



BASELINE SURVEY FOR AQUATIC INVERTEBRATES AND FISHES GELEPHU MINDFULNESS CITY

REPORT



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COLLEGE OF NATURAL RESOURCES



TABLE OF CONTENTS

Acronyms/Abbreviations	iv
1 Introduction	1-1
1.1 <i>Executive Summary</i>	1-1
1.2 <i>Key Literature Review</i>	1-2
1.2.1 <i>Ichthyology and environmental challenges in Bhutan</i>	1-2
1.2.2 <i>Macroinvertebrates diversity and distribution</i>	1-2
2 Materials and Methods	2-1
2.1 <i>Study area</i>	2-1
2.2 <i>Materials required</i>	2-2
2.3 <i>Sampling design</i>	2-3
2.4 <i>Data collection</i>	2-3
2.4.1 <i>Fish sampling</i>	2-3
2.4.2 <i>Macroinvertebrate sampling</i>	2-4
2.4.3 <i>Water Quality</i>	2-4
2.4.4 <i>Data analysis</i>	2-4
3 Result and Discussion	3-1
3.1 <i>Fishes</i>	3-1
3.1.1 <i>Species composition and dominance</i>	3-1
3.1.2 <i>Description of fishes in different plots</i>	3-3
3.1.2 <i>Distribution pattern of fishes across sites and habitats</i>	3-23
3.1.3 <i>Description of fish</i>	3-29
3.2 <i>Macroinvertebrate composition and dominance</i>	3-46
3.2.1 <i>Species Composition and Dominance</i>	3-47
3.2.2 <i>Distribution Pattern of macroinvertebrates across different habitat and sites</i> ..	3-52
4 Conclusion	4-1
5 Reference	5-1



List of Figures

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

Figure 2. 3: YSI ProDSS Multiparameter Water Quality Meter and PCS Testr used for water quality measurement..... 2-2

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

Figure 2. 5: Use of different techniques for fish sampling..... 2-3

Figure 3. 1: Location and habitat of Aquatic Plot 1 with water spread across the cross section of the river bed. 3-5

Figure 3. 2: *Glyptothorax striatus* recorded from plot 1..... 3-5

Figure 3. 3: Fishes found in aquatic plot 1: *Neolissochilus hexagonolepis* (Left) and *Bangana dero* (Right)..... 3-6

Figure 3. 4: Habitat substratum primarily ranged from big stones to large boulders during post-monsoon season..... 3-7

Figure 3. 5: Aquatic plot 2: confluence near the plot (Left) and river stretch (Right) 3-8

Figure 3. 6: *Barilius barna* recorded in abundant from most of the sites including plot 2 3-9

Figure 3. 7: Fishes caught during the post-monsoon season from Plot 2. The confluence makes an important ground for the fishes to thrive (right). 3-11

Figure 3. 8: Stretch where the Aquatic plot 3 was sampled (Left) and the fishes caught (Right) 3-12

Figure 3. 9: *Neolissochilus hexagonolepis* recorded in plot 3..... 3-13

Figure 3. 10: The longest *Mastacembelus armatus* was caught from the stretch..... 3-13

Figure 3. 11: Fish caught from one of the sites from Plot 3 (left) and dry habitat from the plot (right) during the post-monsoon season. 3-14

Figure 3. 12: *Mastacembelus armatus* recorded from the plot 4 3-16

Figure 3. 13: The plot 4 is a river diverted from the main Mau Khola river. 3-17

Figure 3. 14: Fishes from few sites in Plot 4 (first two left); typical habitat and stream bed in plot 4 (latter two right) durring the post-monsoon season..... 3-18

Figure 3. 15: *Cyprinion semiplotus* recorded from plot 5 3-20

Figure 3. 16: Diverse range of habitat in Aquatic plot 5..... 3-20

Figure 3. 17: Fishes found in the plot 5 (left) and aquatic habitat with streams (right) in post-monsoon season..... 3-22

Figure 3. 18: Distribution pattern of fish across different plots and habitat substratum 3-23

Figure 3. 19: Distribution of fishes among different plots and velocity (m/s)..... 3-24

Figure 3. 20: Distribution of habitat type and water depths across plots 3-25

Figure 3. 21: Distribution pattern of fish across different plots and habitat substratum during the post-monsoon 3-26

Figure 3. 22: Distribution of fishes among different plots and velocity (m/s) in post-monsoon 3-27

Figure 3. 23: Distribution of habitat type and water depths across plots in post-monsoon 3-27

Figure 3. 24: Macroinvertebrate found in different aquatic plots: *Heterocloeon* (A); *Heptagenia* (B); *Chironomus*(C); *Arctopsyche* (D); *Drunella* (E); *Perla* (F); *Macrobrachium* (G); *Ambrysus* (H); *Brotia* (I) 3-49

Figure 3. 25: Distribution of macroinvertebrates by Genus across plots and habitat during monsoon. Aquatic plot 3 has the highest abundance 3-52

Figure 3. 26: Distribution of macroinvertebrates by Order across plots and habitat during monsoon 3-53



Figure 3. 27: Distribution of macroinvertebrates by Order across plots and habitat during post-monsoon 3-54
 Figure 3. 28: Distribution of macroinvertebrates by Genus across plots and habitat during post-monsoon 3-54
 Figure 3. 29: Fast flowing and well oxygenated water systems in most of the aquatic plots. 3-55

List of Table

Table 2. 1: Details of methods used to analyse different water quality parameters. 2-4

Table 3. 1: Species diversity and relative abundance of fishes for monsoon 3-1
 Table 3. 2: Species diversity and relative abundance of fishes for post-monsoon 3-2
 Table 3. 3: Details of the fishes found in Aquatic Plot 1 during the monsoon..... 3-4
 Table 3. 4: Details of the fishes found in Aquatic Plot 1 during the post-monsoon..... 3-6
 Table 3. 5: Details of the fishes found in Aquatic Plot 2 during the monsoon season 3-8
 Table 3. 6:Details of the fishes found in Aquatic Plot 2 during the post-monsoon season .. 3-9
 Table 3. 7: Details of the fishes found in Aquatic Plot 3 during the post-monsoon season 3-13
 Table 3. 8: Details of the fishes found in Aquatic Plot 4 in monsoon season 3-15
 Table 3. 9: Details of the fishes found in Aquatic Plot 4 during the post-monsoon season 3-17
 Table 3. 10: Details of the fishes found in aquatic plot 5 in monsoon season 3-19
 Table 3. 11: Details of the Fishes Found in Aquatic Plot 5 During the Post-Monsoon Season 3-21
 Table 3. 12: Diversity and relative abundance for macroinvertebrates in monsoon 3-47
 Table 3. 13: Diversity and Relative Abundance for Macroinvertebrates in Post-Monsoon 3-48
 Table 3. 14: Macroinvertebrates found in different sites in monsoon 3-49
 Table 3. 15: Macroinvertebrates found in different sites in post-monsoon 3-50



ACRONYMS/ABBREVIATIONS

AVFM	Area Velocity Flow Meter
YSI	Yellow Springs Instruments
DSS	Digital Sampling System
TDS	Total Dissolved Solids
pH	Potential of Hydrogen
DO	Dissolved Oxygen
GPS	Global Positioning System
H	Shannon Diversity Index
S _R	Species Richness
E _H	Evenness
EPT	Ephemeroptera, Plecoptera, and Trichoptera
NRCRLF	National Research Centre for Riverine and Lake Fisheries
PCS	Portable Colorimeter System



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.

In total, 35 fish species from 14 families were recorded across both seasons of the study. For the monsoon season, 282 fish were encountered, representing 32 species under eight families. The dominant species were *Garra birostris* and *Garra annandalei*, which accounted for 18.79% and 14.54% of the total fish count, respectively. In contrast, the post-monsoon season recorded a higher total of 849 fish, representing 28 species under nine families. *Garra annandalei* emerged as the dominant species in this season, comprising 27.21% of the total samples.

There were 14 species of macroinvertebrates recorded from seven orders and 14 families from both the seasons. The Baetidae family, particularly the genus *Baetis*, was the most abundant, contributing 39.63% to the total abundance. In the monsoon season, 535 macroinvertebrate samples were collected, while 498 samples were collected in the post-monsoon season. The post-monsoon showed a slight increase in the diversity index ($H' = 1.90$) and species richness ($S_R = 4.82$), indicating a moderate recovery and stabilization of the ecosystem after the monsoon.

In summary, the survey found no species classified as critically endangered or endangered by the IUCN Red List, suggesting that the biodiversity of the area, while rich, is not currently at significant risk of extinction. The dominance of species from the Cyprinidae and Baetidae families highlights the ecological significance of these groups in sustaining local aquatic ecosystems. The findings from this survey provide valuable baseline data that will guide future conservation and mitigation efforts, ensuring that the environmental impacts of the Gelephu Mindfulness City project are minimized, and that biodiversity is preserved for future generations.



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 km² (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



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



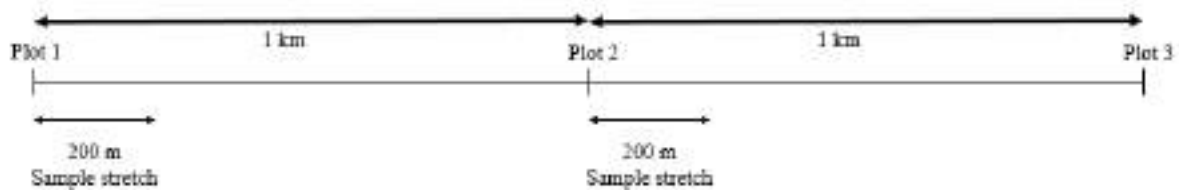
Figure 2. 3: The AVFM 6.1 Area Velocity Flow Meter used for velocity and depth. sample from more than one habitat (McIntosh et al., 2019).

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



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 macroinvertebrates 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) = $-\sum (N \cdot P_i \cdot \ln(N \cdot P_i))$ equation 1

Evenness (E) = $S / \ln(N \cdot s)$ equation 2

Species richness formula (S_R) = $(S - 1) / \ln N$ equation 3

Where P_i = 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) = $n/N \times 100$

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



Baseline survey for Aquatic Invertebrates and Fishes
Gelephu Mindfulness City



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

For the post-monsoon season, a total of 849 fishes were encountered, representing 28 species from nine families across the sampling stretches. The most dominant species was *Garra annandalei* ($N = 231$, $RA = 27.21\%$), followed by *Garra birostris* ($N = 119$, $RA = 14.02\%$). The least dominant species included *Danio dangila* and *Mystus dibrugarensis*, with only a single individual encountered each ($N = 1$, $RA = 0.12\%$).

The overall species diversity at the study site during the post-monsoon was $H' = 2.53$, with species evenness $E_H = 0.76$ and species richness $S_R = 9.22$. The species diversity was higher in monsoon season compared to the post-monsoon season, while the abundance of the species was higher in the later case.

