STUDIES OF FISH DIVERSITY AND ANTHROPOGENIC PRESSURE ON THE ECOLOGY OF VAISHAV STREAM IN KASHMIR HIMALAYAS, INDIA

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Zoology

By

Gowhar Rashid

Registration Number: 41700064

Supervised By

Dr. Rahul Singh (16188)

Department of Zoology (Professor)

School of Bioengineering and Biosciences

LOVELY PROFESSIONAL UNIVERSITY PUNJAB

2025

DECLARATION

I, hereby declare that the presented work in the thesis entitled **“STUDIES OF FISH DIVERSITY AND ANTHROPOGENIC PRESSURE ON THE ECOLOGY OF VAISHAV STREAM IN KASHMIR HIMALAYAS, INDIA”** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision **Dr. Rahul Singh** (16188), working as Professor, in the Department of Zoology/ School of Bioengineering and Biosciences of Lovely Professional University, Punjab, India. In keeping with the general practice of reporting scientific observations, due acknowledgments have been made whenever the work described here has been based on the findingsofother investigators.Thisworkhasnot beensubmitted inpartorfullto anyother University or Institute for the award of any degree.

(Signatureof Scholar)

Name of the scholar:Gowhar Rashid

Registration No.: 41700064

Department/school: Zoology/Schoolof BioengineeringandBiosciences.

Lovely Professional University,

Punjab,India

CERTIFICATE

This is to certifythat the work reported in the Ph.D. thesis entitled **“STUDIESOF FISH DIVERSITY AND ANTHROPOGENIC PRESSURE ON THE ECOLOGY OF VAISHAV STREAM IN KASHMIR HIMALAYAS, INDIA”** submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy(Ph.D)** in the **Department of Zoology/School of Bioengineering and Biosciences**, is a research workcarried outby **GowharRashid** (Reg.No.:41700064) is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

(Signature of Supervisor)

Nameofsupervisor: Dr.Rahul Singh

Designation: Professor

Department/School:

DepartmentofZoology/SchoolofBioengineeringand Biosciences

University: Lovely Professional University

ABSTRACT

Streams and rivers are vital components of freshwater ecosystems, serving as crucial habitats for diverse aquatic life and sources of drinking water for human populations. However, these aquatic ecosystems face increasing threats from anthropogenic activities, including pollution and habitat degradation. This study presents a comprehensive assessment of the Vaishav stream, aiming to analyze its physico-chemical parameters, evaluate the status of fish fauna, and assess anthropogenic threats and challenges. Through seasonal variations analysis and ecological parameter investigations, this research sheds light on the intricate dynamics of the Vaishav stream ecosystem and underscores the urgent need for conservation and management strategies to protect its biodiversity and water quality. Seasonal and site variations in physico-chemical parameters were examined through ANOVA and Fischer's LSD test, revealing fluctuations influenced by natural factors such as geology, weathering, and climate, alongside human activities like agriculture and land use. Cluster analysis delineated differences in water quality between upstream and downstream areas, emphasizing the impact of human habitation. Principal Component Analysis identified key factors contributing to water quality variation, highlighting the need for comprehensive monitoring and management strategies. Simultaneously, the researchers examined spatio-temporal fluctuations in the ecological parameters of the fish community. Field investigations were carried out at three distinct sites over the course of four seasons.

The analysis revealed significant differences in fish abundance among various sites, with higher diversity index values downstream indicating a more conducive environment for fish survival. A total of 630 specimens belonging to 11 fish species, three orders *Cypriniformes*, *Siluriforms* and *Salmoniformes* and four families including *Cyprinidae*, *Nemachelidae*, *Siluridae* and *Salmonidae* were reported from the study sites. Among collected specimens, *Cypriniformes* were dominant with nine species followed by order *Siluriformes* and *Salmoniformes* with one species each. Out of eleven fish species, six fish species belongs to family *Cyprinidae*, three to *Nemachelidae*, one to *Siluridae* and

Salmonidae each. The analysis, employing t-test, NMDS, PCA, ANOSIM and, PERMANOVA on fish abundance data highlighted statistically significant differences among the various sites but not across seasons which may be due to habitat heterogeneity, physical structure and substrate. The results unveil a diverse occurrence and distribution pattern of fishes from upstream to downstream. Furthermore, diversity metrics confirm higher diversity index values downstream, indicating a more conducive environment for fish survival. Jaccard's index reveals greater similarity in fish fauna between site-II and site-III than between site-I and site-III. Overall, study revealed that anthropogenic activities in the stream catchment area have led to a reduction in fish diversity and abundance, with landscape features significantly influencing fish abundance in this unique Himalayan ecosystem.

Moreover, anthropogenic impacts on stream ecology, driven by factors such as illegal fishing practices, siltation, urbanization, encroachment by human settlements, and the influx of sewage, domestic effluents, agricultural runoff, as well as pesticides and fertilizers were assessed. These disturbances pose severe threats to riverine environments worldwide, particularly in sensitive regions like the Himalayas. Human population density and associated land use developments, including urbanization and road construction, were found to significantly impact aquatic organisms and alter stream hydrology and channel morphology. Anthropogenic pollutants from various sources, including industrialization and urbanization, were identified as significant contributors to water pollution, adversely affecting aquatic fauna. The study underscores the urgent need for comprehensive conservation and management strategies to mitigate anthropogenic impacts and safeguard freshwater resources and biodiversity in stream ecosystems.

ACKNOWLEDGEMENT

First, I want to express my sincere gratitude to the Almighty, the creator of this magnificent universe, for granting me the patience and determination to see this research through to completion.

I deeply thank my supervisor, **Dr. Rahul Singh**, for his unwavering support and steadfast commitment throughout this research endeavor. His guidance and positive outlook have been pivotal in maintaining my motivation and perseverance.

I extend my heartfelt appreciation to **Prof. Neeta Raj Sharma, Head of School, Dr. Joydeep Dutta, Head of Department**, and all esteemed faculty members, especially **Dr. Amit Sehgal**, for fostering a nurturing academic environment that has significantly enriched my learning experience.

