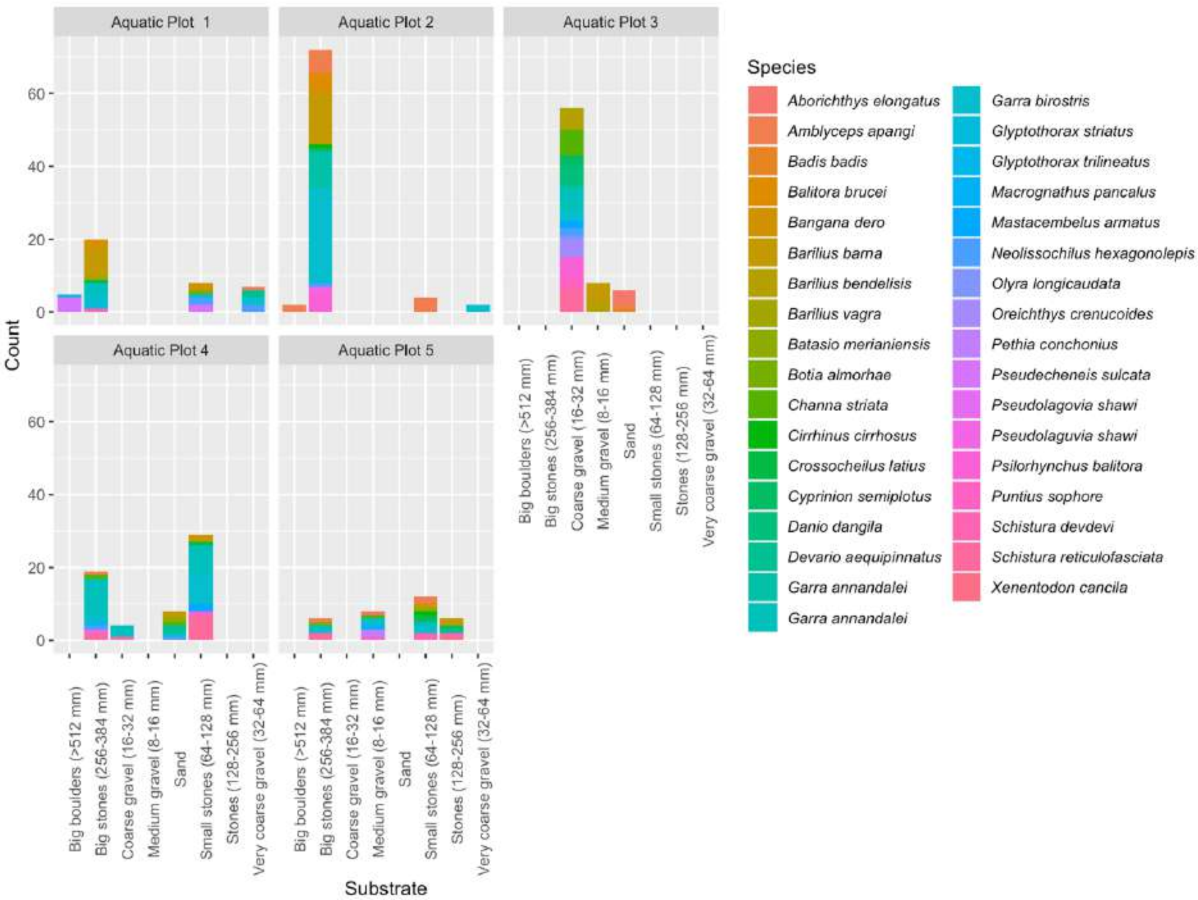


Figure 3. 13: Distribution pattern of fish across different plots and habitat substratum

In contrast, Plot 2 showed a higher occurrence of species associated with faster velocities and smaller stones or gravel. Species like Amblyceps apangi and Balitora brucei were prevalent, with velocities often reaching up to 1.3 m/s. The habitat here was largely characterized by smaller stones (64-128 mm) and big boulders (>512 mm), with depths typically around 35 to 56 cm. This plot had a specialized species composition adapted to swift currents and relatively