Table 3. 2: Species diversity and relative abundance of fishes for post-monsoon

SN	Order	Family	Species	Count	RA (%)
1	Cypriniformes	Nemacheilidae	<i>Aborichthys elongatus</i> (Hora, 1921)	14	1.65



Baseline survey for Aquatic Invertebrates and Fishes
Gelephu Mindfulness City



2	Siluriformes	Amblycipitidae	Amblyceps apangi (Vishwanath & Shanta, 2004)	22	2.59
3	Perciformes	Badidae	Badis badis (Hamilton, 1822)	3	0.35
4	Cypriniformes	Cyprinidae	Barilius barna (Hamilton, 1822)	95	11.19
5	Cypriniformes	Cyprinidae	Barilius bendelisis (Hamilton, 1822)	7	0.82
6	Cypriniformes	Cyprinidae	Barilius vagra (Hamilton, 1822)	29	3.42
7	Siluriformes	Bagridae	Batasio merianiensis (Chaudhuri, 1913)	32	3.77
8	Anabantiformes	Channidae	Channa striata (Bloch, 1793)	34	4.00
9	Cypriniformes	Cyprinidae	Crossocheilus latius (Hamilton, 1822)	12	1.41
10	Cypriniformes	Cyprinidae	Cyprinion semiplotus (McClelland, 1839)	17	2.00
11	Cypriniformes	Cyprinidae	Danio dangila (Hamilton, 1822)	1	0.12
12	Cypriniformes	Cyprinidae	Devario aequipinnatus (McClelland, 1839)	19	2.24
13	Cypriniformes	Cyprinidae	Garra annandalei (Hora, 1921)	231	27.21
14	Cypriniformes	Cyprinidae	Garra birostris (Hora, 1921)	119	14.02
15	Siluriformes	Sisoridae	Glyptothorax striatus (McClelland, 1842)	14	1.65
16	Siluriformes	Sisoridae	Glyptothorax trilineatus (McClelland, 1842)	3	0.35
17	Synbranchiformes	Mastacembelidae	Macroglyphus pancalus (Hamilton, 1822)	2	0.24
18	Synbranchiformes	Mastacembelidae	Mastacembelus armatus (Lacepède, 1800)	12	1.41
19	Siluriformes	Bagridae	Mystus dibrugarensis (Chaudhuri, 1913)	1	0.12
20	Cypriniformes	Cyprinidae	Neolissochilus hexagonolepis (McClelland, 1839)	79	9.31
21	Siluriformes	Bagridae	Olyra longicaudata (McClelland, 1842)	4	0.47
22	Cypriniformes	Cyprinidae	Oreochromis crenucoides (Chu, 1981)	7	0.82
23	Siluriformes	Sisoridae	Pseudecheneis sulcata (McClelland, 1842)	4	0.47
24	Siluriformes	Erethistidae	Pseudolaguvia shawi (Hora, 1921)	34	4.00
25	Cypriniformes	Psilorhynchidae	Psilorhynchus balitora (Hamilton, 1822)	5	0.59
26	Cypriniformes	Cyprinidae	Puntius sophore (Hamilton, 1822)	5	0.59
27	Cypriniformes	Nemacheilidae	Schistura scaturigina (Hora, 1935)	41	4.83
28	Beloniformes	Belonidae	Xenentodon cancila (Hamilton, 1822)	3	0.35
			Total	849	100%

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

Aquatic Plot 1 during the monsoon season recorded an assemblage 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



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

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



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.



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

Table 3. 4: Details of the fishes found in Aquatic Plot 1 during the post-monsoon

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	<i>Barilius barna</i>	Big stones (256-384 mm)	8	39	0.4	26.94101815	90.5185074
2	<i>Batasio merianiensis</i>	Big stones (256-384 mm)	15	39	0.4	26.94101815	90.5185074
3	<i>Garra annandalei</i>	Big stones (256-384 mm)	13	39	0.4	26.94101815	90.5185074
4	<i>Garra birostris</i>	Big stones (256-384 mm)	7	39	0.4	26.94101815	90.5185074
5	<i>Neolissochilus hexagonolepis</i>	Big stones (256-384 mm)	1	39	0.4	26.94101815	90.5185074
6	<i>Barilius vagra</i>	Small boulders (384-512 mm)	13	49	0.9	26.94263763	90.51912999
7	<i>Batasio merianiensis</i>	Small boulders (384-512 mm)	10	49	0.9	26.94263763	90.51912999
8	<i>Garra birostris</i>	Small boulders (384-512 mm)	4	49	0.9	26.94263763	90.51912999



9	<i>Neolissochilus hexagonolepis</i>	Small boulders (384-512 mm)	6	49	0.9	26.94263763	90.51912999
10	<i>Batasio merianiensis</i>	Big boulders (>512 mm)	8	44	0.2	26.94061051	90.51803803
11	<i>Garra annandalei</i>	Big boulders (>512 mm)	17	44	0.2	26.94061051	90.51803803

During the post-monsoon season, Aquatic Plot 1 showed an increase in fish diversity and abundance, with a total of 206 fish recorded across 12 species and substratum types. The predominant species included *Garra annandalei* (N=31) and *Barilius barna* (N=8). The data collection period was favourable as the fishes were either about to complete their spawning stage or they were migrating to the lower reaches. We could spot increasing number of fishes in this area compared to the wet seasons. In addition to the timing of the data collection, the habitat substratum primarily ranged from big stones to large boulders, with water depths varying between 39 and 67 cm and velocities ranging from 0.2 to 0.9 m/s. This variety in substratum and flow regimes likely contributed to the observed increase in species richness and abundance.



Figure 3. 4: Habitat substratum primarily ranged from big stones to large boulders during post-monsoon season

The higher diversity and abundance of fish in post-monsoon season are likely due to improved habitat complexity and food availability facilitated by the receding water levels and stabilized hydrology.

Aquatic Plot 2

During the monsoon, 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



Figure 3. 5: Aquatic plot 2: confluence near the plot (Left) and river stretch (Right)

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. 5: 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	<i>Amblyceps apangi</i>	Big boulders (>512 mm)	2	35	1.3	26.85789806	90.53082691
2	<i>Amblyceps apangi</i>	Small stones (64-128 mm)	3	35	1.3	26.85789806	90.53082691
3	<i>Amblyceps apangi</i>	Big stones (256-384 mm)	7	35-56	0.3-0.9	26.85245184	90.52611044
4	<i>Badis badis</i>	Big stones (256-384 mm)	1	55	0.9	26.85665455	90.53261006
5	<i>Balitora brucei</i>	Big stones (256-384 mm)	4	56	0.9	26.85245184	90.52611044
6	<i>Bangana dero</i>	Big stones (256-384 mm)	1	55	0.9	26.85665455	90.53261006



Figure 3. 6: *Barilius barna* recorded in abundant from most of the sites including plot 2

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

During the post-monsoon season, the aquatic plot 2 showed a rich and varied fish count, with a total of 176 fish across 18 different species. This is also the place where *Mastacembelus armatus* and *Channa striata* were found in plenty. This habitat is also easily spotted by the illegal fisherman. We encountered local villagers who were hunting especially the eels. The fishes found in the sites were not the rare ones; however, the sites had a rich fish species as there was a water confluence just below the suspension bridge, which harbored rich fish diversity. The depth of the water varied between 19 cm to 40 cm, with the velocity ranging from 0.1 to 0.7 m/s. The substrate types recorded were mainly coarse to very coarse gravel, ranging in size from 16 to 64 mm. The most abundant species was *Garra birostris* ($N=46$), followed by *Barilius barna* ($N=42$). In contrast, some species, such as *Glyptothorax trilineatus* and *Schistura scaturigina*, were only represented by a single individual.

Table 3. 6: Details of the fishes found in Aquatic Plot 2 during the post-monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
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Baseline survey for Aquatic Invertebrates and Fishes
Gelephu Mindfulness City



1	<i>Aborichthys elongatus</i>	Very coarse gravel (32-64 mm)	4	28	0.3	26.85665039	90.53007514
2	<i>Amblyceps apangi</i>	Very coarse gravel (32-64 mm)	4	28	0.3	26.85665039	90.53007514
3	<i>Barilius barna</i>	Very coarse gravel (32-64 mm)	20	28	0.3	26.85665039	90.53007514
4	<i>Garra annandalei</i>	Very coarse gravel (32-64 mm)	41	28	0.3	26.85665039	90.53007514
5	<i>Garra birostris</i>	Very coarse gravel (32-64 mm)	46	28	0.3	26.85665039	90.53007514
6	<i>Glyptothorax trilineatus</i>	Very coarse gravel (32-64 mm)	1	28	0.3	26.85665039	90.53007514
7	<i>Mastacembelus armatus</i>	Very coarse gravel (32-64 mm)	4	28	0.3	26.85665039	90.53007514
8	<i>Pseudolagovia shawi</i>	Very coarse gravel (32-64 mm)	14	28	0.3	26.85665039	90.53007514
9	<i>Schistura scaturigina</i>	Very coarse gravel (32-64 mm)	1	28	0.3	26.85665039	90.53007514
10	<i>Barilius barna</i>	Coarse gravel (16-32 mm)	22	19	0.1	26.85666039	90.53053097
11	<i>Channa striata</i>	Coarse gravel (16-32 mm)	2	19	0.1	26.85666039	90.53053097
12	<i>Aborichthys elongatus</i>	Coarse gravel (16-32 mm)	4	40	0.6	26.85743735	90.53047682
13	<i>Amblyceps apangi</i>	Coarse gravel (16-32 mm)	6	40	0.6	26.85743735	90.53047682
15	<i>Channa striata</i>	Coarse gravel (16-32 mm)	3	40	0.6	26.85743735	90.53047682
16	<i>Batasio merieniensis</i>	Coarse gravel (16-32 mm)	2	40	0.6	26.85743735	90.53047682
18	<i>Macrognaathus pancalus</i>	Very coarse gravel (32-64 mm)	2	36	0.7	26.8569409	90.5303522

The habitats appeared relatively undisturbed, with an even distribution of species across samples. Despite the lack of cover, which could potentially leave habitats unshielded, the abundance and diversity of fish suggest a stable environment, especially given the presence



of spawning sites. These areas featured appropriate substrate and habitat conditions, as indicated by fry and fingerlings observed at certain locations.



Figure 3. 7: Fishes caught during the post-monsoon season from Plot 2. The confluence makes an important ground for the fishes to thrive (right).

Overall, the river width was expansive, and the substrate characteristics appeared conducive to various aquatic species, providing both spawning grounds and suitable habitats for different life stages of the fish present.

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	<i>Aborichthys elongatus</i>	Sand	3	40-53	0.3-0.6	26.84810974	90.53748917
2	<i>Amblyceps apangi</i>	Sand	2	24-53	0.1-0.6	26.84678828	90.53491772
3	<i>Badis badis</i>	Sand	1	19	0.1	26.84642829	90.5321491
4	<i>Barilius barna</i>	Medium gravel	5	22-40	0.1-0.4	26.84810974	90.53748917
5	<i>Barilius bendelisis</i>	Medium to coarse gravel	9	22-40	0.1-0.4	26.84810974	90.53748917
6	<i>Channa striata</i>	Coarse gravel	7	19-24	0.1	26.84678828	90.53491772
7	<i>Cyprinion semiplotus</i>	Coarse gravel	3	21	0.4	26.84540269	90.53054138
8	<i>Danio dangila</i>	Coarse gravel	6	22-40	0.3-0.4	26.84810974	90.53748917
9	<i>Devario aequipinnatus</i>	Coarse gravel	1	40	0.3	26.84810974	90.53748917



10	<i>Garra annandalei</i>	Coarse gravel	6	22-53	0.1-0.6	26.84563625	90.53375204
11	<i>Garra birostris</i>	Coarse gravel	3	24-53	0.1-0.6	26.84678828	90.53491772
12	<i>Mastacembelus armatus</i>	Coarse gravel	2	40-53	0.3-0.6	26.84810974	90.53748917
13	<i>Neolissochilus hexagonolepis</i>	Coarse gravel	2	40	0.3	26.84810974	90.53748917
14	<i>Olyra longicaudata</i>	Coarse gravel	1	53	0.6	26.84919889	90.53565462
15	<i>Oreochthys crenuoides</i>	Coarse gravel	6	21-40	0.1-0.4	26.84810974	90.53748917
16	<i>Psilorhynchus balitora</i>	Coarse gravel	3	24	0.1	26.84678828	90.53491772



Figure 3. 8: 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. 10: The longest *Mastacembelus armatus* was caught from the stretch



Figure 3. 9: *Neolissochilus hexagonolepis* recorded in plot 3.

Table 3. 7: Details of the fishes found in Aquatic Plot 3 during the post-monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	<i>Barilius barna</i>	Small stones (64-128 mm)	9	36	0.2	26.84845957	90.53444772
2	<i>Channa striata</i>	Small stones (64-128 mm)	4	36	0.2	26.84845957	90.53444772
3	<i>Cyprinion semiplotus</i>	Small stones (64-128 mm)	7	36, 38	0.2, 1.1	26.84845957	90.53444772
4	<i>Danio dangila</i>	Small stones (64-128 mm)	1	36	0.2	26.84845957	90.53444772
5	<i>Garra annandalei</i>	Small stones (64-128 mm)	44	36, 38	0.2, 1.1	26.84845957	90.53444772
6	<i>Garra birostris</i>	Small stones (64-128 mm)	19	38	1.1	26.84790039	90.53445709
7	<i>Glyptothorax trilineatus</i>	Small stones (64-128 mm)	1	38	1.1	26.84790039	90.53445709
	<i>Neolissochilus hexagonolepis</i>	Small stones (64-128 mm)	2	36	0.2	26.8484596	90.5344477



	<i>Oreochthys crenocoides</i>	Small stones (64-128 mm)	4	36	0.2	26.8484596	90.5344477
8	<i>Pseudolaguvia shawi</i>	Small stones (64-128 mm)	4	38	1.1	26.84790039	90.53445709
9	<i>Aborichthys elongatus</i>	Small stones (64-128 mm)	2	38	1.1	26.84790039	90.53445709
	<i>Schistura scaturigina</i>	Small stones (64-128 mm)	4	38	1.1	26.8479004	90.5344571
10	<i>Amblyceps apangi</i>	Small stones (64-128 mm)	2	38	1.1	26.84790039	90.53445709

During the post-monsoon season, the aquatic plot 3 recorded a diverse fish population with a total of 103 individuals under 10 species. The river discharge was subsided enormously compared to the monsoon season data collection in August 2024. The river section where the team collected the data was dried.