I am especially thankful to **Dr. Aadil Hameed, Dr. Iqbal, Dr. Lateef, Dr. Adil Nanda, Dr. Sartaj, and Dr. Najeeb**, whose valuable guidance, constructive suggestions, and constant encouragement greatly helped me during the preparation of this thesis.

I am grateful to my friends, seniors, and colleagues, **Dr. Shaista Manzoor, Dr. Sufiara Yousuf, Nafiaah Naqash, Amit Chambial, Asma Masood, Kritika Singh, Reetika Rani, and Laxmi R**, for their unwavering support and encouragement.

Finally, I am profoundly grateful to my **parents**, for their unwavering love and encouragement. Their faith in my abilities has been a constant source of motivation throughout my academic journey.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

INTRODUCTION

CHAPTER 1 - INTRODUCTION

The Kashmir Valley is situated within the tectonically formed Himalayan Mountains with a north-western orientation and is renowned for its intricate network of lentic and lotic ecosystems including distinctive fish species (Hussain, 2000). Surrounded by mountains capped with snow, the valley spans an area of 101387 square kilometers, positioned between 33°.20' and 34°.54' north latitude and 73°.55' and 73°.35' east longitude (Figure 1) (Itoo *et al*., 2015). The region, situated at an average elevation of approximately 6,000 feet above sea level (Hussain, 2000) and is bordered by China to the north and east (Xinjiang and Tibet), Afghanistan to the northwest (Wakhan Corridor), Pakistan to the west (Khyber Pakhtunkhwa and Punjab), and the Indian states of Himachal Pradesh and Punjab to the south (Tamang and Prakash, 2009). The Kashmir Valley's drainage basin is delineated by the Indus River system originating in Ladakh at the southeastern corner of the Tibetan Plateau and flowing northwestward through Ladakh and Gilgit-Baltistan. The rivers originating from the Himalayan region contribute to the Indus river system (Khan *et al.,* 2015). Upon reaching the end of the Great Himalayan range, the Indus moves southwest into the Punjab plains (McIntosh, 2008), with the Jhelum and Chenab rivers running parallel and joining the Indus River in the southern Punjab plains of Pakistan (Garzanti *et al.,* 2005).

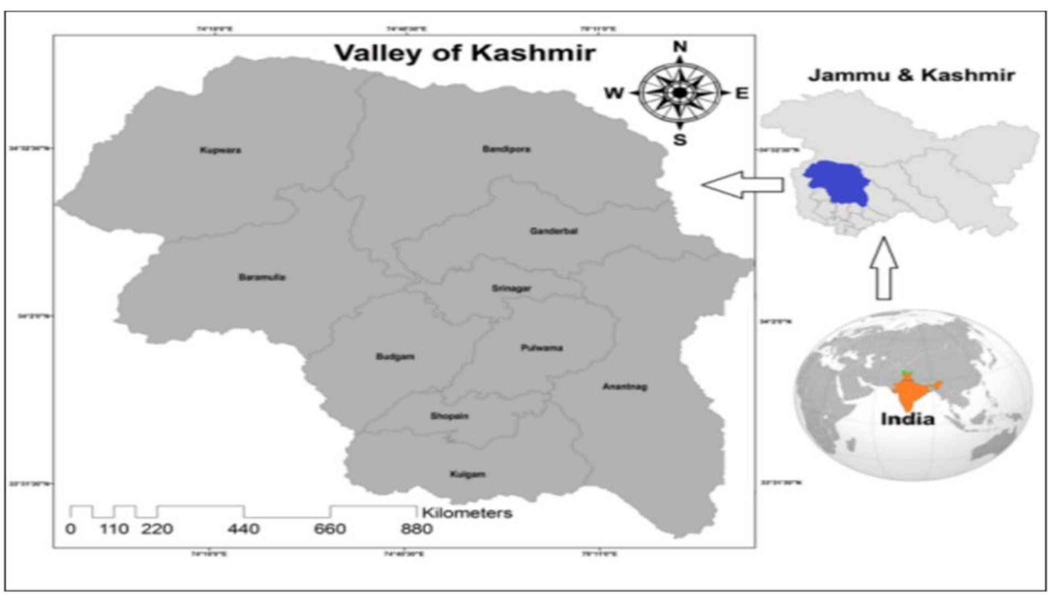


Figure 1: Map of India showing the location of Kashmir valley.

The Valley experiences marked seasonality similar to sub-Mediterranean climates, characterized by variable rainfall throughout the year, Besides that lush green forests, snow-capped peaks, and abundant freshwater bodies, including streams, rivers, and lakes, offer diverse habitats for fisheries growth and expansion (Khan and Ali, 2013). Major rivers in the region include Ravi, Ujh, Tawi, and Chenab in Jammu, while Kashmir hosts streams like Liddar, Vaishav, Rambiara, and others, along with freshwater lakes such as Wular Lake, Dal Lake, and Hokersar Lake (Jamal and Ahmad, 2020). These aquatic resources present significant potential for fisheries development, catering to social demands and contributing to the national economy (Sultan & Kant, 2016). The region's lakes, rivers, and streams support a rich variety of indigenous and exotic fish species, offering recreational opportunities and serving as sources of natural products like fish and fodder (Qadri, 2022). Indigenous fish species such as *Schizothorax* spp., *Labeobarbus* spp., and *Barbus* spp., alongside introduced species like trout (*Salmo trutta fario* and *Oncorhynchus mykiss*), thrive in the waters of the Kashmir Himalayas (Hussain and Rashid, 2021). Trout, introduced in the early 20th century, has become integral to both sport fishery and local cuisine, generating employment opportunities and contributing to food security (Sareer *et al.*, 2012). The unique hydrology, topography, and morphology of Himalayan streams and rivers contribute to the distinctiveness of the region's fish fauna (Badoni, 2018).