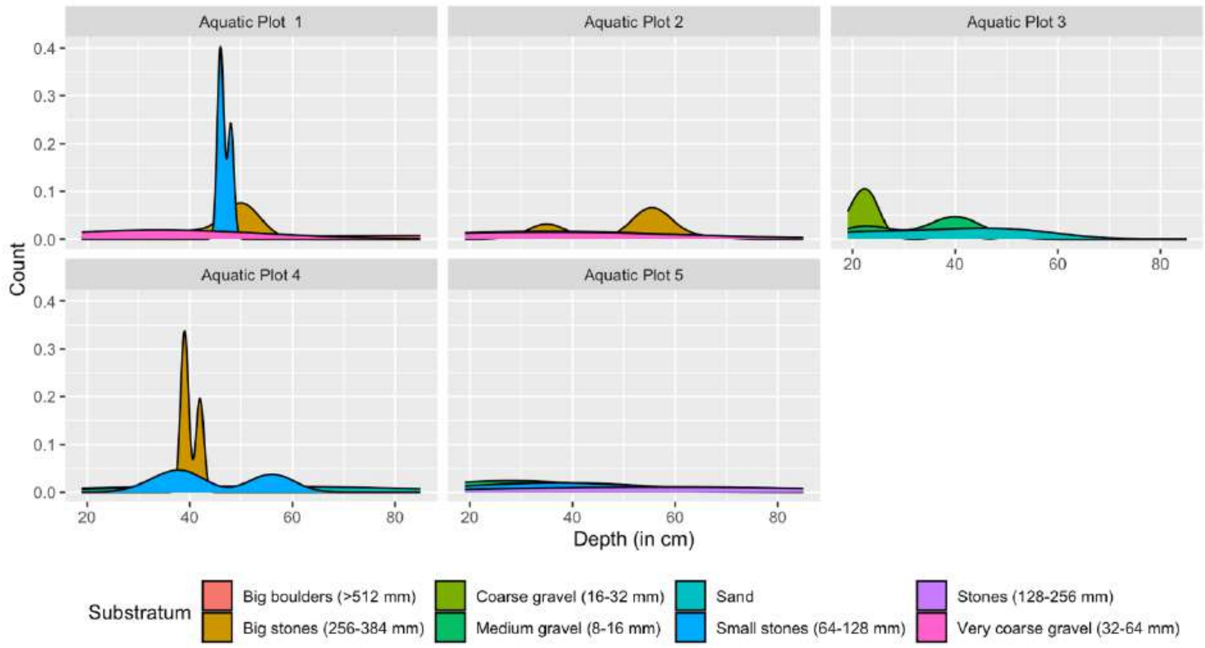


Figure 3. 15: Distribution of habitat type and water depths across plots

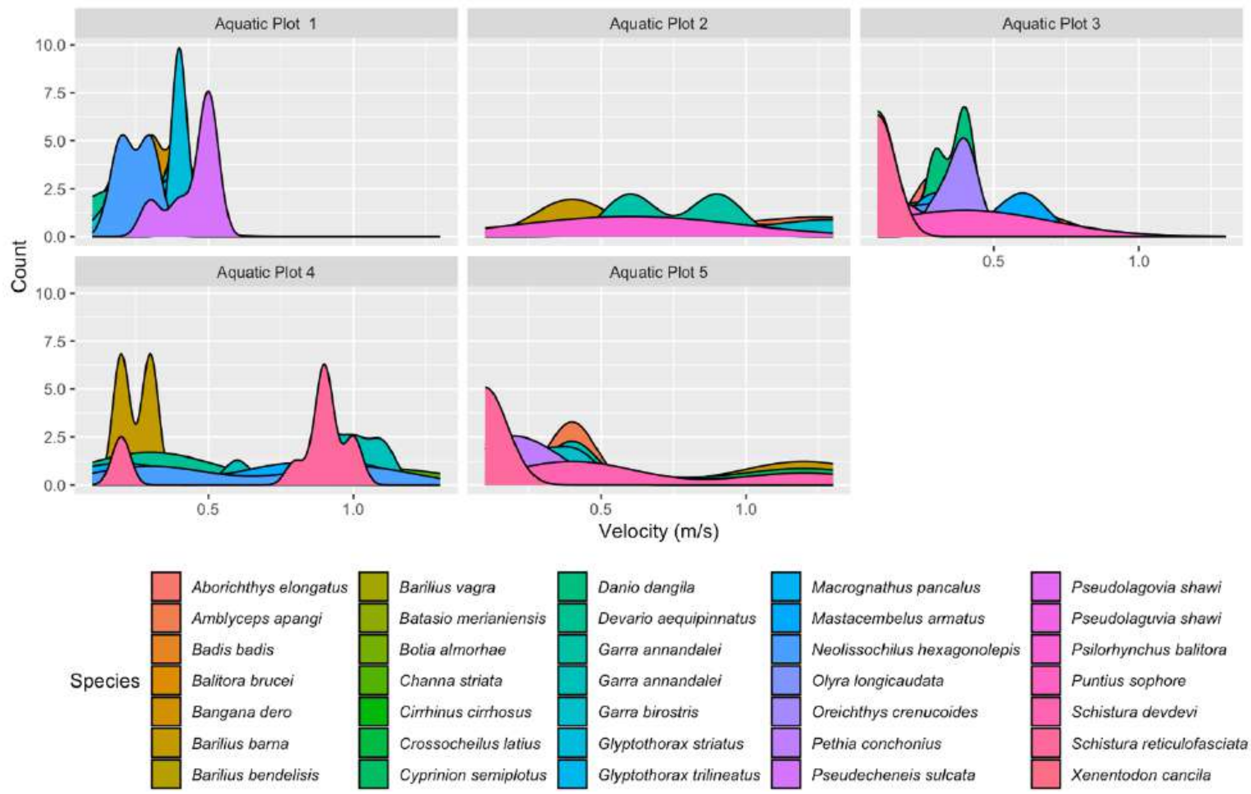


Figure 3. 14: Distribution of fishes among different plots and velocity (m/s)

shallower depths.Certain species were found to be closely associated with specific habitat conditions. For example, Barilius barna and Garra birostris were prevalent in habitats with large stones and moderate depths, while Amblyceps apangi and Balitora brucei were more common in faster-*flowing, shallower waters. The remaining plots (Plots 3 to 5) recorded a lower fish counts and species diversity, with habitats that included more varied substratum types like very coarse gravel and big stones. The velocities in these plots ranged more widely, and depths varied between 30 and 65 cm, indicating that these plots offered less favorable conditions for a diverse range of fish species compared to Plots 1 and 2. Species in these plots were more sparsely distributed, reflecting less optimal habitat conditions.*

3.1.3 Description of fish

1. ***Garra birostris***

Description: Has a prominent bi-lobed proboscis, a transverse lobe on the snout with 11-19 tubercles, and a black pigmentation on the lower caudal-fin margin.