Figure 3. 11: Fish caught from one of the sites from Plot 3 (left) and dry habitat from the plot (right) during the post-monsoon season.

The predominant habitat substrate across samples was small stones, ranging from 64 to 128 mm in size. Water depths were recorded at 36 cm and 38 cm, with flow velocities varying between 0.2 and 1.1 m/s. The most abundant species was *Garra annandalei* (N=44), followed by *Garra birostris* (N=19). *Barilius barna* (N=9) and *Cyprinion semiplotus* (N=7) showed moderate abundance. *Channa striata* and *Oreochthys crenocoides* were each recorded with four individuals (N=4), and *Pseudolaguvia shawi* and *Schistura scaturigina* also had lower numbers, each with four individuals (N=4). The rarest species in the sample included *Danio*



dangila, *Glyptothorax trilineatus*, *Aborichthys elongatus*, and *Amblyceps apangi*, each represented by one or two individuals ($N=1-2$).

The habitat was dominated by small stone substrates (64-128 mm) with recorded water depths of 36 cm and 38 cm. The flow velocities ranged from 0.2 to 1.1 m/s. Species like *Garra annandalei* were present across various depth and velocity conditions, indicating a high level of adaptability. In contrast, species like *Glyptothorax trilineatus* were confined to areas with higher velocity and depth, suggesting specific habitat preferences. The habitat conditions, particularly the substrate type and hydrodynamics, appeared to support a diverse and well-distributed fish community.

Aquatic Plot 4

Table 3. 8: 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	<i>Amblyceps apangi</i>	Big stones (256-384 mm)	1	42	1.1	26.862907	90.502803
2	<i>Bangana dero</i>	Small stones (64-128 mm)	1	39	0.2	26.865019	90.503679
3	<i>Barilius barna</i>	Sand	1	53	0.3	26.865780	90.503976
4	<i>Barilius barna</i>	Small stones (64-128 mm)	1	39	0.2	26.865019	90.503679
5	<i>Barilius bendelisis</i>	Sand	1	53	0.3	26.865780	90.503976
6	<i>Batasio merianiensis</i>	Sand	1	53	0.3	26.865780	90.503976
7	<i>Channa striata</i>	Big stones (256-384 mm)	1	42	1.1	26.862907	90.502803
8	<i>Channa striata</i>	Sand	1	53	0.3	26.865780	90.503976
9	<i>Crossocheilus latius</i>	Small stones (64-128 mm)	1	38	0.6	26.862247	90.502361
10	<i>Devario aequipinnatus</i>	Sand	1	53	0.3	26.865780	90.503976
11	<i>Devario aequipinnatus</i>	Sand	1	53	0.3	26.865780	90.503976
12	<i>Garra annandalei</i>	Big stones (256-384 mm)	8	42	1.1	26.862907	90.502803
13	<i>Garra annandalei</i>	Small stones (64-128 mm)	6	38	0.6	26.862247	90.502361
14	<i>Garra birostris</i>	Big stones (256-384 mm)	2	39	1.0	26.862907	90.502803
15	<i>Garra birostris</i>	Coarse gravel (16-32 mm)	1	46	0.9	26.864587	90.503015
16	<i>Garra birostris</i>	Sand	1	53	0.3	26.865780	90.503976



17	<i>Glyptothorax trilineatus</i>	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
18	<i>Mastacembelus armatus</i>	Small stones (64-128 mm)	2	39	0.2	26.865019	90.503679
19	<i>Neolissochilus hexagonolepis</i>	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
20	<i>Neolissochilus hexagonolepis</i>	Sand	1	53	0.3	26.865780	90.503976
21	<i>Pseudolaguvia shawi</i>	Big stones (256-384 mm)	1	39	1.0	26.862907	90.502803
22	<i>Psilorhynchus balitora</i>	Small stones (64-128 mm)	1	38	0.6	26.862247	90.502361
23	<i>Schistura reticulofasciata</i>	Big stones (256-384 mm)	4	39	1.0	26.862907	90.502803
24	<i>Schistura reticulofasciata</i>	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. 12: *Mastacembelus armatus* recorded from the plot 4



Figure 3. 13: The plot 4 is a river diverted from the main Mau Khola river.

Table 3. 9: Details of the fishes found in Aquatic Plot 4 during the post-monsoon season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	<i>Batasio merianiensis</i>	Big stones (256-384 mm)	2	65	1.4	26.86506102	90.50355515
2	<i>Crossocheilus latius</i>	Big stones (256-384 mm)	10	35, 65	1, 1.4	26.86273861, 26.86506102	90.50282082, 90.50355515
3	<i>Glyptothorax striatus</i>	Big stones (256-384 mm)	9	65	1.4	26.86506102	90.50355515
4	<i>Schistura scaturigina</i>	Big stones (256-384 mm)	32	35	1	26.86273861	90.50282082
5	<i>Amblyceps apangi</i>	Small stones (64-128 mm)	6	65	1.4	26.86506102	90.50355515
6	<i>Barilius barna</i>	Small stones (64-128 mm)	3	35	1	26.86273861	90.50282082
7	<i>Barilius vagra</i>	Small stones (64-128 mm)	3	65	1.4	26.86506102	90.50355515
8	<i>Barilius bendelisis</i>	Small stones (64-128 mm)	7	35	1	26.86273861	90.50282082
9	<i>Cyprinion semiplotus</i>	Coarse gravel (16-32 mm)	5	46	0.8	26.84896398	90.53584125



10	<i>Devario aequipinnatus</i>	Small stones (64-128 mm)	5	46	0.8	26.84896398	90.53584125
11	<i>Aborichthys elongatus</i>	Big boulders (>512 mm)	3	46	0.8	26.84896398	90.53584125
12	<i>Channa striata</i>	Big boulders (>512 mm)	1	46	0.8	26.84896398	90.53584125
13	<i>Badis badis</i>	Small stones (64-128 mm)	2	35	1	26.86273861	90.50282082
14	<i>Garra annandalei</i>	Big boulders (>512 mm)	66	46	0.8	26.84896398	90.53584125
15	<i>Neolissochilus hexagonolepis</i>	Coarse gravel (16-32 mm)	1	32	0.3	26.86368584	90.50304606
16	<i>Olyra longicaudata</i>	Small stones (64-128 mm)	1	41	0.9	26.848358	90.53504935
17	<i>Psilorhynchus balitora</i>	Big boulders (>512 mm)	5	41	0.9	26.848358	90.53504935
18	<i>Pseudolagovia shawi</i>	Big boulders (>512 mm)	12	41	0.9	26.848358	90.53504935
19	<i>Garra birostris</i>	Big boulders (>512 mm)	25	46	0.8	26.84896398	90.53584125
20	<i>Xenentodon cantila</i>	Small stones (64-128 mm)	2	37	0.9	26.8625527	90.50271596

During the post-monsoon season, aquatic plot 4 recorded 202 samples under 20 species of fishes. The river on which the plot 4 was situated seemed to be a diversion of the main river for irrigation, however, we could not confirm the diversion point and the purpose for the diversion as well.



Figure 3. 14: Fishes from few sites in Plot 4 (first two left); typical habitat and stream bed in plot 4 (latter two right) durring the post-monsoon season.

The survey observed a variety of habitat substrata, predominantly big boulders (>512 mm) and small stones (64-128 mm), with depths ranging from 32 cm to 65 cm and water velocities between 0.3 m/s and 1.4 m/s. The most abundant species was *Garra annandalei* (N=66)



primarily associated with big boulder habitats and moderate water flow. Other well-represented species included *Schistura scaturigina* (N=32) and *Garra birostris* (N=25). In contrast, *Channa striata* and *Neolissochilus hexagonolepis* were the least observed, with only one individual each. The prevalence of *Garra annandalei* and other species favoring larger substrates and moderate flow conditions suggests that these habitat types offer ideal conditions during the monsoon season, possibly due to enhanced shelter, food availability, and oxygenation.

Aquatic Plot 5

Table 3. 10: 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	<i>Aborichthys elongatus</i>	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
2	<i>Amblyceps apangi</i>	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
3	<i>Amblyceps apangi</i>	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
4	<i>Barilius barna</i>	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
5	<i>Barilius barna</i>	Stones (128-256 mm)	2	57	1.2	26.88753646	90.51923073
6	<i>Batasio merianiensis</i>	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
7	<i>Botia almorhae</i>	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
8	<i>Channa striata</i>	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
9	<i>Cirrhinus cirrhosus</i>	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
10	<i>Crossocheilus latius</i>	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
11	<i>Cyprinion semiplotus</i>	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
12	<i>Cyprinion semiplotus</i>	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
13	<i>Devario aequipinnatus</i>	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
14	<i>Garra annandalei</i>	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986
15	<i>Garra annandalei</i>	Small stones (64-128 mm)	1	37	0.4	26.88060737	90.51506087
16	<i>Garra birostris</i>	Big stones (256-384 mm)	1	54	0.1	26.88486816	90.51717986



17	<i>Garra birostris</i>	Medium gravel (8-16 mm)	2	28	0.2	26.88753646	90.51923073
18	<i>Garra birostris</i>	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
19	<i>Macrognaathus pancalus</i>	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
20	<i>Pethia conchonius</i>	Medium gravel (8-16 mm)	2	28	0.2	26.88753646	90.51923073
21	<i>Puntius sophore</i>	Medium gravel (8-16 mm)	1	28	0.2	26.88753646	90.51923073
22	<i>Schistura devdevi</i>	Small stones (64-128 mm)	2	37	0.4	26.88060737	90.51506087
23	<i>Schistura devdevi</i>	Stones (128-256 mm)	1	57	1.2	26.88753646	90.51923073
24	<i>Schistura reticulofasciata</i>	Big stones (256-384 mm)	2	54	0.1	26.88486816	90.51717986
25	<i>Xenentodon cancila</i>	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



Figure 3. 15: *Cyprinion semiplotus* recorded from plot 5



environment supporting various species. Species like *Xenentodon cancila* and *Macrognathus pancalus* are usually found in this stretch and the team also recorded the fishes.

Table 3. 11: Details of the Fishes Found in Aquatic Plot 5 During the Post-Monsoon Season

SN	Species	Habitat Substratum	Count	Depth (cm)	Velocity (m/s)	Latitude	Longitude
1	<i>Channa striata</i>	Small stones (64-128 mm)	21	47	0.6	26.88752594	90.5187381
2	<i>Crossocheilus latius</i>	Small stones (64-128 mm)	2	47	0.6	26.88752594	90.5187381
3	<i>Cyprinion semiplotus</i>	Small stones (64-128 mm)	5	47	0.6	26.88752594	90.5187381
4	<i>Mastacembelus armatus</i>	Small stones (64-128 mm)	5	47	0.6	26.88752594	90.5187381
5	<i>Neolissochilus hexagonolepis</i>	Small stones (64-128 mm)	17	47	0.6	26.88752594	90.5187381
6	<i>Barilius barna</i>	Organic	4	9	0.2	26.88756378	90.51905652
7	<i>Devario aequipinnatus</i>	Organic	12	9	0.2	26.88756378	90.51905652
8	<i>Garra birostris</i>	Organic	12	9	0.2	26.88756378	90.51905652
9	<i>Mystus dibrugarensis</i>	Organic	1	9	0.2	26.88756378	90.51905652
10	<i>Aborichthys elongatus</i>	Big boulders (>512 mm)	1	48	0.5	26.8849758	90.51621422
11	<i>Amblyceps apangi</i>	Big boulders (>512 mm)	4	48	0.5	26.8849758	90.51621422
12	<i>Badis badis</i>	Small boulders (384-512 mm)	1	19	0.2	26.88457068	90.51650883
13	<i>Barilius barna</i>	Organic	33	9	0.2	26.88756378	90.51905652
14	<i>Devario aequipinnatus</i>	Organic	10	9	0.2	26.88756378	90.51905652
15	<i>Garra annandalei</i>	Big boulders (>512 mm)	31	48	0.5	26.8849758	90.51621422
16	<i>Glyptothorax trilineatus</i>	Big boulders (>512 mm)	1	48	0.5	26.8849758	90.51621422



17	<i>Olyra longicaudata</i>	Small boulders (384-512 mm)	3	19	0.2	26.88457068	90.51650883
18	<i>Oreichthys crenocoides</i>	Organic	3	9	0.2	26.88756378	90.51905652
19	<i>Pseudolagovia shawi</i>	Big boulders (>512 mm)	4	48	0.5	26.8849758	90.51621422
20	<i>Puntius sophore</i>	Organic	5	9	0.2	26.88756378	90.51905652
21	<i>Schistura scaturigina</i>	Stones (128-256 mm)	3	37	0.9	26.8625527	90.50271596
22	<i>Xenetodon cancila</i>	Organic	1	9	0.2	26.88756378	90.51905652

During the post-monsoon season, the aquatic plot 5 recorded a total of 162 fishes under 19 species. This area has a river as described in the monsoon section, and it has a stream which gets connected from the nearby forest towards the river bank with human settlements. The stream has rich characteristics and unique habitat characterized by moderate flow water and habitat conditioned for specific specific of fishes such as eels and freshwater ghar fish. *Mystus dibrugarensis* was also caught in this area together with other important fishes. It was also point to be noted that there are illegal fisherman who are well acquainted with this habitat and illegal fishing is rampant in this site.