Riverine ecosystems experience fluctuations in species abundance due to seasonal changes in physicochemical properties and various factors contribute to these variations, influencing species survival positively or negatively (Sharma *et al.*, 2016). Water, essential for sustaining all life forms, is a scarce resource, with only about 1% of Earth's water accessible to humans (Longo and York, 2022). Increasing demands for freshwater globally, driven by population growth, agricultural practices, and climate fluctuations, pose uncertainties for future generations (Okello *et al.*, 2015). India constitutes rich water resources supporting diverse freshwater fish species across streams, lakes, rivers

However, these resources face threats from illegal fishing, environmental disturbances, and pollution, leading to biodiversity decline (Mishra *et al.*, 2021). Deteriorating water quality profoundly impacts ecosystems, disrupting dynamics and habitat integrity with anthropogenic activities like agricultural runoff and sewage discharge being primary contributors (Slathia *et al.*, 2023).

Fisheries are vital for national economies, providing income, employment, and nutrition globally (Norman *et al.*, 2019). India, renowned for its fish diversity, ranks second in global fish production contributing significantly to nutrition and food security with high-quality proteins and essential nutrients, fish serve as a cost-effective dietary staple worldwide particularly in combating malnutrition and food insecurity (FAO, 2022; Mansour *et al.,* 2021). Freshwater habitats host diverse fish species, with India harboring approximately 2,500 species, notably in regions like the Western Ghats and Eastern Himalayas (Awas *et al.,* 2023). Fisheries significantly contribute to India's GDP and agricultural sector, with vast employment potential (Prakash, 2021). Understanding fish community dynamics, including diversity and abundance, is crucial for effective management (Nisa *et al.*, 2020), considering factors like physicochemical parameters and food availability (Brown, 1984). Anthropogenic activities threaten freshwater biodiversity, with over 5,000 species at risk of extinction due to factors like .overexploitation and pollution.Moreover, urgent conservation measures are necessary, with fishes serving as excellent indicators of water quality (Froese and Pauly, 2020). Invasive species, habitat loss, and overfishing further endanger freshwater fish diversity (Mishra *et al.*, 2021). Safeguarding freshwater fish diversity requires addressing threats like pollution and habitat degradation through effective conservation measures and sustainable management practices (Arthington *et al*., 2016).

Issues concerning surface water quality are particularly acute in densely populated areas, exacerbated by rapid urban growth and improper waste disposal practices, impacting both surface and groundwater quality Rivers and streams serve as conduits for municipal, industrial, and agricultural wastewater, laden with pollutants that threaten human health and aquatic life (Saqib *et al*., 2023). Assessing the complete water quality parameters necessitates monitoring the spatial-temporal fluctuations in stream water quality (Kerega *et al*., 2017). Changes in water chemistry are influenced by factors such as temperature, light, discharge, and water velocity, which vary spatially and temporally due to hydrologic inputs and stream conditions (Islam *et al*., 2017). Urbanization, industrialization, and agricultural activities contribute to increased water demand and pollution, rendering water unfit for consumption, aquatic life, and irrigation (Qadri and Faiq, 2020). Controlling pollutants and monitoring water quality are essential for preserving water bodies. Illegal mining and extraction of riverbed materials and deforestation and soil erosion further degrade riverine ecosystems and aquatic biodiversity (Kamboj *et al*., 2018).

Stream characteristics like bed composition, shape, order, length, and gradient regulate fish fauna distribution and abundance, making protection of stream habitats crucial for fish conservation (Ashok, 2018). Anthropogenic pressures, such as untreated sewage discharge, illegal mining, and overfishing, contribute to the decline of native fish species, particularly cold-water species like *Schizothorax* (Rumysa *et al*., 2016; Khan and Ali, 2013). The influx of pollutants into streams alters their trophic status and water characteristics, impacting aquatic ecosystems.Anthropogenic activities, including agricultural practices, urban development, and river dredging, threaten freshwater fish species by reducing floodplains, diverting water for irrigation, and polluting aquatic environments (Allan and Castillo, 2021; Ekka *et al.*, 2020). Aquatic pollution from sewage, solid waste, and chemical runoff affects fish physiology, behavior, and reproductive success, leading to diseases and population decline (Bukalo *et al.*, 2015). Mining activities for construction purposes contribute to habitat destruction, soil erosion, and riverbed degradation, exacerbating environmental issues Uncontrolled sand and gravel mining, along with illegal fishing practices, further degrade aquatic ecosystems, threatening fish populations globally (Kamboja *et al*., 2018). Addressing these anthropogenic pressures through effective management strategies and conservation efforts is crucial for safeguarding freshwater ecosystems and the species they support.

In developing countries, the escalating human population is driving a heightened demand for freshwater fishes and their products, placing immense pressure on easily accessible resources. Nonetheless, the increase in demand aligns with a troubling decrease in freshwater fish diversity across the country, reflecting worldwide concerns about the decline of aquatic ecosystems and their biodiversity, especially in river systems (Baggio *et al*., 2021). Overexploitation emerges as a critical threat to fish and aquatic biodiversity, jeopardizing the livelihoods of communities reliant on rivers and lakes. Several taxa, including high-value food fish such as the Murray cod (*Maccullochella peelii*), freshwater whipray (*Himantura chaophraya*), and Mekong giant catfish (*Pangasianodon gigas*), along with some *Schizothorax* species like *S. rechidoson* from Kashmir waters, face significant population declines (Rumysa *et al.*, 2019). Assessment of water quality has assumed paramount importance due to the potential hazards associated with contaminated water supplies (Mir *et al*., 2024). Typically, pollution levels are evaluated by scrutinizing the physical and chemical characteristics of water bodies. Despite freshwater being a vital resource for human sustenance, factors such as population growth, development, and environmental changes continue to strain these limited resources (Bhat *et al*., 2021). The Vaishav stream, a perennial left-bank tributary of the River Jhelum, serves as a lifeline for numerous communities along its banks and harbors great potential for supporting freshwater fish fauna. However, sewage and municipal waste influx from settlement areas have significantly deteriorated water quality, while various anthropogenic factors such as habitat alteration, urban land use, chemical contamination, surface runoff, and intensive agriculture have contributed to the widespread degradation of lotic ecosystems (Arfat *et al*., 2022). Consequently, aquatic ecosystems have become receptacles for wastes from human settlements, agricultural fields, and surface runoff, adversely impacting the resident biota, particularly fishes (Khan and Ali, 2013).