Distribution: Found in one site, Martangchhu in Samdrup Jongkhar.

Conservation Status: Data Deficient.

2. ***Garra annandalei***

Common Names: Stone roller, chuche buduna.

Description: Dorsal-fin rays 9-10, pectoral 15, ventral 8, anal 10-12, and caudal 19. Lateral scales 38-42. The body is silvery-yellowish with a brown upper back; the mouth is inferior with a blunt snout; no barbels. Maximum length is 15 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Toorsa/Amochhu at Phuntsholing (Chukha), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

3. ***Barilius barna***

Common Names: Barna baril, titer kane faketa.

Description: Dorsal-fin rays 2/7, pectoral 15, ventral 9, anal 3/10-11, and caudal 19. Lateral scales 39-42. The body is silvery with 9-11 vertical bands crossing down the lateral line; barbels are absent. Maximum length is 10 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Toorsa/Amochhu at Phuntsholing (Chukha), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

4. ***Amblyceps apangi**:* The document does not contain specific information on this species.

5. ***Schistura reticulofasciata***

Description: The species has broad stripes and rounded caudal lobes, measuring about 6-7.8 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar).

Conservation Status: Vulnerable.

6. ***Psilorhynchus balitora***

Common Names: Balitora, balitora minnow, tite buduna

Description: Dorsal-fin rays 9-10, pectoral 17, ventral 9, anal 2/5, and caudal 18. Lateral scales 30-35. The head is depressed with blotches on the body, the mouth is ventrally placed, and barbels are absent. The maximum standard length is 7 cm.

Distribution: Found in the Manas River at Panbang, Zhemgang.

Conservation Status: Least Concern.

7. ***Channa striata***

Common Names: Chevron snakehead, striped snakehead, saura, hille

Description: Dorsal-fin rays 37-46, pectoral 17, ventral 6, anal 23-28, caudal 13, and lateral scales 50-57. The body is dark brown with darker vertical bands. The maximum length can reach up to 100 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Manas at Panbang (Zhemgang), Maukhola at Gelephu (Sarpang), and Singhikhola at Pasakha (Chukha).

Conservation Status: Least Concern.

8. ***Barilius bendelisis***

Common Names: Baril, fageta, Hamilton's barila

Synonyms: Includes various names such as *Barilius bendelisis bendelisis* and *Cyprinus apiatus*.

Distribution: Specific distribution information was not detailed for this entry, but the species is commonly found in Bhutan.

9. ***Neolissochilus hexagonolepis (McClelland, 1839)***

Distribution: Specific distribution information was not detailed in the retrieved sections, but it is commonly found in Bhutan.

10. ***Devario aequipinnatus***

Common Names: Bhitti

Description: Dorsal-fin rays 12-14, pectoral 17, ventral 8, anal 14-16, and caudal 19. The body is silvery bluish with yellow or orange stripes, sometimes interrupted at the head. The maximum length is 15 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Maukhola at Gelephu (Sarpang), Manas at Panbang (Zhemgang), Toorsa/Amochhu at Phuntsholing (Chukha), and Dhamdum in Samtse.

Conservation Status: Least Concern.

11. ***Cyprinion semiplotus***

Common Names: Assamese kingfish, chepti, rajah-mas.

Description: Dorsal-fin rays 2-4/23-25, pectoral 16, ventral 10, anal 2/7.

Distribution: Found in the tributaries of the Kurichhu.

Conservation Status: Unknown. Further study is needed to determine the full extent of its range.

12. ***Bangana dero***

Common Names: Gurdi, kalabans, river rohu.

Description: Dorsal-fin rays 3/9-10, pectoral 16-17, ventral 9, anal 3/5, caudal 19.

Distribution: Found in Manas at Panbang (Zhemgang).

Conservation Status: Least Concern.

13. ***Pseudecheneis sulcata***

Common Names: Sucker throat catfish, kabre.

Description: Dorsal-fin rays 1/6, pectoral 1/13, ventral 6, anal 2-4/7-9, caudal 17.

Distribution: Found in Sherichhu in Mongar, Budichhu in Tsirang, Kabjisa-rongchhu in Punakha, Taksachhu in Wangdue, and Gamrichhu (Trashigang).

Conservation Status: Least Concern.

14. ***Balitora brucei***

Common Names: Gray's stone loach, tite buduna.

Description: Dorsal-fin rays 3/8, pectoral 21, ventral 11, anal 6-8, caudal 17.

Distribution: Found in Maukhola at Gelephu (Sarpang), Dungsamchhu (Samdrup Jongkhar).

Conservation Status: Near Threatened.

15. ***Danio dangila***

Common Names: Dangila danio, butte bhitti.

Description: Dorsal-fin rays 11-13, pectoral 12, ventral 7, anal 17-18, caudal 20.

Distribution: Found in Maukhola at Gelephu (Sarpang) and Manas at Panbang (Zhemgang).

Conservation Status: Vulnerable.

16. ***Oreichthys crenuchoides***

Distribution: Not explicitly mentioned in the document.

Conservation Status: Not explicitly mentioned in the document.