Figure 3. 17: Fishes found in the plot 5 (left) and aquatic habitat with streams (right) in post-monsoon season.

The predominant habitat substrate across samples was small stones (64-128 mm), small boulders (384-512 mm), and organic materials. Water depths were recorded at varying levels, with values ranging from 9 cm to 48 cm, while flow velocities fluctuated between 0.2 and 0.9 m/s. The most abundant species were *Barilius barna* ($N=33$), followed by *Garra*



annandalei (N=31) and species such as *Devario aequipinnatus* (N=22), *Channa striata* (N=21), followed by *Neolissochilus hexagonolepis* (N=17) exhibited moderate abundance, while species such as *Mystus dibrugarensis*, *Glyptothorax trilineatus*, and *Xenentodon cancila* appeared infrequently (N=1).

The habitat was dominated by organic substrates and small stones (64-128 mm), with water depths predominantly at 9 cm and 47 cm and flow velocities ranging from 0.2 to 0.6 m/s. Species like *Channa striata* and *Neolissochilus hexagonolepis* were present across varied conditions, indicating adaptability to different water depths and velocities. Conversely, species such as *Aborichthys elongatus* and *Amblyceps apangi* were mostly associated with deeper areas containing larger boulders. The habitat conditions, particularly the substrate types and hydrodynamics, appeared to support a well-distributed fish community.

3.1.2 Distribution pattern of fishes across sites and habitats

Monsoon season

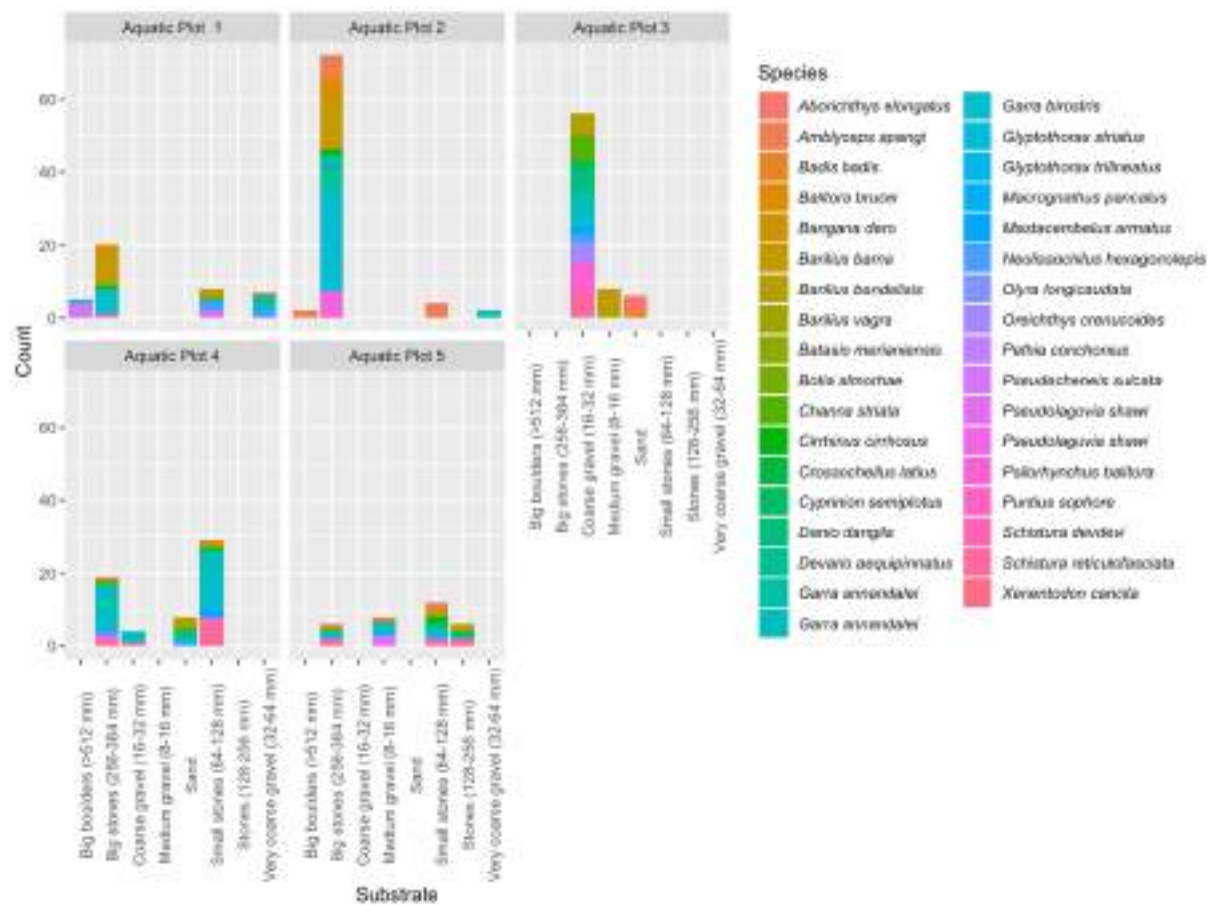


Figure 3. 18: Distribution pattern of fish across different plots and habitat substratum

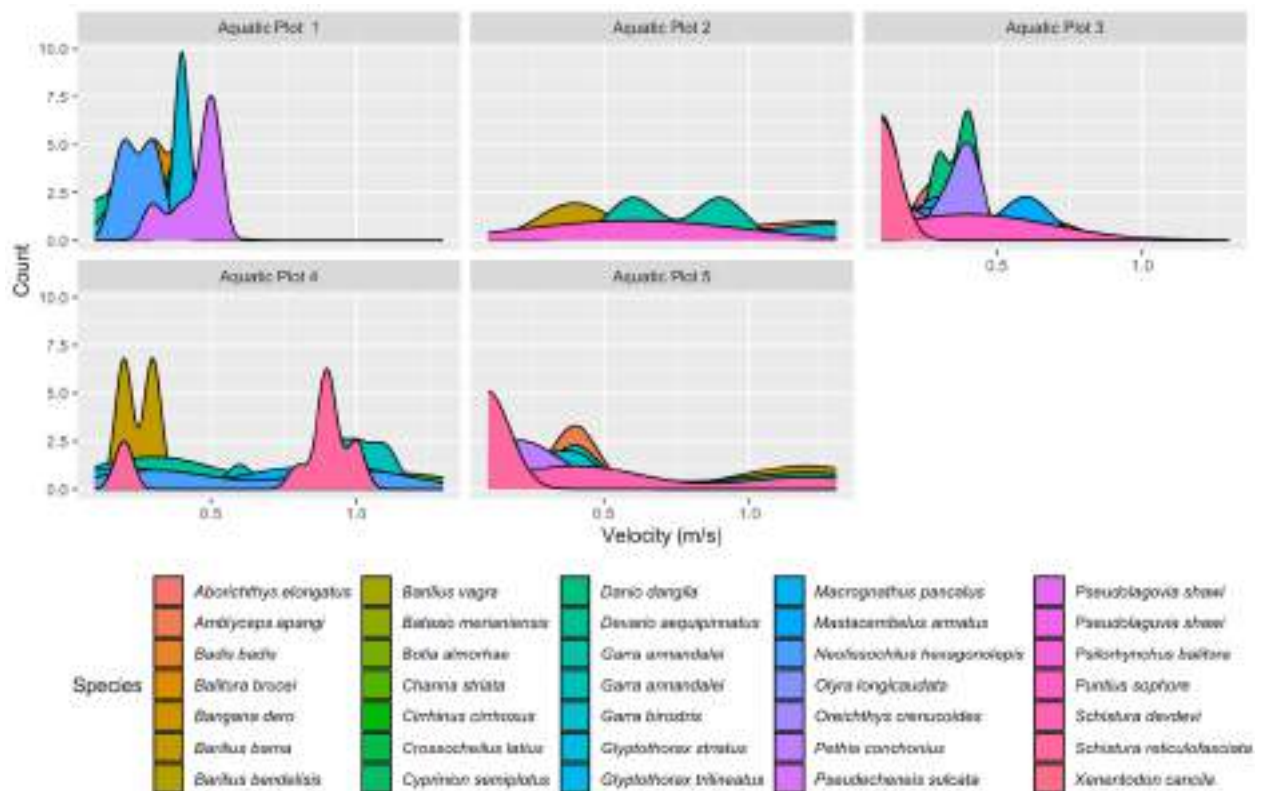


Figure 3. 19: Distribution of fishes among different plots and velocity (m/s)

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.

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

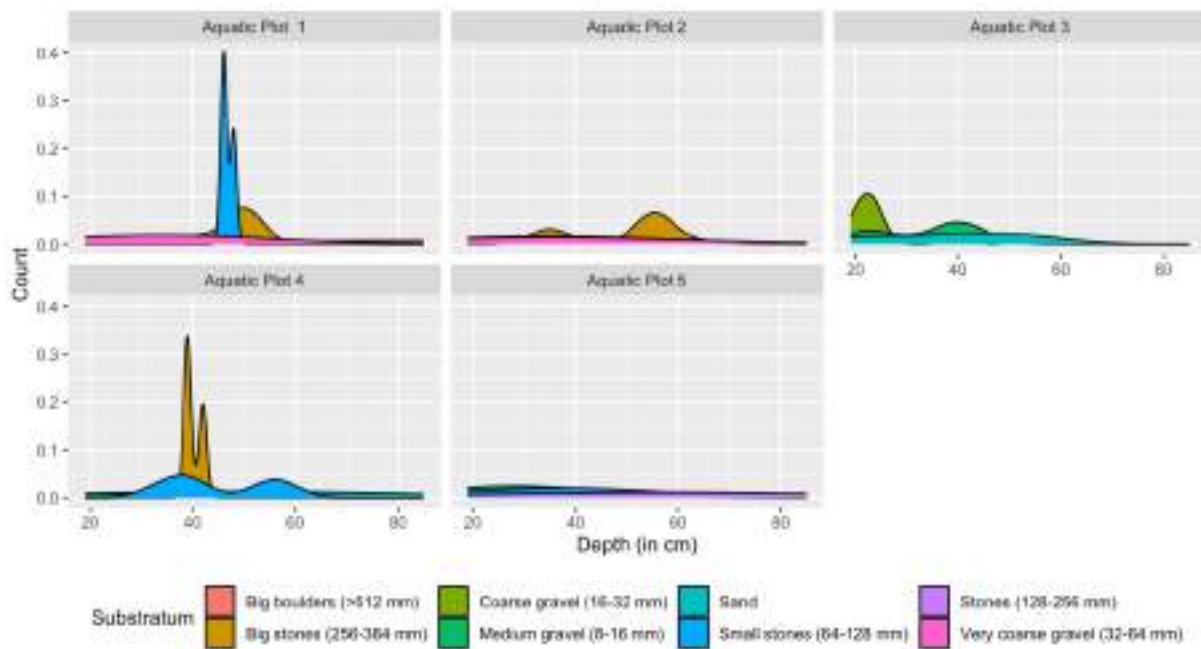


Figure 3.20: Distribution of habitat type and water depths across plots

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.