Research on fisheries assumes critical importance in the face of increasing contamination of aquatic ecosystems by numerous anthropogenic disturbances, leading to the continuous decline of fish populations worldwide. Such research aids policymakers in devising appropriate measures to conserve and manage fish populations, emphasizing the necessity of regular monitoring of abiotic factors influencing habitat stability (Hader *et al.,* 2020). Understanding physicochemical parameters can elucidate their influence on fish diversity and composition, thereby informing conservation efforts (Brraich and Malik, 2016). To conserve freshwater fish diversity, sustainable fishery practices must be developed, necessitating the assessment of anthropogenic deterioration and the implementation of effective conservation and restoration measures. Detailed information on stream fish communities, particularly in critical ecosystems like the Vaishav Stream, is crucial for designing conservation strategies and mitigating threats to fish populations (Bhat *et al.,* 2020). Therefore, comprehensive studies on fish diversity and anthropogenic pressures in streams like the Vaishav Stream are imperative for generating baseline data, guiding conservation efforts, and ensuring the long-term sustainability of freshwater ecosystems.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2 – REVIEW OF LITERATURE

Aquatic environment serves as a critical reservoir and facilitates a significant portion of Earth's biological productivity. Both aquatic biodiversity and resources are intricately interconnected, performing numerous invaluable functions essential for biotic community sustainability. Despite being the oldest, most diverse vertebrate group, aquatic diversity loss often receives insufficient attention (Williams *et al.*, 2021). The importance of biodiversity in aquatic habitats underscores the necessity for their conservation efforts. Aquatic environments play a crucial role as reservoirs of earth's biodiversity and productivity interconnected with aquatic resources, biodiversity fulfills numerous critical functions for biotic communities (Smith *et al.*, 2022). However, freshwater and marine biodiversity continue to decline owing to various human disturbances as well as overexploitation, introduction of non-native species, contamination and habitat loss (Irfan & Alatawi, 2019).

Fish diversity encompasses the variety of fish species within populations or across aquatic ecosystems in terms of genotypes or life structures (Kar *et al.*, 2006). Extensive scientific literature exists on fish diversity, elucidating its structural and functional stability within aquatic environments (Chakraborty and Chakraborty, 2021). Maintaining rich diversity in aquatic environments is crucial to preserving their stability and ensuring the proper functioning of food chains (Bakhtiyar *et al.*, 2022). The distribution patterns of freshwater fish fauna vary across continents, influenced by historical factors such as physical barriers and temperature adaptations. Regions that have never experienced glaciation tend to be relatively species-rich, while those affected by glaciation typically exhibit less diverse fish fauna (Leveque *et al.*, 2008). Asia, in particular, boasts a high number of fish families recorded from inland waters, with dominant groups such as Cypriniformes, Siluriformes, and others, highlighting the region's significant freshwater fish diversity (Leveque *et al.*, 2008).

2.1 Global Fish Diversity

Research on fish composition and their ecological requirements dates back to the 1980s, with studies conducted in Sri Lankan streams, the Western Himalaya, and the Kumaon Himalaya (Moyle and Senanayake, 1984; Negi *et al.,* 2007). Globally, riverine dimensions and primary production play crucial roles in influencing species richness and regulating local factors such as competition, predation, and habitat diversity (Arunachalam, 2000). Furthermore, limnological factors like temperature, water flow, and stream morphology also significantly influence fish diversity composition (Bhat, 2004). Studies on specific river systems across different regions have shed light on their fish diversity. For instance, the Barandu River in Khyber Pakhtunkhwa, Pakistan, reported 11 species under three orders and four families, with *Schizothorax plagiostomus* being widely distributed but facing population decline due to overhunting and pollutants (Saeed *et al.,* 2013). Similarly, freshwater fish studies in China reported a diverse composition, with a significant number of native and threatened species (Xing *et al.*, 2016; Shuai *et al.,* 2017). In Indonesia's Koto Panjang Reservoir, 1300 fish species were recorded, with Cyprinidae being the dominant family (Aryani *et al*., 2019). Similar observations were made in Nepal's Kamala River, where cyprinids dominated the fish community (Ghimire and Koju, 2021).

Studies in various river basins worldwide have further contributed to our understanding of fish diversity. For example, research in the West Rapti River, Nepal, identified 42 species, with Cypriniformes being the most dominant order (Chaudhari, 2022). In Sarawak, Borneo, the Baleh River Basin study revealed 76 species, with Cyprinidae dominating, followed by Gastromyzontidae (Soo *et al.,* 2021). Similarly, studies in the Lohore River of Dailekh, Western Nepal, and the Taizi River in China documented fish diversity patterns along longitudinal gradients (Shrestha, 2021; Wang *et al.,* 2022). Furthermore, research in Iran's Karun River basin highlighted 37 species, including endemics, while studies in Central Europe's small watercourses reported 9339 species belonging to 33 families (Shahraki *et al*., 2022; Brysiewicz, 2022). Similarly, investigations in the Anning River, China, and a semi-arid mountainous river basin in Iran identified diverse fish assemblages (Ma, 2023; Shahraki *et al.,* 2022). These studies underscore the importance of understanding fish composition and distribution patterns across different river systems to inform conservation and management efforts effectively.