17. ***Schistura devdevi***

Distribution: Jiti (Samtse) and Toorsa/Amochhu at Phuntsholing (Chukha).

Conservation Status: Least Concern.

18. ***Aborichthys elongatus***

Distribution: Sarpangkhola, Maukhola, and Kamikhola (Sarpang), Jiti (Samtse).

Conservation Status: Least Concern.

19. ***Mastacembelus armatus***

Distribution: Diglai in Samdrupcholing (Samdrup Jongkhar), Manas at Panbang (Zhemgang), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

20. ***Puntius sophore***

Distribution: Toorsa/Amochhu and Duteykhola at Phuntsholing (Chukha).

Conservation Status: Least Concern.

21. ***Crossocheilus latius (Hamilton, 1822)***

Common Names: Gangetic latia, minor carp, lohari.

Description: The fish has 10-11 dorsal-fin rays, 15 pectoral rays, 9 ventral rays, 7 anal rays, and 19 caudal rays. Its body is elongated with a small head and inferior mouth with a fringed upper lip. It usually has a pair of rostral barbels, and sometimes 2 pairs of barbels are present. The maximum length is 12.5 cm.

Distribution: Found in Cherichhu at Salamji (Dagana), Diglai at Samdrupcholing (Samdrup Jongkhar), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

22. ***Glyptothorax striatus (McClelland, 1842)***

Common Name: Jantaray, catfish.

Description: Features include 1/6 dorsal-fin rays, 1/10 pectoral rays, 6-7 ventral rays, 11 anal rays, and 18 caudal rays. The body is dark brown with an adhesive apparatus present on the pectoral fins. The maximum length is 20 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Dakpaichhu at Tingtibi (Zhemgang), and Dhamdum in Samtse.

Conservation Status: Near Threatened.

23. ***Badis badis (Hamilton, 1822)***

Common Names: Badis, dwarf chameleon fish, lati macha, limbuni macha.

Description: This fish has 15-18 dorsal spines, 7-10 dorsal soft rays, 12 pectoral rays, 1/5 ventral rays, 3/6-8 anal rays, and 16 caudal rays. Its body is variegated with bands of black and green, with a blotch behind the gill and a row of black blotches at the base of the dorsal fin. The maximum length is 5(-8) cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Manas at Panbang (Zhemgang), Maukhola at Gelephu (Sarpang), Dhamdum in Samtse, and Toorsa/Amochhu at Phuntsholing (Chukha).

Conservation Status: Least Concern.

24. ***Barilius vagra***

Common Names: Vagra baril, lam fageta.

Description: The fish has 9 dorsal-fin rays, 16 pectoral rays, 9 ventral rays, 13-15 anal rays, and 19 caudal rays. Its body is silvery white with 10-14 bars reaching half the body depth, and it has 2 pairs of barbels—rostral pair half as long as the head and maxillary pair very short. The maximum length is 12.5 cm.

Distribution: Found in Dagachhu at about bridge (Dagana), Diglai at Samdrupcholing (Samdrup Jongkhar), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

25. ***Batasio merianiensis***

Distribution: Not found in the provided document, further research may be necessary to provide details on this species.

26. ***Botia almorhae***

Common Name: Almora loach

Description: Not detailed in the provided excerpts.

Distribution: Not listed in the provided excerpts.

Conservation Status: Not listed in the provided excerpts.

27. ***Cirrhinus cirrhosus***

Common Names: Mrigal carp, mrigal

Description: Dorsal-fin rays 15-19, pectoral 19, ventral 9, anal 3/5, and caudal 15. It has lateral scales of 40-45 and a body height 4 to 5.5 times in total length. A slender body with a pair of short rostal barbels present.

Distribution: Found in Samdrup Jongkhar, Sarpang, and Samtse.

Conservation Status: Popular in aquaculture.

28. ***Pethia conchonius***

Common Names: Red barb, rosy barb, sidre pothi

Description: Dorsal-fin rays 3/8, pectoral 11-15, ventral 9, anal 7-8, and caudal 19. It has a deep silvery body with a large black spot above the lateral line in the peduncle region. The body is deep, silvery, with a length up to 9 cm.

Distribution: Found in Diglai at Samdrupcholing (Samdrup Jongkhar), Maukhola at Gelephu (Sarpang), and Toorsa/Amochhu at Phuntsholing (Chukha).

Conservation Status: Least Concern.

29. ***Macrognathus pancalus***

Common Names: Indian spiny eel, barred spiny eel, kathgainchi, baam

Description: Dorsal-fin rays 24-26/30-42, pectoral 17-19, anal 3/31-46, and caudal 12. The body is dark brown with a trilobed snout and a short, rounded caudal fin. The maximum length is 18 cm.

Distribution: Found in Diglai in Samdrupcholing (Samdrup Jongkhar), Manas at Panbang (Zhemgang), and Maukhola at Gelephu (Sarpang).

Conservation Status: Least Concern.

30. ***Olyra longicaudata***

Common Names: Himalayan olyra, botsingi, dharke loolee

Description: Dorsal-fin rays 7, pectoral 1/4, ventral 5, and anal 18-23. The body is slender with stripes, a forked caudal fin where the upper lobe is longer, and 8 barbels. The maximum length is 11 cm.

Distribution: Not listed in the provided excerpts.

Conservation Status: Not listed in the provided excerpts.