Post-monsoon season

During the post-monsoon season, the overall distribution of fish species across the five aquatic plots reflects significant variability influenced by habitat characteristics such as substratum type, depth, and water velocity (figure 3.17). It was found that plots with well-oxygenated, moderately fast-flowing waters and larger stones or boulders, like Plot 1 near the Sherzong Bridge and Plot 3 near the Umling Bridge, supported higher species richness and abundance. In contrast, areas with more uniform or less favorable habitat conditions, like organic substrata or extreme depth variations in Plot 5, exhibited more specialized or lower fish diversity. These patterns emphasize the critical role of habitat features in shaping aquatic biodiversity.

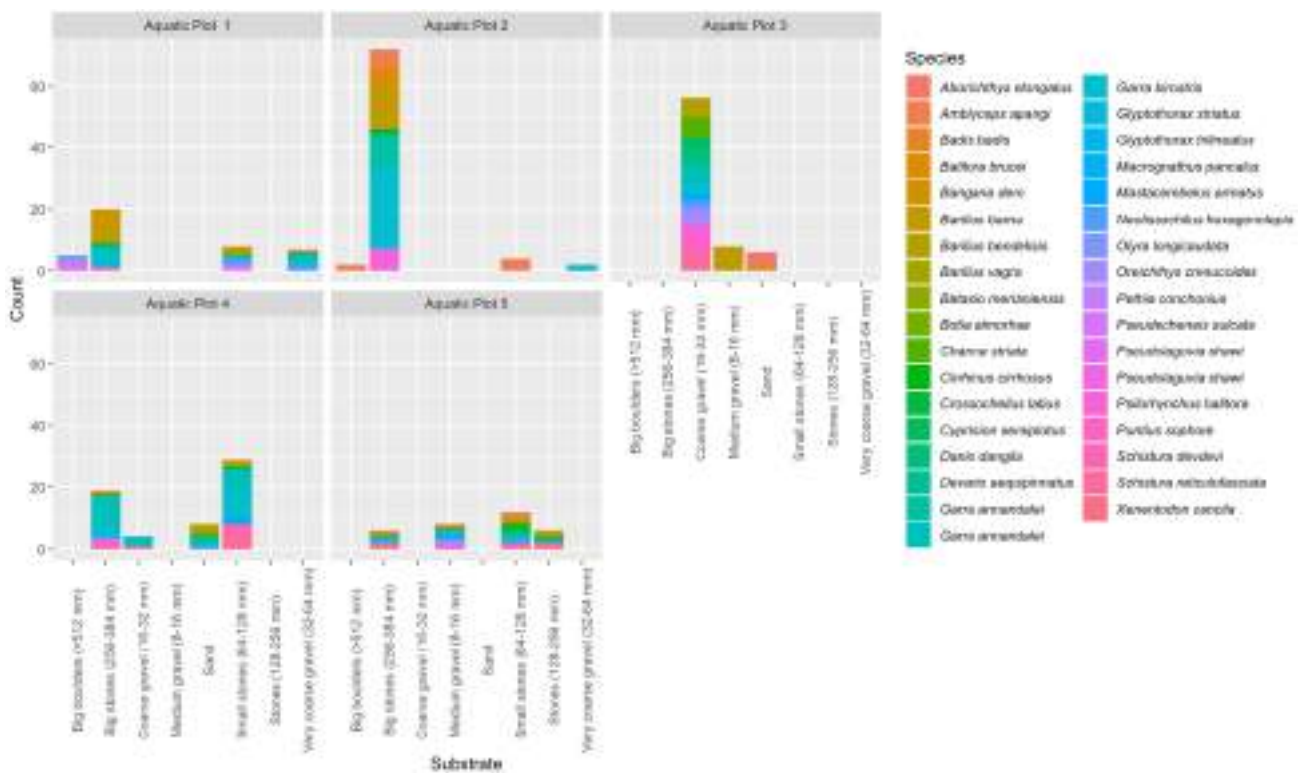


Figure 3. 21: Distribution pattern of fish across different plots and habitat substratum during the post-monsoon

During the post-monsoon survey, plot 1 was dominated by large stones and big boulders, which exhibited a relatively high diversity of fish species, particularly in areas with moderate depths (around 39 to 50 cm) and varying velocities. Species richness was observed in habitats featuring substratum like big stones (256-384 mm) and small boulders (384-512 mm). The average velocity ranged from 0.4 to 1.8 m/s, contributing to a well-oxygenated environment that supported species like *Barilius barna* and *Garra birostris*.

Aquatic Plot 2 featured habitats with coarser gravel and stones, with fish species like *Amblyceps apangi* and *Balitora brucei* being more common. This plot had an average depth of approximately 32 to 62 cm and velocities ranging from 0.4 to 1.1 m/s. The variety in substratum, especially coarse and very coarse gravel, seemed to favor species adapted to faster currents and varied depths.

Plot 3 displayed the highest species count and diversity, with an abundance of small stones (64-128 mm) and an average depth of around 38 cm. The velocities in this plot were relatively moderate at 0.6 m/s. The habitat variety likely provided refuge and foraging opportunities for a range of fish species, making it an optimal area for fish diversity. Plot 4 had a moderate species richness, with habitats comprising big boulders and smaller stones. The average depth was around 34 to 47 cm, with varying velocities up to 1.2 m/s. This plot's substrate



Baseline survey for Aquatic Invertebrates and Fishes
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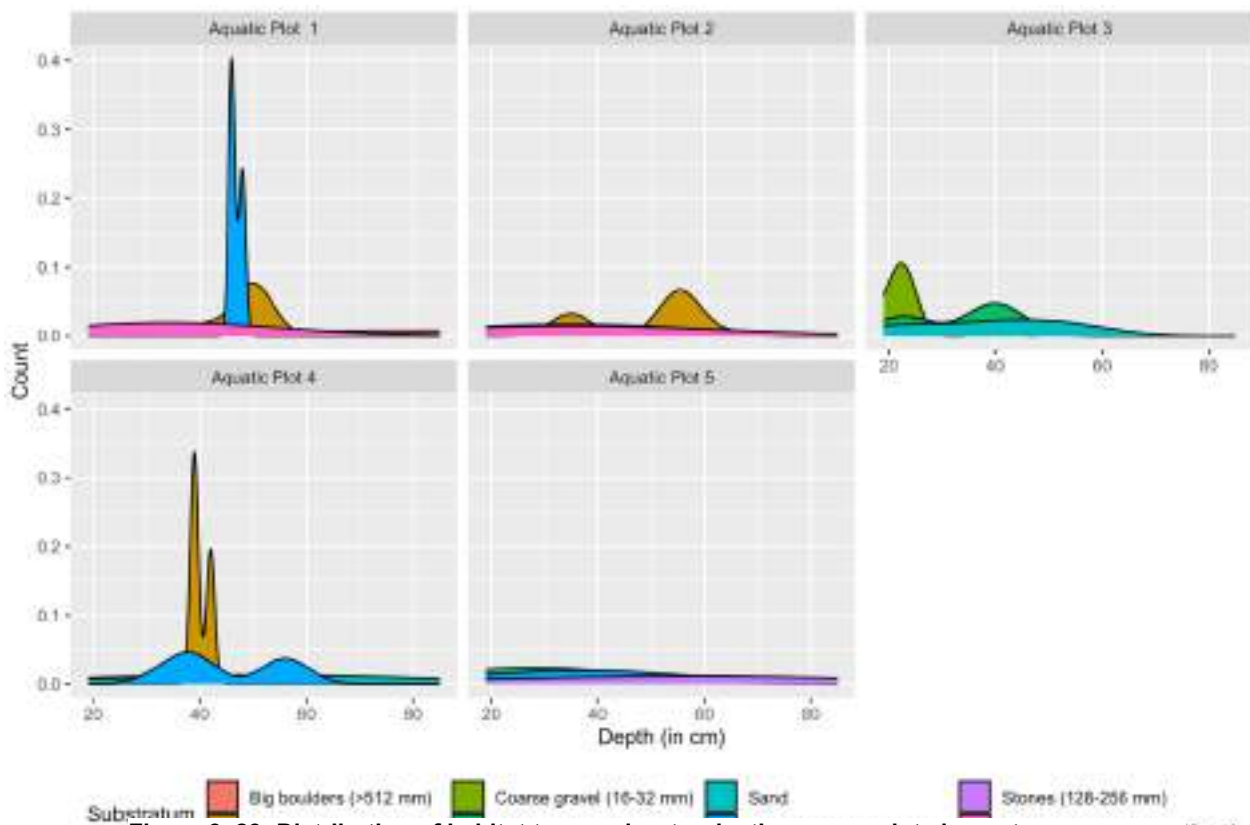


Figure 3. 23: Distribution of habitat type and water depths across plots in post-monsoon 4 mm

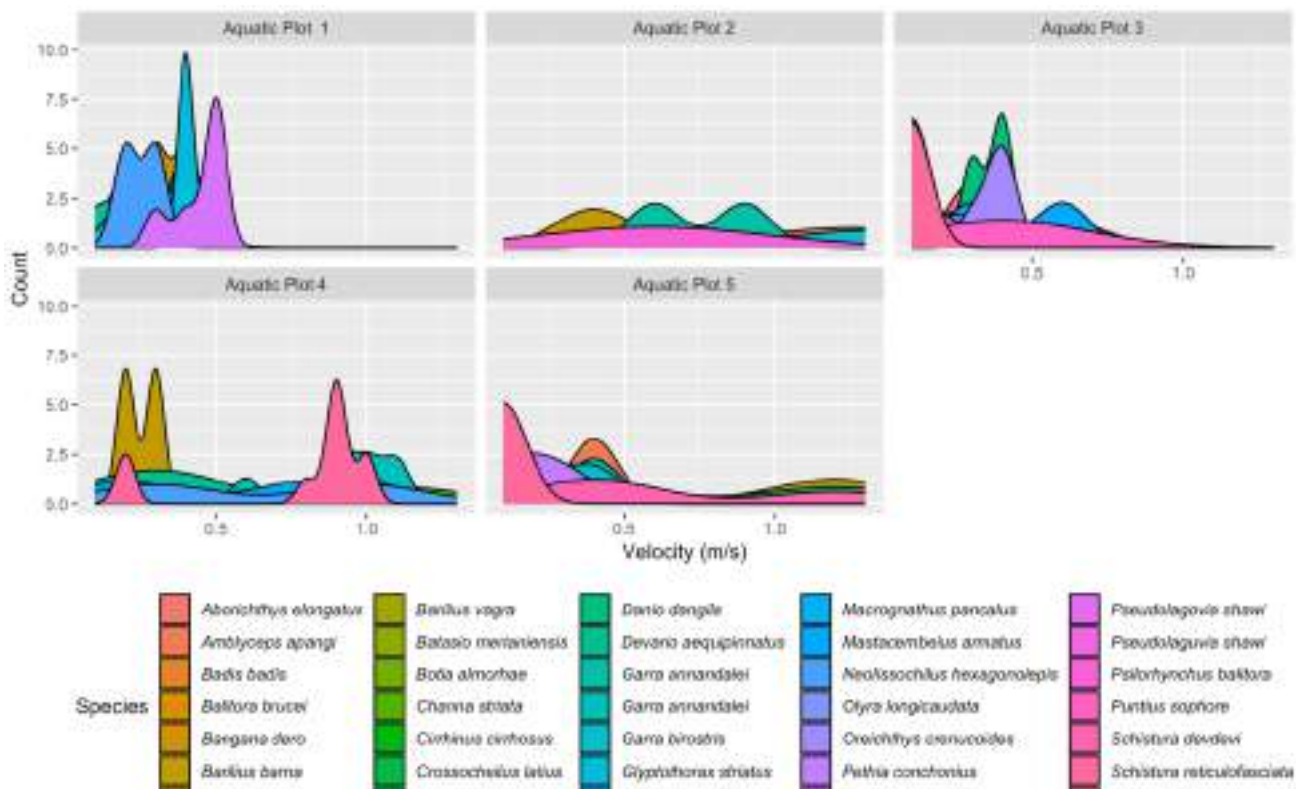


Figure 3. 22: Distribution of fishes among different plots and velocity (m/s) in post-monsoon

composition and swift current provided suitable conditions for some species but not as broad



a diversity as Plot 3. Plot 5, characterized by a combination of boulders and organic substratum, recorded a unique set of fish species. The depths varied significantly, with organic areas being shallower (around 9 cm) and small boulders areas deeper (47 cm). The average velocity was generally lower (0.2 to 0.6 m/s), which influenced species adapted to calmer waters.