2.2 Fish Diversity in India

Research on fish diversity and composition has been extensive, with studies spanning various regions and ecosystems. Chondrichthyes and Osteichthyes, the two major classes of fishes, are represented by 67 and 902 genera, respectively (Nair, 2024). In the Indian subcontinent, initial contributions to the study of freshwater ecosystems were made by British officers of the British East India Company, including notable works such as "The Fishes of the Ganges" (Hamilton-Buchanan, 1822) and "Fishes of India" (Francis Day, 1875-1878). Over time, numerous researchers have delved into exploring fish diversity across different aquatic bodies. For instance, studies on the Ponnani estuary in Kerala revealed 112 fish species under 14 orders, with certain families like Clupeidae and Cyprinidae being prominent (Sushama, 2014). Research on specific water bodies, such as the Ramsagar reservoir, has provided insights into fish composition, with Cypriniformes being the dominant order (Garg *et al.,* 2009). Studies in Mizoram conducted by the Zoological Survey of India reported 89 species under 49 genera and 20 families (Kar and Sen, 2007). Similarly, investigations into the Ranjit Sagar reservoir in Jammu and Kashmir revealed 18 species belonging to 5 orders and 9 families (Kumar *et al.,* 2006).

In Arunachal Pradesh, systematic surveys of rivers documented 138 fish species, contributing to the development of a comprehensive checklist for the state (Bagra *et al.,* 2009). Further studies in Karnataka, Maharashtra, and other regions highlighted the diversity of fish species and their distribution patterns (Shinde *et al.,* 2011; Katwate *et al.,* 2014). Studies also focused on specific rivers, such as the Meghalaya region, which reported 68 fish species (Ramanujam *et al.,* 2010). In the Western Himalayas, research on tributaries of the Ramganga River documented 43 species, highlighting the prevalence of threatened species and the dominance of the Cyprinidae family (Atkore *et al.,* 2011). The northeastern region of India reported 422 fish species, further emphasizing the region's rich aquatic biodiversity (Goswami *et al.,* 2012). Studies in Assam's rivers and other regions continued to expand our understanding of fish diversity. An examination of the Charju River in Arunachal Pradesh uncovered a total of 37 species spanning three orders and twelve families (Tesia and Bordoloi, 2012). Overall, these studies underscore the importance of ongoing research to monitor and conserve fish diversity in various aquatic ecosystems, contributing to our understanding of their ecological roles and the need for effective management strategies.

2.3 Fish Diversity in Kashmir

Kashmir, renowned for its freshwater habitats, has been a focal point for researchers seeking to explore its diverse fish fauna over the years. The fish fauna within the Kashmir Valley exhibits notable distinctions from those found in other regions of the country, with a prevalence of species belonging to the *Schizothorax* genus. Variances in elevation and topography contribute to varying successional sequences in water bodies across the Kashmir region. While the water bodies of the Kashmir Valley boast a rich array of fish species, much of the research has historically focused on fisheries within standing water habitats, with comparatively less attention directed towards flowing water environments (Yousuf, 2004). Riverine environments, which encompass various streams like Vaishav, Lidder, Dudhganga, and Sindh, coursing through the valley and feeding into the Jhelum River, support a rich collection of native fish species such as *Schizothorax*,*Glyptothorax*, *Triplophysa*, *Barbus*,and *Nemachilus* Additionally, these aquatic habitates also host trout species like *Oncorhynchusmykiss* and *Salmo trutta fario* (Rashid and Singh, 2020). Despite this richness, high-altitude water bodies have historically received less attention in terms of comprehensive exploration to elucidate current fish diversity (Hussain and Rashid, 2021). Significant contributions to the understanding of Kashmir's ichthyo-fauna have been made by various researchers over the years, including Steindachner (1866), Gunther (1868), Day (1878), Hora (1939), and Misra (1949). Hora's comprehensive account of the Mahseer (*Tor putitora*) in "Game Fishes of India" shed light on their distribution along the Himalayas. Subsequent contributions by researchers such as Silas (1960), Sunder (1979), Yousuf *et al.*, (2006), Bulkhi (2007), Bhat *et al*., (2010) expanded upon earlier work, providing updated checklists with an increased number of species.

Studies by Das and Subla (1964) classified the fish population of the Kashmir Valley into three categories based on their origins and species of central Asiatic origin, Indian origin, and exotic species. While initial reports documented sixteen fish species, primarily from the Cyprinidae family (Heckel, 1839), subsequent research by various scholars, including Day (1878), Hora (1936), and Yousuf (1996), has contributed significantly to a more exhaustive understanding of the fish population in all the aquatic bodies of the Kashmir Valley. A comprehensive survey of fish fauna in the Kashmir valley recorded thirteen fish species, with the majority falling under the order Cypriniformes. Families represented in this survey include Cyprinidae, Cobitidae, Siluridae, Poecilidae, Sisoridae, and Salmonidae (Kullander *et al*., 1999; Mushtaq *et al*., 2018). The introduction of common carp in 1956 has had significant ecological implications, as its prolific breeding has led to its widespread invasion of main water bodies, impacting native Schizothorax fishes negatively (Vass *et al.*, 1977). Recent studies have continued to expand our knowledge of fish diversity in Kashmir, with Bhat *et al.* (2020) identifying twenty-three species in the Kashmir region, predominantly belonging to the order Cypriniformes and families Cyprinidae, Cobitidae, and Balitoridae. Further investigations into specific tributaries and streams have revealed additional nuances in fish diversity. For example, studies on the Basantar River in Samba district, Jammu, uncovered thirty-five fish species belonging to five orders, while investigations into the Vaishav stream reported seven species (Sharma and Dutta, 2012; Naikoo *et al.*, 2015). Similarly, surveys of other tributaries such as the Wajoo nullah and river Ujh have documented significant fish diversity, underscoring the importance of these water bodies in supporting diverse aquatic ecosystems (Rathore and Dutta, 2015). Taxonomic studies of freshwater fish species, focusing on morphology, morphometrics, and meristics, have provided crucial insights into species identification and population diversity. These studies conducted by researchers such as Jayaram (1999) and Talwar and Jhingran (1991), emphasize the importance of accurate species identification and the role of traditional ecological knowledge (TEK) in integrating local expertise with modern ichthyology. Assessment of physicochemical parameters is essential for understanding water quality and its implications for aquatic ecosystems and human health. Studies have revealed significant variations in water quality parameters along various rivers and streams in Kashmir, influenced by factors such as land use, urbanization, and agricultural activities (Khadse *et al.,* 2016). Continuous monitoring and assessment of water quality are imperative for effective water resource management and environmental conservation efforts.