31. ***Pseudolagovia shawi***

Common name: None.

Synonyms: None.

Description: Dorsal-fin rays 5-8, pectoral 8-11, ventral 6-8, anal 7-9, and caudal 17. The body is grayish brown, with an adhesive apparatus featuring a central median depression. The maximum length is 2.5 cm.

32. ***Xenentodon cancila***

Common names: Freshwater garfish, kakila, kauwa, chuche bam.

Synonyms: Belone cancila (Hamilton, 1822); B. graii Sykes, 1839; Esox cancila (Hamilton, 1822); E. hindostanicus Falconer, 1868; E. indica McClelland, 1842.

Description: Dorsal-fin rays 14-18, pectoral 11, ventral 6, anal 16-18, and caudal 15. The body is elongated with 4-5 blotches, and the jaw is beak-like with sharp opposing teeth. The maximum length is 40 cm.

3.2. Macroinvertebrate composition and dominance

3.2.1. Species Composition and Dominance

For the monsoon season, a total of 535 samples of macroinvertebrates were recorded, belonging to 11 families under 9 orders. The most dominant species was *Baetis* sp. (*N*= 212) under the Baetidae family, accounting for 39.63% of the total abundance. This was followed by *Ambrysus* sp. (*N*=109) under the Naucoridae family, representing 20.37% of the total. The species diversity for the monsoon season was calculated to be H' = 1.69, species evenness E_H = 0.70, and species richness S_R = 3.67.

Table 3. 7: Diversity and relative abundance for macroinvertebrates in monsoon

SN	Order	Family	Genus	Count	RA (%)
1	Hemiptera	Naucoridae	*Ambrysus*	109	20.37
2	Trichoptera	Hydropsychidae	*Arctopsyche*	15	2.80
3	Ephemeroptera	Baetidae	*Baetis*	212	39.63
4	Diptera	Chironomidae	*Chironomus*	31	5.79
5	Diptera	Culicidae	*Culex*	4	0.75
6	Ephemeroptera	Ephemerellidae	*Drunella*	37	6.92
7	Ephemeroptera	Heptageniidae	*Heptagenia*	104	19.44
8	Decapoda	Palaemonidae	*Macrobrachium*	10	1.87
9	Plecoptera	Perlidae	*Perla*	5	0.93
10	Gastropoda	Pachychilidae	*Brotia*	3	0.56
11	Trichoptera	Rhyacophilidae	*Rhyacophila*	5	0.93
		Total Count	**535**		**100**

The high abundance of *Baetis* sp. during the monsoon season indicates that this period was particularly favorable for the reproduction and growth of this species, likely due to favorable environmental conditions such as increased water flow and nutrient availability. Overall, the dominance of *Baetis* sp., combined with the presence of other species such as *Ambrysus* sp. and *Heptagenia* sp., suggests that the aquatic ecosystem during the monsoon season supported a diverse and stable community of macroinvertebrates. However, it is also important to note that the diversity indices were low compared rivers systems which are in higher altitude and other intake ecosystem. The low diversity indices might be due to the time of data collection as there could have been flood before the data collection as the time of data collection was in mid-August. The team expects to find more diverse macroinvertebrates. Overall, the presence of indicator species such as Baetis sp. and Heptagenia sp. also reflects the overall good water quality during the monsoon season.

Figure 3. 16: Macroinvertebrate found in different aquatic plots: ***Heterocloeon (A); Heptagenia (B); Chironomus(C); Arctopsyche (D); Drunella (E); Perla (F); Macrobrachium (G); Ambrysus (H); Brotia (I)***

Table 3. 8: Macroinvertebrates found in different sites in monsoon

SN.	Site	Count	Habitat	Common Name	Latitude	Longitude
1	Aquatic Plot 1	3	Pool	Small Minnow Mayfly	26.94108942	90.51848532
2		15	Riffle	Small Minnow Mayfly	26.94108942	90.51848532
3		14	Run	Small Minnow Mayfly	26.94108942	90.51848532
4		3	Pool	Flat-headed Mayfly	26.94108942	90.51848532
5		15	Riffle	Flat-headed Mayfly	26.94108942	90.51848532
6		5	Run	Flat-headed Mayfly	26.94108942	90.51848532
7		2	Pool	Free-living Caddisfly	26.94108942	90.51848532
8		3	Pool	Small Minnow Mayfly	26.94108942	90.51848532
9		5	Riffle	Spiny Crawler Mayfly	26.94108942	90.51848532
10	Aquatic Plot 2	4	Pool	Common Stonefly	26.85662572	90.52962944
11		10	Pool	Creeping Water Beetle	26.85662572	90.52962944
12		19	Pool	Small Minnow Mayfly	26.85662572	90.52962944
13		7	Riffle	Spiny Crawler Mayfly	26.85662572	90.52962944
14		2	Riffle	Flat-headed Mayfly	26.85662572	90.52962944
15		1	Run	Common Stonefly	26.85662572	90.52962944
16		5	Run	Flat-headed Mayfly	26.85662572	90.52962944
17		3	Riffle	Creeping Water Beetle	26.85662572	90.52962944
18	Aquatic Plot 3	27	Pool	Creeping Water Beetle	26.84859487	90.53392336
19		40	Riffle	Creeping Water Beetle	26.84859487	90.53392336
20		29	Run	Creeping Water Beetle	26.84859487	90.53392336
21		68	Riffle	Small Minnow Mayfly	26.84859487	90.53392336
22		8	Riffle	Net-spinning Caddisfly	26.84859487	90.53392336
23		10	Run	Small Minnow Mayfly	26.84859487	90.53392336
24	Aquatic Plot	7	Pool	Small Minnow Mayfly	26.86453678	90.50309306
25		12	Riffle	Small Minnow Mayfly	26.86453678	90.50309306