Certain species were closely associated with specific substratum and flow conditions. For example, species like *Barilius barna* and *Garra birostris* thrived in habitats with moderate depths and well-oxygenated, fast-flowing waters. In contrast, species like *Amblyceps apangi* preferred habitats with faster currents and coarser gravel.

The varied distribution across plots reflects differences in habitat suitability influenced by substratum type, depth, and velocity. In summary, the observed patterns in fish distribution are largely driven by the availability of preferred habitat features, including substratum composition, depth, and flow velocity, which influence species richness and diversity.



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.

Seasons found in the study: Monsoon and Post-monsoon.

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.

Seasons found in the study: Monsoon and Post-monsoon.



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.

Seasons found in the study: Monsoon and Post-monsoon.

4. *Amblyceps apangi*



Common name: Catfish, loolee.

Synonyms: None.

Description: Dorsal-fin rays 1/5, ventral 6, anal 9, and caudal 7+7 (-19). Body depth 13.3% of standard length, upper jaw slightly longer or equal; adipose fin continues to caudal fin but not confluent, caudal fin truncate. Total length up to 15 cm.

Distribution: Diglai at Samdrupcholing (Samdrup Jongkhar) and Manas at Panbang (Zhemgang).

Conservation status: Least Concern.



Seasons found in the study: Monsoon and Post-monsoon.

5. *Schistura scaturigina*



Common names: Gadera, gadela, dari.

Synonyms: *Cobitis scaturigina* (McClelland, 1839); *Nemacheilus mugah* Day, 1869; *N. scaturigina* (McClelland, 1839); *N. shebbearei* Hora, 1935; *Noemacheilus scaturigina* (McClelland, 1839).

Description: Dorsal-fin rays 9-11, pectoral 10, ventral 8, anal 6, and caudal 18. Body with 9-12 vertical bands. Caudal lobes rounded. Measures about 10 cm.

Distribution: Dakpaichhu at Tingtibi (Zhemgang).

Conservation status: Least Concern

Seasons found in the study: Monsoon and Post-monsoon.

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.



Seasons found in the study: Monsoon and Post-monsoon.

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.

Seasons found in the study: Monsoon and Post-monsoon.

8. *Barilius bendelisis*



Common Names: Baril, fageta, Hamilton's barila

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

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

Seasons found in the study: Monsoon and Post-monsoon.



9. *Neolissochilus hexagonolepis*



Common names: Copper mahseer, chocolate mahseer, katlae, katli.

Synonyms: *Acrossocheilus hexagonolepis* (McClelland, 1839); *Barbodes hexagonolepis* (McClelland, 1839); *Barbus hexagonolepis* McClelland, 1839.

Description: Dorsal-fin rays 3/9, pectoral 17, ventral 9, anal 2/5-7, and caudal 19. Lateral scales 28-31. Length of head is 5 to 5.5 and body depth 5 to 5.5 in total length; body silvery with copper tinge scales; two pairs of barbels present. Pores present sometimes in cheek. Maximum length is 60 cm and weighs up to 6 kg.

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

Conservation status: Near Threatened, but widely distributed in Bhutan.

Seasons found in the study: Monsoon and Post-monsoon.

10. *Devario aequipinnatus*



Common Names: Bhatti



Synonyms: *Danio aequipinnatus* (McClelland, 1839); *D. lineolatus* (Blyth, 1858); *Leuciscus aequipinnatus* (McClelland, 1839); *Leuciscus lineolatus* Blyth, 1858; *Perilampus aequipinnatus* McClelland, 1839; *Pteropsarion aequipinnatus* (McClelland, 1839).

Description: Dorsal-fin rays 12-14, pectoral 17, ventral 8, anal 14-16, and caudal 19. Lateral scales 32-34. Body silvery bluish with yellow or orange stripes, interrupted or not at about the head; mouth pointed upward; barbels absent or very short. Maximum length 15 cm.

Distribution: 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.

Seasons found in the study: Monsoon and Post-monsoon.

11. *Cyprinion semiplotus*



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

Synonyms: *Cyprinus semiplotus* McClelland, 1839; *Semiplotus macclellandi* Bleeker, 1860; *S. semiplotus* (McClelland, 1839).

Description: Dorsal-fin rays 2-4/23-25, pectoral 16, ventral 10, anal 2/7, and caudal 19. Lateral scales 27-33 and transverse 6/6. Body height 3.5 in total length; snout obtuse with about 6 pores; barbels absent. Maximum length 60 cm.

Distribution: Diglai at Samdrupcholing (Samdrup Jongkhar), Toorsa/ Amochhu at Phuntsholing (Chukha), and Dhamdum in Samtse.

Conservation status: Vulnerable.



Seasons found in the study: Monsoon and Post-monsoon.

12. *Bangana dero*



Common names: Gurdi, kalabans, river rohu.

Synonyms: *Chondrostoma semivelatus* Valenciennes, 1844; *Cyprinus dero* Hamilton, 1822; *Labeo dero* (Hamilton, 1822); *L. rilli* Caudhuri, 1912; *Sinilabeo dero* (Hamilton, 1822).

Description: Dorsal-fin rays 3/9-10, pectoral 16-17, ventral 9, anal 3/5, and caudal 19. Lateral scales 38-43. Body bluish-black, stout and rounded; snout grooved with tubercles/pores, no lateral lobes; a pair of short maxillary barbel. Maximum length 75 cm.

Distribution: Manas at Panbang (Zhemgang).

Conservation status: Least Concern.

Seasons found in the study: Monsoon

13. *Pseudecheneis sulcata*



Common names: Sucker throat catfish, kabre.



Synonyms: *Glyptosternon sulcatus* McClelland, 1842.

Description: Dorsal-fin rays 1/6, pectoral 1/13, ventral 6, anal 2-4/7-9, and caudal 17. Body dark with yellowish blotches; presence of 14 transverse folds at thoracic sucker. Maximum length 20 cm.

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

Conservation status: Least Concern.

Seasons found in the study: Monsoon and Post-monsoon.

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.

Seasons found in the study: Monsoon and Post-monsoon.

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.

Seasons found in the study: Monsoon and Post-monsoon.

16. *Oreochthys crenuchoides*



Common Names: Neon Highfin Barb, High-Fin Variable Barb

Description: *Oreochthys crenuchoides* is a small cyprinid fish, typically reaching a maximum size of approximately 4.5 cm (1.8 inches) in total length. The body is deep, stout, and strongly compressed, with a smooth texture and absence of barbels. It has 11-13 dorsal fin rays and 17-21 lateral line scale

Distribution: Primarily found in freshwater environments across Assam and West Bengal in India, inhabiting ditches, ponds, and streams.

Conservation Status: Data Deficient (DD)

Seasons found in the study: Monsoon and Post-monsoon.

17. *Schistura devdevi*





Common names: Gadera.

Synonyms: *Nemacheilus montanus* (Day, 1878); *Noemacheilus montanus* (Day, 1889).

Description: Dorsal-fin rays 2/8, pectoral 10, ventral 9, anal 2/5, and caudal 16. Body with few, broad, irregular bands on body, much wider than interspaces between them; bands extend from dorsal surface to the sides, usually restricted to above, or only slightly below lateral line. Two black bands on dorsal fin.

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

Conservation status: Least Concern.

Seasons found in the study: Monsoon

18. *Aborichthys elongatus*



Common names: Gadera.

Synonym: *Noemacheilus elongatus* (Hora, 1921).

Description: Dorsal-fin rays 8, pectoral 11, ventral 8, anal 7, and caudal 19. Striped body, round tailed - red. Body is long and slender. Anal opening closer to caudal fin than tip of base snout. Maximum length 5.4 cm.

Distribution: Sarpangkhol, Maukhol, and Kamikhola (Sarpang), Jiti (Samtse).

Conservation status: Least Concern

Seasons found in the study: Monsoon and Post-monsoon.



19. *Mastacembelus armatus*



Common names: Spiny eel, zig-zag eel, chusi baam.

Synonyms: *Macrogathus armatus* Lacepède, 1800; *M. caudatus* McClelland, 1842; *M. hamiltonii* McClelland, 1844; *Mastacembelus manipurensis* Hora, 1921; *M. marmoratus* Cuvier, 1832; *M. ponticerianus* Cuvier, 1832.

Description: Dorsal rays 33-40/67-82 anal 67-83. Body long and reticulated with row of blotches along base of dorsal fin; snout pointed. Maximum length 90 cm and weighs up to 500 g.

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

Conservation status: Least Concern.

Seasons found in the study: Monsoon and Post-monsoon.

20. *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.

Seasons found in the study: Monsoon and Post-monsoon.

21. *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.

Seasons found in the study: Monsoon and Post-monsoon.

22. *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.

Seasons found in the study: Monsoon and Post-monsoon.

23. *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.

Seasons found in the study: Monsoon and Post-monsoon.



24. *Batasio merianiensis*



Common name: Chilne macha.

Synonyms: *Macrones merianiensis* Chaudhuri, 1913.

Description: Dorsal-fin rays II/7, pectoral I/7-8, ventral i/5, anal iii-v/8-9, and caudal 17. Body with four dark vertical band. Maximum length 7.5 cm.

Distribution: Diglai at Samdrupcholing (Samdrup Jongkhar) and Manas at Panbang (Zhemgang).

Conservation status: Data Deficient.

Seasons found in the study: Monsoon and Post-monsoon.

25. *Botia almorhae*



Common names: Almorha loach, baghae, jabo, tiger loach.

Synonyms: *Botia blythi* Bleeker 1863; *B. grandis* Gray, 1832; *Schistura maculata* McClelland, 1839.

Description: Dorsal-fin rays 2/9-10, pectoral 14, ventral 8, anal 2/5, and caudal 19. Body reticulated with grey on yellow, sometimes appearing as vertical bands. Maximum length 15 cm.



Distribution: Dagachhu at Dagana, Samdrupcholing (Samdrup Jongkhar).

Conservation status: Least Concern.

Seasons found in the study: Monsoon and Post-monsoon.

26. *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 rostral barbels present.

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

Conservation Status: Popular in aquaculture.

Seasons found in the study: Monsoon.

27. *Macrogathus 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.

Seasons found in the study: Monsoon and Post-monsoon.

28. *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.

Seasons found in the study: Monsoon and Post-monsoon.

29. *Pseudolaguvia shawi*





Description: Dorsal-fin rays 5-8, pectoral 8-11, ventral 6-8, anal 7-9, and 33 caudal 17. Body grayish brown; adhesive apparatus with central median depression. Maximum length 2.5 cm.

Distribution: Sarpangkholā and Maukholā at Gelephu (Sarpang).

Conservation status: Data Deficient.

Seasons found in the study: Monsoon and Post-monsoon.

30. *Puntius sophore*



Common names: Pool barb, pothi.

Synonyms: *Barbus annandalei* Fowler, 1924; *B. chrysopterus* (McClelland, 1839); *B. sophore* (Hamilton, 1822); *B. stigma* (Valenciennes, 1844); *Cyprinus sophor* Hamilton, 1822; *Leuciscus duvaucellii* Valenciennes, 1844; *L. stigma* Valenciennes, 1844; *Puntius chrysopterus* (McClelland, 1839); *P. modestus* Kner, 1867; *P. stigma* (Valenciennes, 1844); *Systemus chrysopterus* McClelland, 1839; *S. sophore* (Hamilton, 1822).

Description: Dorsal-fin rays 3/8-9, pectoral 15-17, ventral 9, anal 7-8, and caudal 19. Lateral scales 23-26 and transverse 4.5 to 5/5.5. Body depth 3.5 to 3.7 in total length, silvery with golden tinge below eye; a black spot at the root of caudal fin and one at the base of dorsal rays; last undivided ray entire; barbel absent. Measures about 8 cm in length.

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

Conservation status: Least Concern.

Seasons found in the study: Monsoon and Post-monsoon.



31. *Mystus dibrugarensis*



Common names: Tengra.

Synonyms: *Macrones montanus dibrugarensis* Chaudhuri, 1913; *Mystus montanus dibrugarensis* (Chaudhuri, 1913); *M. vittatus dibrugarensis* (Chaudhuri, 1913).

Description: Body with two black blotches on the body, one tympanic and one at caudal base. It differs from *M. tengana* in absence of distinct bands. **Distribution:** Manas at Panbang (Zhemgang). **Conservation status:** Least Concern.