2.4 Anthropogenic threat

Pollution in riverine environments resulting from the multifaceted impact of human activities worldwide presents a significant challenge. Despite the earth's surface being comprised of 71% water, only a minute fraction, approximately 0.3%, is freshwater and accessible for human use in both rural and urban areas. This freshwater, derived from both ground and surface water sources, is subject to various human-induced threats (Akther *et al.,* 2021). Freshwater fishes represent one of the most imperiled vertebrate groups on the planet, following amphibians, with a global extinction rate believed to surpass that of higher vertebrates. The primary drivers behind the decline in freshwater biodiversity include habitat degradation, fragmentation, increased sedimentation, introduction of exotic species, water extraction, overexploitation, pollution, and the impacts of global climate change (Adla *et al*., 2022). Previous studies have found that the anthropogenic activities on streams and rivers tend to degrade the water quality as well as aquatic biota like fishes (Ogida and Akpan, 2022). The aquatic ecosystem of India has greatly suffered due to anthropogenic disturbances which results in loss and degredation of habitat. In case of lotic systems, physicochemical variables were reflected as the vital factors in changing the fish assemblage and pattern (Sharma *et al*., 2024). Stream bed is made up of rocks and boulders and provides shelter for breeding and spawning for fresh water fishes (Singh and Kumar, 2003). Therefore, it is essential to monitor the water quality parameters inwater bodies continuously. By analysing the Neeru Nallah of

Bhaderwah district of Jammu and Kashmir it was found that multiple anthropogenic threats were responsible for destruction of breeding habitats and overall population of *Schizothorax richardsoni* in Neeru Nallah of Bhaderwah district (J&K) is declining at a very alarming rate by soil erosion, land sliding, illegal fishing and various other anthropogenic avtivities (Malhotra *et al.,* 2003). Fish species of Kashmir valley had declined due to degredation of aquatic environment and the decline in native Schizothoracine population was due to encroachment of shallow peripheral areas of the water bodies (Ahmad *et al.,* 2017). Fishes are subjected to a number of anthropogenic threats which includes habitat loss, hydrological changes, climate change, over-exploitation, and dispersal of invasive species (Arthington *et al*., 2016).

Rivers, streams, and their associated tributaries, spanning both urban and rural regions, have become receptacles for a significant influx of pollutants stemming from industrial discharges, domestic waste and agricultural runoff. This pollution burden is exacerbated by population growth, rapid urbanization, and heightened economic activities, which drive the demand for potable water for human consumption (Kumar *et al*., 2020). The indiscriminate release of these hazardous effluents into aquatic ecosystems poses serious challenges, rendering water unsuitable for drinking, agricultural purposes and sustaining aquatic life (Bashir *et al*., 2020). Various physicochemical parameters such as water temperature and oxygen levels, play crucial role in determining the distribution, growth, and survival of fishes, with elevated temperatures leading to decreased dissolved oxygen concentrations in water (Ahmad *et al*., 2024). Studies examining anthropogenic impacts and other human activities on water bodies within the valley yield foundational data essential for the conservation and management of fish populations as well as for the formulation of new fisheries policies (Acharjee and Bharat, 2010). Specific anthropogenic factors, including agro-industrial waste, excessive extraction of river water, sedimentation, and overfishing, have been identified as major threats to fish diversity in the Baral River, Natore, Bangladesh (Flowra *et al.*, 2013). The introduction of allochthonous matter into these ecosystems may have long-term repercussions on water quality, with potential future consequences (Odigie, 2019). The impact of anthropogenic disturbances on quality of water in the Lidder stream, a right bank tributary of River Jhelum was investigated. Agricultural and horticultural activities within the stream's catchment area were found to be significant contributors to the degradation of water quality (Rashid and Romshoo, 2013). The water resource of West Bengal is scarce due to population growth, expansion of irrigation network and developmental needs (Mahapatra *et al.*, 2014). The significant alterations in the physicochemical parameters of River Krishna, Sangli Maharashtra are due to the anthropogenic disturbances through immersion of idols, irrigation, domestic use, discharge of sewage, sand dredging (Sarwade and Kamble, 2014). Continuous pollution in the aquatic environment is harmful for the fishes which leads to mortality and accumulation of pollutants in the body and also causes diseases in gills and tail rott ulceration (Dawodu *et al.,* 2015). Fish communities shows high degree of variability and act as bioindicators of pollution by showing signs of morphological deformities and lasens (Dawodu *et al.*, 2015). The deterioration and increased silt load of water quality due to human activities have been investigated in the River Jhelum of Kashmir Himalayas India had worsen due to reckless application of pesticides, fertilizers and unplanned urbanization in the immediate vicinity ofthe river (Ahmad, 2019). Increased pollutant levels in the Buyuk Menderes basin, Turkey, have led to the disappearance of many endemic species due to their inability to thrive in polluted water (Yilmaz and Koc, 2016). Human activities have significantly impacted the Wular Lake, with the *Schizothorax richdosonia* species nearly disappearing due to human intervention (Rumysa *et al.,* 2016). In the perennial Wajoo Nullah, a vital tributary of the River Ravi in Kathua district, overexploitation and illegal fishing during the breeding season have caused a decline in fish fauna (Dutta, 2016). Anthropogenic pressures, such as agricultural runoff, urban development, and domestic sewage discharge, are the primary drivers of deteriorating water quality in the Vaishav stream, a left bank tributary of the Jhelum (Hamid *et al.,* 2016).