26		5	Run	Small Minnow Mayfly	26.86453678	90.50309306
27		8	Pool	Flat-headed Mayfly	26.86453678	90.50309306
28	Aquatic Plot 5	7	Pool	Small Minnow Mayfly	26.88459181	90.51680404
29		12	Riffle	Small Minnow Mayfly	26.88459181	90.51680404
30		11	Run	Small Minnow Mayfly	26.88459181	90.51680404
31		7	Riffle	Spiny Crawler Mayfly	26.88459181	90.51680404

Mayfly fauna such as *Baetis* sp. are qualified bioindicators for water quality monitoring. Species under the order Ephemeroptera such as mayflies are very sensitive to pollution, and as such, are usually only found at high-quality, minimally polluted sites. Along with caddisflies and stoneflies, they are one of the three most commonly used indices of aquatic ecosystem health. Because they are found in a wide variety of habitats and are so widely sensitive to pollution, they are valuable indicators of water pollution. Their presence in an ecosystem is an indication of good water quality. The Ephemeroptera was dominant order in the sites. The dominance could be due to their adaptivity to different ecological niche and wide range of food source (Miess et al., 2022).

3.2.2. Distribution Pattern of macroinvertebrates across different habitat and sites.

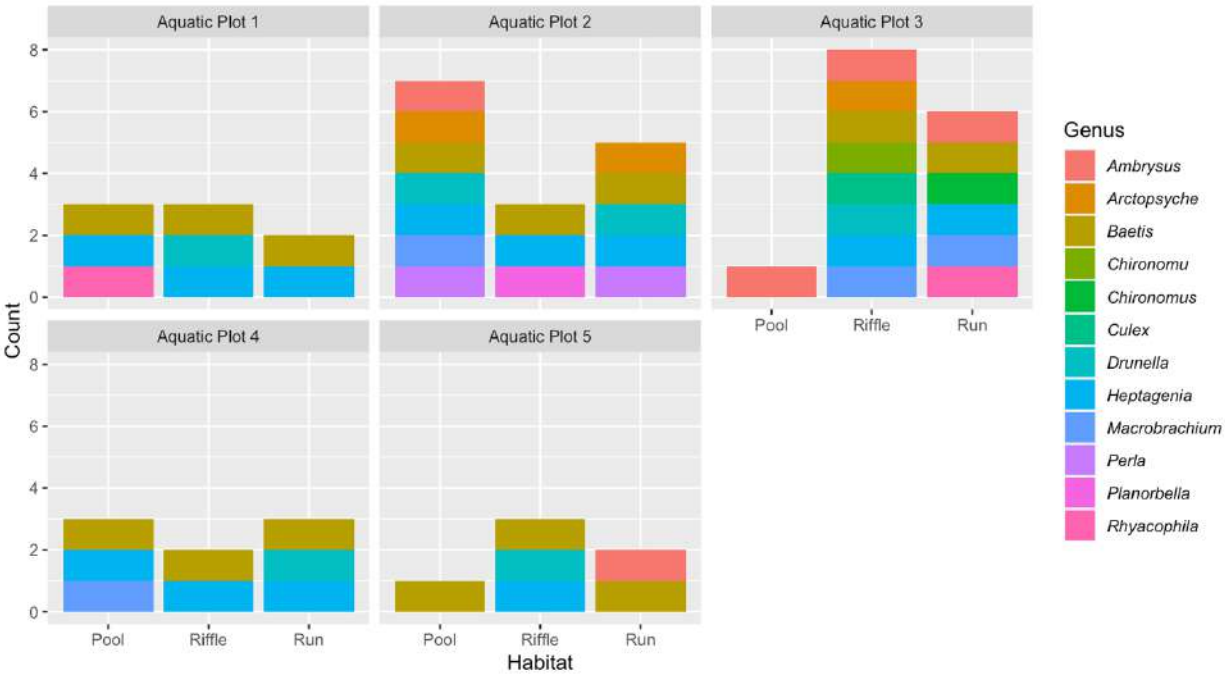


Figure 3. 17: Distribution of macroinvertebrates by Genus across plots and habitat. Aquatic plot 3 has the highest abundance

The distribution of macroinvertebrate across different sampling sites shows that Aquatic Plot 3 has the highest overall count of macroinvertebrates, with a significant presence of Creeping Water Beetles (*Ambrysus*) and Small Minnow Mayflies (*Baetis*). Specifically, the Creeping Water Beetle population peaks with 40 individuals in the riffle habitat, while the Small Minnow Mayflyreaches 68 individuals in the same habitat. This site also displays a diverse array of pollution tolerance levels, ranging from the highly tolerant *Culex* mosquitoes (tolerance level 10) to the more sensitive Spiny Crawler Mayflies (tolerance level 2). This diversity suggests a relatively stable environment in terms of water quality, supporting a range of species with varying pollution tolerances.