Seasons found in the study: Post-monsoon.

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.

Seasons found in the study: Monsoon and Post-monsoon.

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. 12: Diversity and relative abundance for macroinvertebrates in monsoon

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

For the post-monsoon season, a total of 498 macroinvertebrate samples were collected, representing 14 species across 12 families under 9 orders. The most dominant species was *Baetis* ($N=178$) from the Baetidae family, accounting for 35.74% of the total abundance, followed by *Arctopsyche* ($N=68$) under the Hydropsychidae family, contributing 13.65% of the



total abundance. The species diversity for the post-monsoon season was calculated as $H' = 1.90$, species evenness $E_H = 0.72$, and species richness $S_R = 4.82$.

Table 3. 13: Diversity and Relative Abundance for Macroinvertebrates in Post-Monsoon

SN	Order	Family	Genus	Count	RA (%)
1	Hemiptera	Naucoridae	<i>Ambrysus</i>	4	0.80
2	Trichoptera	Hydropsychidae	<i>Arctopsyche</i>	68	13.65
3	Ephemeroptera	Baetidae	<i>Baetis</i>	178	35.74
4	Decapoda	Palaemonidae	<i>Caridina</i>	1	0.20
5	Diptera	Chironomidae	<i>Chironomus</i>	49	9.84
6	Diptera	Culicidae	<i>Culex</i>	7	1.41
7	Ephemeroptera	Ephemerellidae	<i>Drunella</i>	72	14.46
8	Ephemeroptera	Heptageniidae	<i>Heptagenia</i>	68	13.65
9	Oligochaeta	Lumbricidae	<i>Lumbricus</i>	1	0.20
10	Decapoda	Palaemonidae	<i>Macrobrachium</i>	11	2.21
11	Plecoptera	Perlidae	<i>Perla</i>	24	4.82
12	Decapoda	Potamidae	<i>Himalayapotamon</i>	10	2.01
13	Diptera	Tabanidae	<i>Tabanus</i>	2	0.40
14	Trichoptera	Rhyacophilidae	<i>Rhyacophila</i>	3	0.60
			Total Count	498	100

The high abundance of *Baetis* was also observed during the post-monsoon season similar to the monsoon season, which suggests favorable environmental conditions for this species, possibly due to moderate water flow and nutrient availability in both the seasons. This period also saw significant contributions from species like *Drunella* (N=72) and *Heptagenia* (N=68), both from the Ephemeroptera order, indicating that the aquatic ecosystem continued to support a relatively diverse and stable community of macroinvertebrates. However, the species diversity indices were still relatively low when compared to river systems at higher altitudes or other freshwater ecosystems. The overall nutrient availability and organic matter in the river in the areas where the plots were laid were relatively low.

Overall, the presence of key indicator species such as *Baetis*, *Arctopsyche*, and *Drunella* reflects the ongoing good water quality in the system during the post-monsoon season. The diversity indices suggest a moderately diverse macroinvertebrate community, with the abundance of *Baetis* and *Heptagenia* supporting the stability of the ecosystem during this transitional period. The diversity for both the seasons seems to be similar with not major changes in species composition.



Figure 3. 24: 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. 14: 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	Aquatic Plot	10	Run	Small Minnow Mayfly	26.84859487	90.53392336
24		7	Pool	Small Minnow Mayfly	26.86453678	90.50309306
25		12	Riffle	Small Minnow Mayfly	26.86453678	90.50309306



Baseline survey for Aquatic Invertebrates and Fishes
Gelephu Mindfulness City



26	Aquatic Plot 5	5	Run	Small Minnow Mayfly	26.86453678	90.50309306
27		8	Pool	Flat-headed Mayfly	26.86453678	90.50309306
28		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).

Table 3. 15: Macroinvertebrates found in different sites in post-monsoon

SN	Site	Count	Habitat	Common name	Latitude	Longitude
1	Aquatic Plot 1	2	Pool	Common stonefly	26.9409108	90.5184364
2		4	Riffle	Common stonefly	26.9409108	90.5184364
3		4	Pool	Flat-headed mayfly	26.9409108	90.5184364
4		7	Riffle	Flat-headed mayfly	26.9409108	90.5184364
5		5	Run	Flat-headed mayfly	26.9409108	90.5184364
6		3	Pool	Net-spinning caddisfly	26.9409108	90.5184364
7		4	Pool	Non-biting midge	26.9409108	90.5184364
8		3	Riffle	Non-biting midge	26.9409108	90.5184364
9		5	Run	Non-biting midge	26.9409108	90.5184364
10		3	Pool	Small minnow mayfly	26.9409108	90.5184364
11		15	Riffle	Small minnow mayfly	26.9409108	90.5184364
12		3	Run	Small minnow mayfly	26.9409108	90.5184364
13		6	Riffle	Spiny crawler mayfly	26.9409108	90.5184364
14		7	Run	Spiny crawler mayfly	26.9409108	90.5184364
15	Aquatic Plot 2	7	Riffle	Flat-headed mayfly	26.8565662	90.5296757
16		3	Riffle	Free-living caddisfly	26.8565662	90.5296757
17		2	Pool	Freshwater prawn	26.8565662	90.5296757
18		3	Run	Freshwater prawn	26.8565662	90.5296757
19		1	Riffle	Freshwater shrimp	26.8565662	90.5296757
20		2	Riffle	Horsefly larvae	26.8565662	90.5296757
21		17	Riffle	Net-spinning caddisfly	26.8565662	90.5296757
22		2	Run	Net-spinning caddisfly	26.8565662	90.5296757
23		3	Pool	Non-biting midge	26.8565662	90.5296757
24		18	Pool	Small minnow mayfly	26.8565662	90.5296757
25		38	Riffle	Small minnow mayfly	26.8565662	90.5296757
26		18	Run	Small minnow mayfly	26.8565662	90.5296757
27		6	Pool	Spiny crawler mayfly	26.8565662	90.5296757
28		7	Riffle	Spiny crawler mayfly	26.8565662	90.5296757
29	5	Run	Spiny crawler mayfly	26.8565662	90.5296757	
30	Aquatic Plot 3	3	Riffle	Common stonefly	26.8480777	90.5347672
31		15	Run	Common stonefly	26.8480777	90.5347672



Baseline survey for Aquatic Invertebrates and Fishes
Gelephu Mindfulness City



32		5	Run	Flat-headed mayfly	26.8480777	90.5347672	
33		6	Pool	Flat-headed mayfly	26.8480777	90.5347672	
34		3	Riffle	Freshwater crab	26.8480777	90.5347672	
35		6	Riffle	Freshwater prawn	26.8480777	90.5347672	
36		40	Run	Net-spinning caddisfly	26.8480777	90.5347672	
37		2	Pool	Non-biting midge	26.8480777	90.5347672	
38		13	Riffle	Non-biting midge	26.8480777	90.5347672	
39		15	Pool	Small minnow mayfly	26.8480777	90.5347672	
40		8	Riffle	Small minnow mayfly	26.8480777	90.5347672	
41		35	Run	Small minnow mayfly	26.8480777	90.5347672	
42		10	Pool	Spiny crawler mayfly	26.8480777	90.5347672	
43		8	Run	Spiny crawler mayfly	26.8480777	90.5347672	
44		Aquatic Plot 4	1	Riffle	Earthworm	26.8650782	90.5035531
45			4	Riffle	Flat-headed mayfly	26.8650782	90.5035531
46	6		Run	Flat-headed mayfly	26.8650782	90.5035531	
47	2		Pool	Freshwater crab	26.8650782	90.5035531	
48	5		Run	Freshwater crab	26.8650782	90.5035531	
49	5		Pool	Small minnow mayfly	26.8650782	90.5035531	
50	2		Run	Small minnow mayfly	26.8650782	90.5035531	
51	6		Run	Small minnow mayfly	26.8650782	90.5035531	
52	5		Riffle	Spiny crawler mayfly	26.8650782	90.5035531	
53	Aquatic Plot 5		1	Riffle	Blood worm	26.8837689	90.5162019
54		4	Pool	Flat-headed mayfly	26.8837689	90.5162019	
55		7	Riffle	Flat-headed mayfly	26.8837689	90.5162019	
56		13	Run	Flat-headed mayfly	26.8837689	90.5162019	
57		2	Run	Mosquito larvae	26.8837689	90.5162019	
58		5	Riffle	Mosquito larvae	26.8837689	90.5162019	
59		3	Pool	Net-spinning caddisfly	26.8837689	90.5162019	
60		3	Riffle	Net-spinning caddisfly	26.8837689	90.5162019	
61		10	Pool	Non-biting midge	26.8837689	90.5162019	
62		5	Riffle	Non-biting midge	26.8837689	90.5162019	
63		3	Run	Non-biting midge	26.8837689	90.5162019	
64		2	Riffle	Creeping water bug	26.8837689	90.5162019	
65		2	Run	Creeping water bug	26.8837689	90.5162019	
66		3	Pool	Small minnow mayfly	26.8837689	90.5162019	
67		9	Run	Small minnow mayfly	26.8837689	90.5162019	
68		5	Pool	Spiny crawler mayfly	26.8837689	90.5162019	
69		4	Riffle	Spiny crawler mayfly	26.8837689	90.5162019	
70	9	Run	Spiny crawler mayfly	26.8837689	90.5162019		

The comparison between macroinvertebrate communities observed in the monsoon and post-monsoon seasons show important changes in both diversity and abundance, driven by seasonal environmental factors. During the monsoon season, the data shows a high abundance of species like the Small Minnow Mayfly and Creeping Water Beetle, especially in riffle habitats, which are well-oxygenated and turbulent. The monsoon season's high water velocity and increased turbidity due to heavy rainfall support species that thrive in fast-flowing, oxygen-rich conditions. The monsoon flow dynamics also result in a more homogenized community structure, with species adapted to resist strong currents dominating.



By the post-monsoon season, the diversity pattern shifts. There is a rise in species that prefer more stable, slower-moving waters, such as Non-Biting Midges and Freshwater Prawns. The reduced water flow, lower sediment suspension, and improved water clarity in the post-monsoon period lead to habitats that can support a wider range of ecological niches. These seasonal differences are driven by water quality changes: monsoon flows cause higher turbidity, lower stability, and sediment flux, while post-monsoon flows settle, improving habitat diversity and allowing species less tolerant to physical disturbances to proliferate.

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

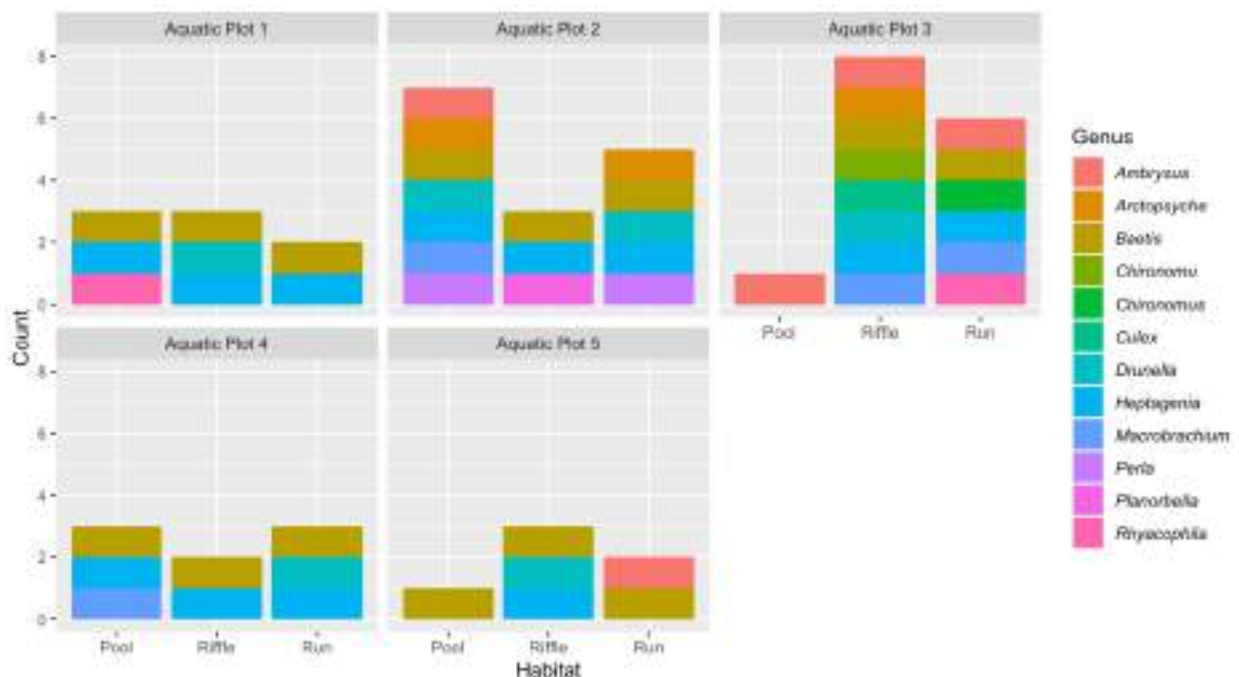


Figure 3. 25: Distribution of macroinvertebrates by Genus across plots and habitat during monsoon. Aquatic plot 3 has the highest abundance

During the monsoon season, 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 Mayfly reaches 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.