Similar deteriorations have been observed in the fish catch and diversity in the River Jhelum due to external influences (Khan and Ali, 2013). Wular Lake, Asia's largest freshwater lake, faces threats from sewage and disturbances in its catchment area, leading to a decline in the population of native snow trouts (Brraich and Malik, 2016). Mullai Periyar River in Theni district, Tamil Nadu, suffers from high pollution levels due to domestic, municipal, industrial, and agricultural waste contamination (Sivamanikandan and john, 2015). The biodiversity of the Lohalia river indicates vulnerability, with a significant proportion of species classified as endangered or critically endangered due to anthropogenic disturbances (Rubel *et al.,* 2016). Overfishing, pollution, sedimentation, urbanization, and human encroachment have all contributed to a decrease in fish diversity in the Bhairab River (Islam *et al.,* 2017). Poor water quality in downstream areas of the Vaigai River, Tamil Nadu, India, is attributed to urban wastewater discharge (Ramprasad *et al.,* 2017). Anthropogenic threats to rivers and streams, such as sedimentation and mining activities, have modified limnological and biological parameters, increasing susceptibility to biotic invasions and causing cascading effects in adjacent and downstream environments (Chiu *et al.,* 2017). Anthropogenic factors have severely impacted fish habitats in the Ganjiang River, China, resulting in a decline in fish diversity (Guo *et al.,* 2018). Overfishing and pollution pose significant threats to fish diversity in the Narmada River (Yogesh and Mudgal, 2018). The spatial and temporal variation in water quality of Tongzhou Beiyun River and the findings revealed that temporal variation is greater than spatial moreover sewage discharge was considered as dominant factor causing seasonal variation in river (Ren *et al.,* 2018). The increasing demand of river bed materials, illegal mining in stream and even in agricultural fields, flood plains area have been increased which degrade the riparian area and subsequently effects the aquatic and terrestrial biodiversity (Kamboj *et al.,* 2018). The various anthropogenic activities that gradually deteriorated the water quality of Vaishav stream are mining, extraction of sand and boulders from stream and over fishing has resultedin decline of fishes (Hamid and Singh, 2019; Shahraki *et al.,* 2022). The fluctuations in river water parameters stem from the influx of diverse domestic waste, sewage from residential and industrial areas, and agricultural activities involving the excessive use of pesticides and fertilizers. Urbanization has led to the introduction of contaminants into aquatic environments, acting as a sink for pollutants, thereby contributing to the spread of infectious diseases such as dysentery, diarrhea, and jaundice (Bashir *et al.,* 2020). In Nepal, research on freshwater fish diversity across various water bodies has highlighted damming and pollution as major threats, leading to an increased number of threatened species (Khatri *et al.,* 2021). Untreated sewage discharge, laden with nutrients like nitrogen and phosphorus, triggers eutrophication in water bodies, resulting in biodiversity loss, behavioral and physiological changes in species, community shifts, and fish mortality, posing a formidable challenge to freshwater ecosystem conservation efforts (Bhat *et al.*, 2021). The anthropogenic activities transformed the Limnological variables which consequently interrupted the altitudinal gradient of fish diversityassemblages (Soo *et al.*, 2021). Studies of various anthropogenic threats to the aquatic ecosystems revealed that the pollutants discharged due to anthropogenic activities are categorized based on land use practices, solid/liquid wastes, chemical compounds leeching due to mining activities, municipal wastes and agricultural practices including fertilizers and pesticides (Akther *et al.,* 2021). By studying the spatio-temporal variation in pollution dynamics of highly fragile watersheds of Jhelum river basin of Kashmir Himalayas, India it was found that deteriorationof water quality was related with agricultural expansion, urbanization which results in presence of faecal coliform Bactria in water (Bhat *et al.,* 2021). The fish diversity and composition of Ganges river basin are mostly affected due to change in land use pattern, over fishing, waterdiversion, sedimentation, pollution, deforestation, soil erosion and exotic species invasion (Moniruzzaman *et al.,* 2021). The anthropogenic disturbances are primary factors responsible for seasonal variation and biodiversity loss. Besides that these disturbances results intaxonomic change as well as functional composition of fish assemblages (Zhang, 2022).Fish diversity composition in streams was influenced by various longitudinal anthropogenic patterns as well as local disturbances induced by adjacent land use activities (Soranam, 2022). While studying the fish diversity of Rapti River U.P it was concluded that fishes are under the serious threat due to anthropogenic disturbances like illegal fishing and pollution (Sanjay and Sadguru, 2020). Similarly, studies in the river basin of North American reveled that urbanization, agriculture, road compactness, runoff and other anthropogenic activities were greatly influenced with spatio-temporal scale and can exert considerable influence on the health and integrity of stream ecosystems (Green *et al.,* 2022). In evaluating the impacts of human activities on habitat and fish diversity in Neotropical streams, researchers aimed to comprehend the repercussions on fish fauna. They noted that heightened human pressure, particularly from urbanization and agricultural practices, diminishes habitat extent and leads to alterations in fish assemblage composition within stream ecosystems (Larentis *et al.,* 2022). Similarly, investigations into the effects of anthropogenic activities on aquatic ecosystems in Africa revealed that water quality degradation resulting from human disturbances contributes to the decline in aquatic biodiversity (Ogida and Akpan, 2022). Disturbances causedby sand excavation, pollution, and overfishing pose significant threats to fish biodiversitywhich effects on fish feeding, migration, and reproductivegrounds across the globe as well as in Asia (Yang *et al.,* 2022). Studies on streams characterized by dense forest cover and habitat diversity have indicated a decline in sensitive fish species, particularly endemics. Conversely, streams with higher levels of human disturbance and urban land use have shown a significant decline in non-native species-resistant fishes (Larentis *et al.,* 2022). To mitigate the loss of fish diversity for future generations, it is imperative to raise awareness and implement measures such as controlling illegal fishing and safeguarding fish breeding grounds (Atkore *et al.,* 2011). Recommendations for safeguarding fish diversity in the study area include preventing water pollution, ensuring adequate water flow, raising awareness, enforcing fisheries laws, and establishing fish sanctuaries. Additionally, conducting periodic and systematic surveys to monitor fish status for effective management and conservation efforts is advised (Flowra *et al.,* 2013; Sharma *et al.,* 2015). Urgent attention is required to limit anthropogenic activities in riparian areas to prevent the influx of sediments and nutrients into streams (Mir *et al.,* 2019).