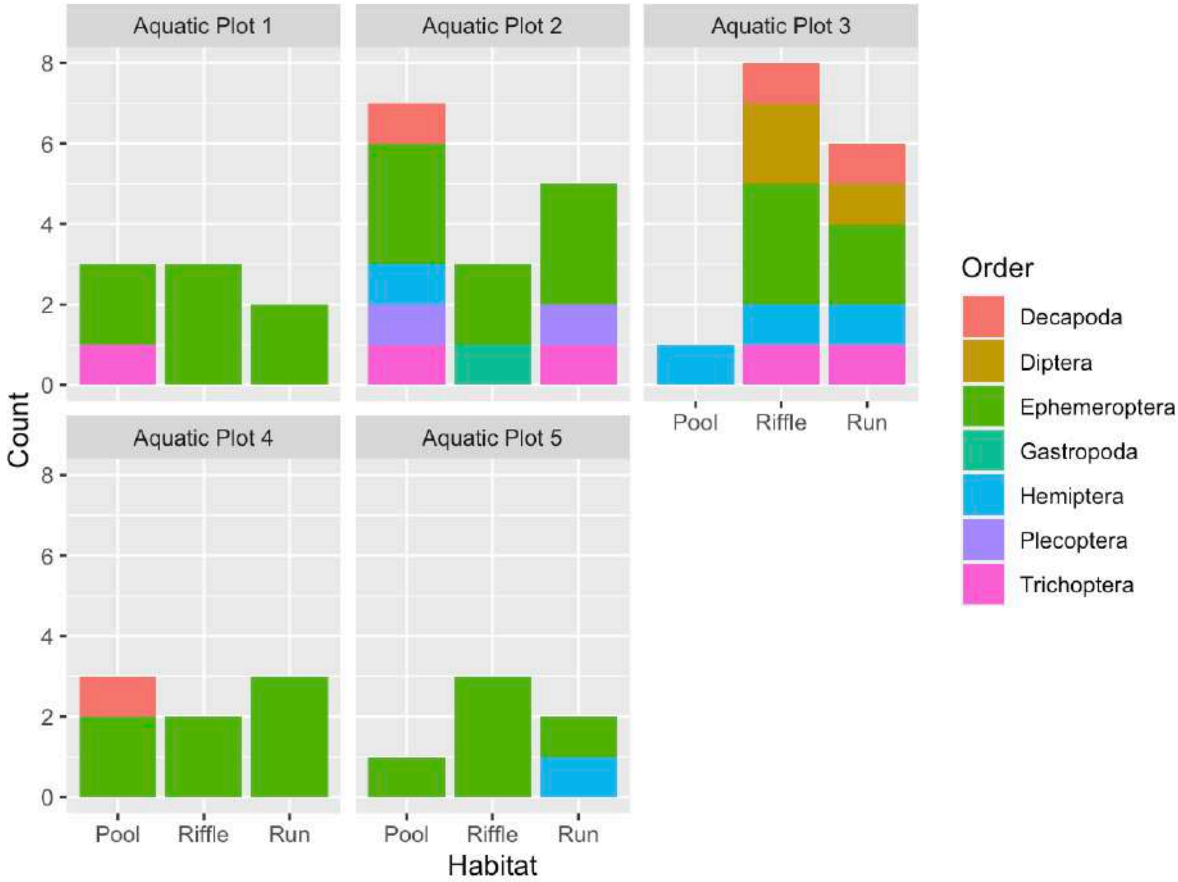


Figure 3. 18: Distribution of macroinvertebrates by Order across plots and habitat. Aquatic plot 3 has the highest abundance

In contrast, Aquatic Plot 1 shows a lower overall count, with a notable absence of high counts in any single species category. While it does host species like Flat-headed Mayflies (*Heptagenia*) and Small Minnow Mayflies, their numbers are lower compared to those in Aquatic Plot 3. The pollution tolerance levels of the species here also vary, but the overall abundance and diversity are less pronounced, which could indicate either lower habitat quality or less favorable conditions compared to other plots.

Aquatic Plot 2 falls in between, with notable high counts for Small Minnow Mayflies reaching up to 19 individuals in both pool and riffle habitats. This plot also features a mix of high and low pollution tolerance species, such as the highly tolerant Lamarck's Prawn (tolerance level 8) and Net-spinning Caddisflies (tolerance level 4). The diversity of macroinvertebrates at Plot

2, coupled with its varied pollution tolerance levels, suggests a moderately stable environment but not as robust as Aquatic Plot 3.