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

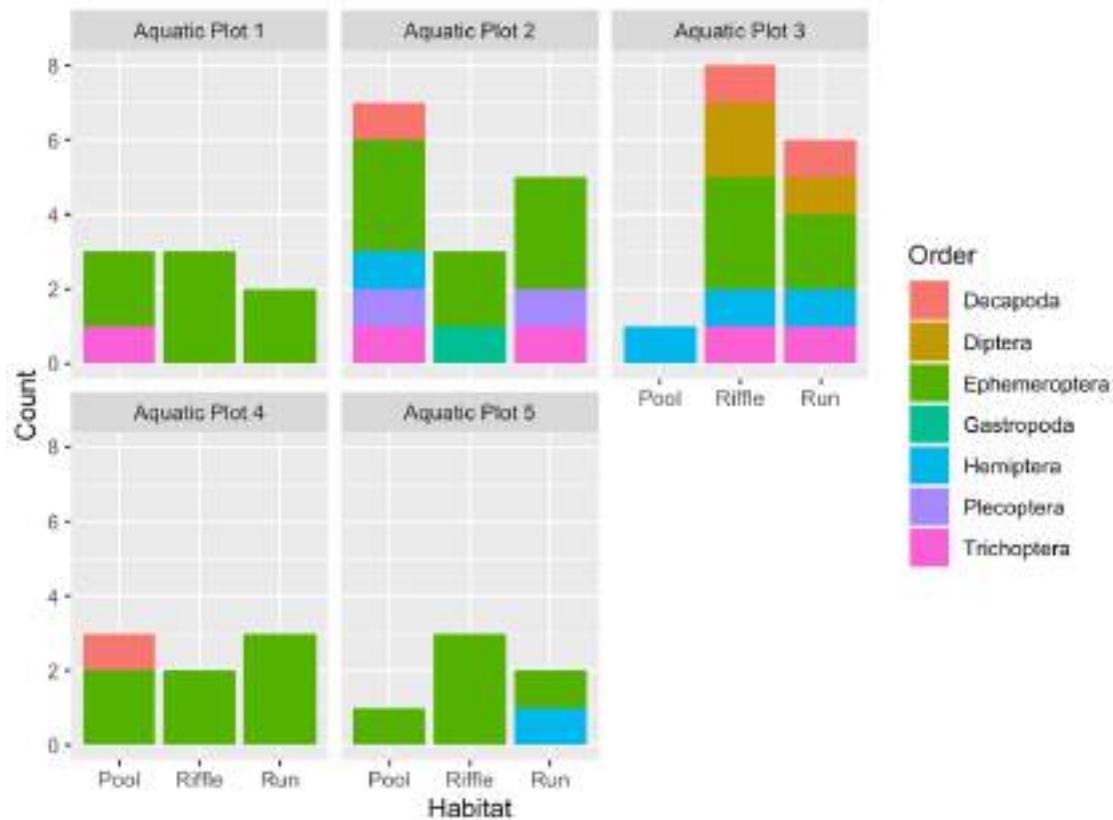


Figure 3. 26: Distribution of macroinvertebrates by Order across plots and habitat during monsoon

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.

During the post-monsoon season, Ephemeroptera, particularly *Baetis* and *Heptagenia*, were higher in riffle and run habitats, indicative of their preference for well-oxygenated, flowing waters. *Baetis*, a genus of the Baetidae family, is notably abundant, especially in Aquatic Plot 2, with counts as high as 38 in riffles, suggesting favorable conditions such as elevated dissolved oxygen and lower pollution levels. Plecoptera, represented solely by *Perla*, are

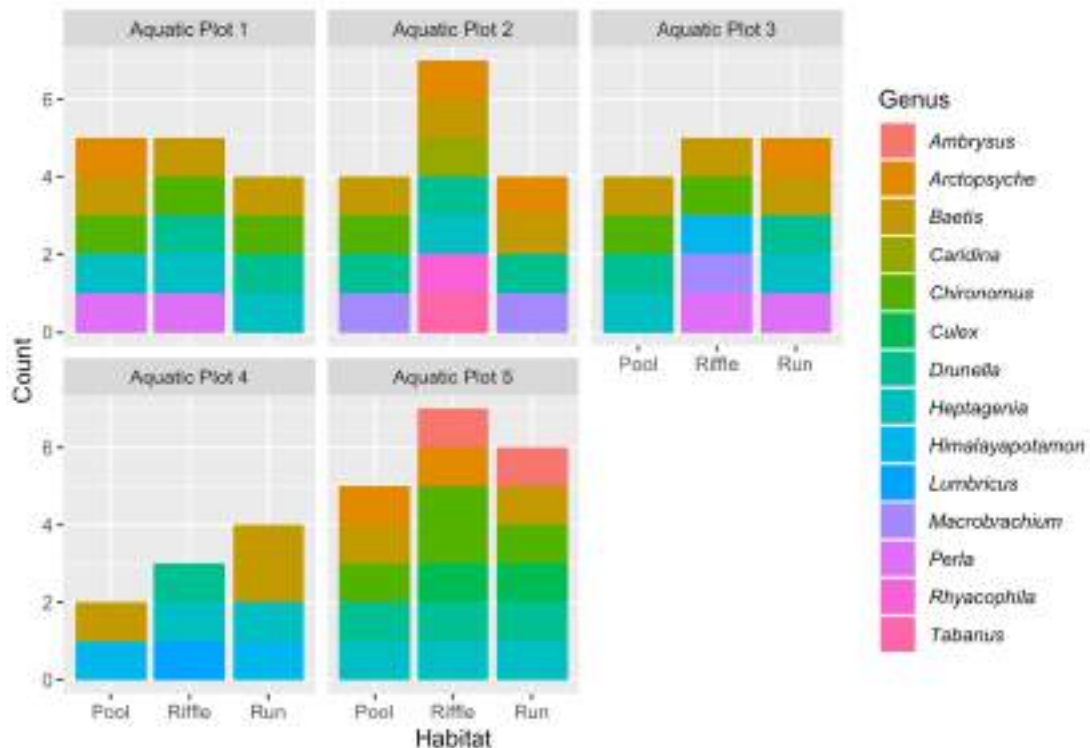


Figure 3. 28: Distribution of macroinvertebrates by Genus across plots and habitat during post-monsoon

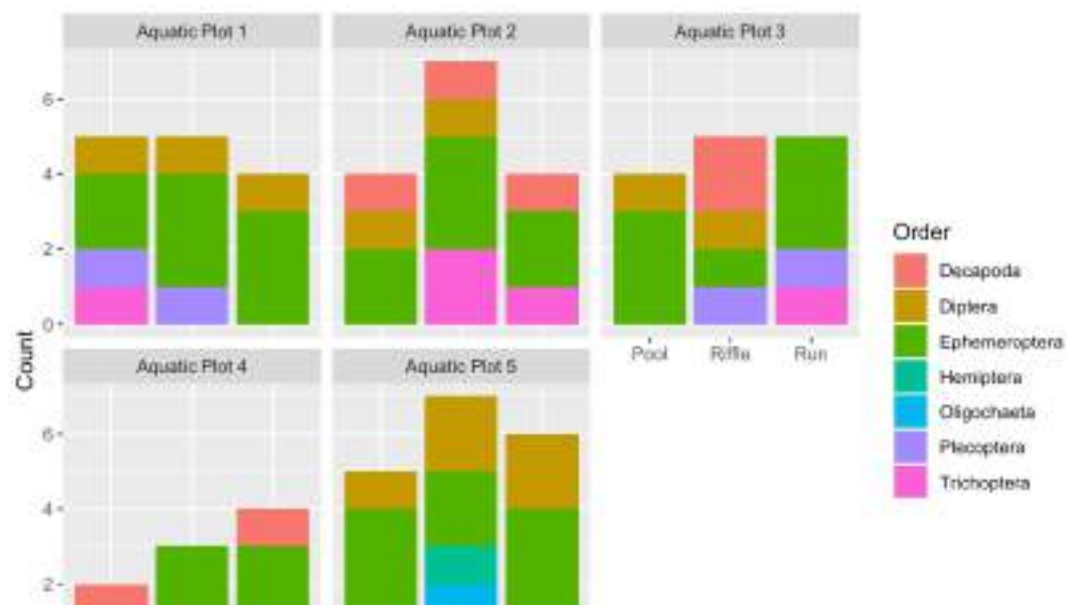


Figure 3. 27: Distribution of macroinvertebrates by Order across plots and habitat during post-monsoon

found in fewer numbers but are spread across various habitats, indicating a more specialized ecological niche requiring clear, cold waters, aligning with high-quality habitat indicators.



Figure 3. 29: Fast flowing and well oxygenated water systems in most of the aquatic plots.

Trichoptera displayed genus-specific distribution, with *Arctopsyche* dominating riffle habitats in Aquatic Plot 3, where their counts peak at 40. This suggests a habitat preference for swift currents, essential for their net-spinning behavior to capture prey. Diptera, particularly *Chironomus*, are distributed broadly across all habitat types but have higher occurrences in pools, reflective of a broader tolerance range to environmental variables, including moderate levels of organic pollution. The presence of *Culex* larvae (Diptera: Culicidae) in Aquatic Plot 5 riffles and runs suggests transient or stagnant areas within otherwise flowing waters, signaling potential localized eutrophication.

Overall water quality appears high across the sites, as evidenced by the prevalence of sensitive taxa like *Heptagenia*, *Baetis*, and *Perla*. However, the presence of Diptera like *Chironomus* and *Culex* larvae in some habitats indicates pockets of organic matter accumulation, possibly from natural or anthropogenic sources. Distribution patterns reveal habitat partitioning, with sensitive genera favoring riffles and more resilient taxa spread across diverse environments. This indicates that, while overall conditions support a diversity of macroinvertebrates, there are nuanced habitat differences that may influence community structure and composition.



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 macroinvertebrates in the proposed development area. For both the seasons, in total, 35 species of fishes were recorded from the study area in two seasons belonging to 14 different families. The majority of species were from the Cyprinidae family, which dominated both seasons with key genera such as *Barilius*, *Garra*, and *Devario*. In terms of macroinvertebrates, a total of 14 species were recorded across a seven orders and 14 families. The Baetidae family, with the genus *Baetis*, was the most abundant ($N=390$). 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.

For the monsoon season, a total of 282 fishes were encountered, representing 32 species from eight families. The most dominant species was *Garra birostris* ($N = 53$, Relative Abundance [RA] = 18.79%), followed by *Garra annandalei* ($N = 41$, RA = 14.54%). For the post-monsoon season, a total of 849 fishes were encountered, representing 28 species from nine families across the sampling stretches. The most dominant species was *Garra annandalei* ($N = 231$, RA = 27.21%), followed by *Garra birostris* ($N = 119$, RA = 14.02%).

For macroinvertebrates, the monsoon season recorded 535 samples from 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. In the post-monsoon season, a total of 498 samples from 14 species across 12 families were collected, with a slight increase in the diversity index to $H' = 1.90$. This improvement, along with higher species richness ($S_R = 4.82$), indicated a gradual recovery and stabilization of the ecosystem, although diversity remained moderate.

Overall, the dominance of certain species, particularly from the Cyprinidae family and the Baetidae family, underscores the ecological importance of these groups in maintaining ecosystem functions. Although no critically endangered species were found, the presence of diverse taxa suggests that the area provides a healthy habitat for a variety of aquatic organisms. These findings contribute to a better understanding of the aquatic biodiversity in the region, which will inform future conservation and development strategies for the Gelephu Mindfulness City project.



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