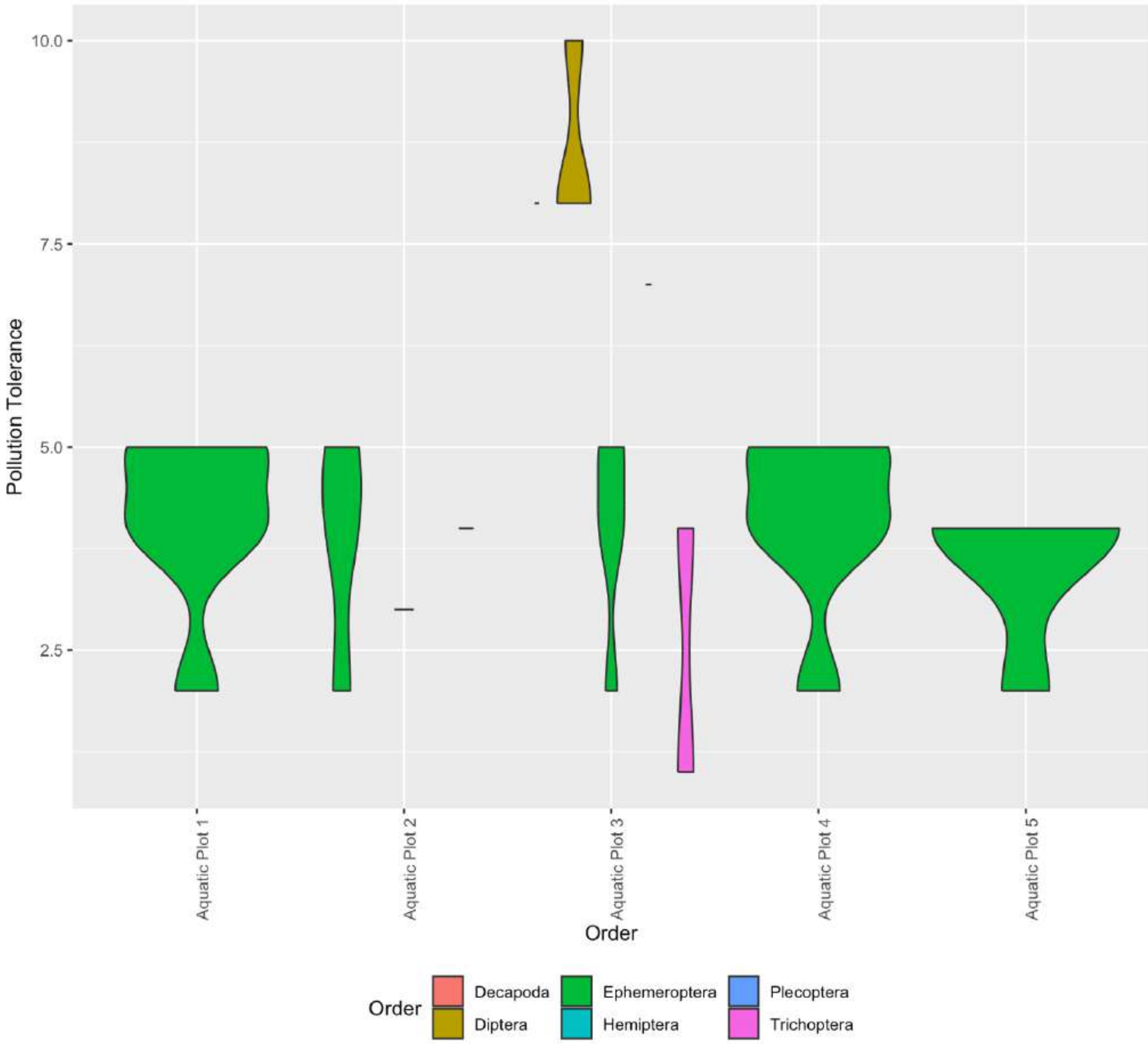


Figure 3. 19: Pollution tolerance level (out of 10) across 5 aquatic plots

Overall, the macroinvertebrates survey from the monsoon indicates that Aquatic Plot 3 is the most ecologically diverse and resilient site, while Aquatic Plot 1 may face environmental stress or limitations. Wangchuk & Dorji (2018) also found that, species distribution is more in run and riffles compared to pool (Gurung et al., 2014) & (UWICER ,2018).

4 CONCLUSION

The biodiversity baseline survey conducted for the Gelephu Mindfulness City project studied the current state of aquatic biodiversity with focus on fish and macroinvertebrats in the proposed development area. For the monsoon season, a total of 282 fishes were encountered, representing 32 species from eight families across various sampling stretches. The most dominant species was *Garra birostris* (*N* = 53, Relative Abundance [*RA*] = 18.79%), followed by *Garra annandalei* (*N* = 41, *RA* = 14.54%). For macroinvertebrates, a total of 535 samples were recorded, belonging to 11 families under 9 orders. The most dominant species was *Baetis* sp. (*N*= 212) under the Baetidae family, accounting for 39.63% of the total abundance. The survey confirmed the absence of any species classified as critically endangered or endangered by the IUCN Red List, suggesting that while the area supports a rich variety of aquatic life, it does not currently have species at significant risk of extinction.

The spatial distribution patterns observed during the survey showed that certain habitats such as Aquatic Plots 2 and 3 within the project area support more diverse and abundant communities. For macroinvertebrates, Aquatic Plot 3 has the highest abundance (*N*= 119, while Aquatic Plot 2 has the highest diversity (*N*=8). On the other hand, for fishes, Aquatic Plot 3 has the highest diversity (*N*=27) while Aquatic Plot 2 has the highest abundance (*N*=82). Areas with slower flow velocities and abundant vegetation were found to have higher macroinvertebrate diversity, whereas fast-flowing sections of the river were dominated by fewer, more specialized fish species. These findings suggest that the proposed infrastructure development could have varying impacts on different sections of the river, necessitating a habitat-specific approach.

In conclusion, the data collected from this survey will serve as a reference point against which future changes can be measured, providing early warning signs of potential ecological degradation. Continued monitoring and adaptive management strategies will be essential to mitigate the impacts of construction activities on the aquatic ecosystems, ensuring that the region's biodiversity is preserved despite the development.

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