The biodiversity of Himalayan rivers encompasses high degree of endangerment and endemism (Dudgeon *et al.,* 2006). Despite the fact that it has not received as much attention as in other parts of the world, particularly from the temperate rivers of European and North American nations, (Jun *et al.,* 2016). Habitat degradation is typically a result of anthropogenic activity and growing economic growth, which also degrades the water quality of riverine ecosystems (Kumar *et al.*, 2017; Vörösmarty *et al.*, 2010). Biodiversity plays a crucial role in stabilizing ecosystems and safeguarding overall environmental quality, underlining the intrinsic value of all species on Earth (Ehrlich & Wilson, 1991). The diversity of species within an ecosystem often correlates with the quantity of living and nonliving organic matter present. While species diversity pertains to population level properties, the concept of functional diversity is closely linked to ecosystem stability, stress resilience, and the role of physical and chemical factors in determining population dynamics within lentic ecosystems. Various organisms, including plankton, play significant roles in ecosystem dynamics (Kar *et al.,* 2003). Fish constitute nearly half of the total number of vertebrates globally and inhabit a wide range of aquatic habitats (Dudgeon *et al.*, 2006). In India, there are reported to be 2500 species of fish, with 930 species found in freshwater habitats and 1570 in marine environments (Kar, 2013). Approximately 60% of people in developing countries derive 30% of their animal protein from fish, while 80% of the population in these countries obtains less than 20% of their animal protein from fish (Delgado *et al.,* 2003). The Kashmir Valley boasts a diverse array of freshwater streams, rivers, and lakes with varied topographical features, providing conducive environments for a variety of fish species. Over time, ichthyologists have explored these freshwater habitats to protect and conserve their faunal elements. Numerous researchers have invested considerable effort in examining the diversity, distribution, and abundance of fishes across the water bodies of the Kashmir Valley.

CHAPTER 3

HYPOTHESIS

CHAPTER 3 – HYPOTHESIS

Vaishav stream is vital component of freshwater ecosystems, serving as crucial habitats for diverse aquatic life and sources of drinking water for human populations and irrigation. In Kashmir, research efforts concerning the Vaishav stream have been notably sparse, highlighting a critical need for further investigation to enhance the region's fishery resources. This study aims to provide a contemporary assessment of the region's fish fauna, facilitating the evaluation of necessary management strategies. Human activities have persistently degraded the aquatic environment, leading to the extinction and decline of fish populations. By examining the Vaishav stream, this study seeks to elucidate overall fish diversity and enrich our understanding of species sequencing, distribution, and habitat availability. Furthermore, the study aims to elucidate the impact of both anthropogenic and allochthones pressures on the ecological equilibrium of the system under scrutiny.

The Vaishav stream contends with various anthropogenic pressures including sand and boulder excavation, soil erosion, and agricultural practices characterized by excessive pesticide and fertilizer usage. Additionally, heightened exploitation of water resources, sewage runoff, agricultural expansion, and urban sprawl exacerbate the deterioration of water quality. Hence, physicochemical parameters of the Vaishav stream, including water temperature, pH, dissolved oxygen levels, and concentrations of pollutants such as heavy metals and nutrients, have faced significant variation due to anthropogenic stress from upstream to downstream which resulted in deteriotion of water quality. It is hypothesized that these parameters will vary spatially and temporally along the stream, correlating with anthropogenic activities in the surrounding areas. Analysis of physicochemical parameters will offer insights into pollution levels and aid in pinpointing sources of pollution, be they point or non-point.

The generation of scientific insights is anticipated to inform adaptive management techniques conducive to the sustained well-being of the Vaishav stream. Moreover, this study endeavors to contribute significantly to the broader understanding of the health and productivity status of fish diversity within the Vaishav stream. It is hypothesized that the Vaishav stream's fish diversity has been significantly impacted by anthropogenic activities. The study seeks to quantify the extent of this impact and identify specific stressors contributing to changes in fish diversity. The escalating demand for fish products, driven by burgeoning population pressures, necessitates a commensurate increase in fish production. Consequently, prioritizing water quality management becomes imperative. Although other streams and rivers have garnered significant attention from limnologists and fish biologists, the Vaishav stream has largely been overlooked in terms of comprehensive Limnological profiling and assessment of fishery potential. Through rigorous data collection, analysis, and hypothesis testing, this study aims to contribute valuable insights into the complex interplay between anthropogenic activities and aquatic ecosystems, ultimately informing evidence-based management decisions for the conservation and sustainable utilization of the Vaishav stream's fishery resources.

CHAPTER 4

OBJECTIVES

CHAPTER 4 – OBJECTIVES

1. To analyze the Physico-chemical parameters of Vaishav stream along its longitudinal gradient.

2. To study the current status of fish fauna, by analyzing the species richness,abundance and distribution of Vaishav stream

3. To assess the anthropogenic threats and challenges of Vaishav stream.

Chapter 5

MATERIALS AND METHODS

Chapter 5 –Materials and Methods

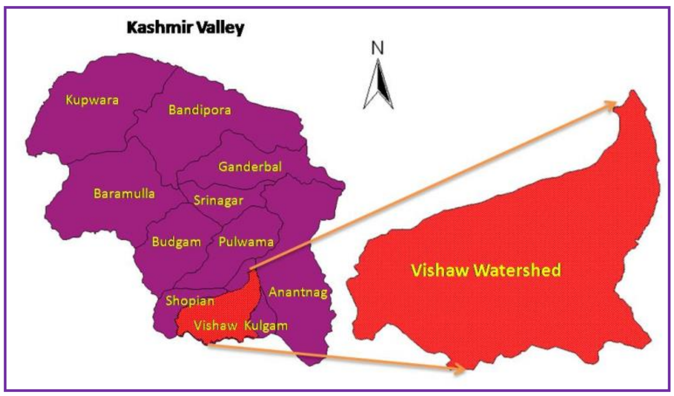
Objective 1

To analyze the Physico-chemical parameters of Vaishav stream along its longitudinal gradient.

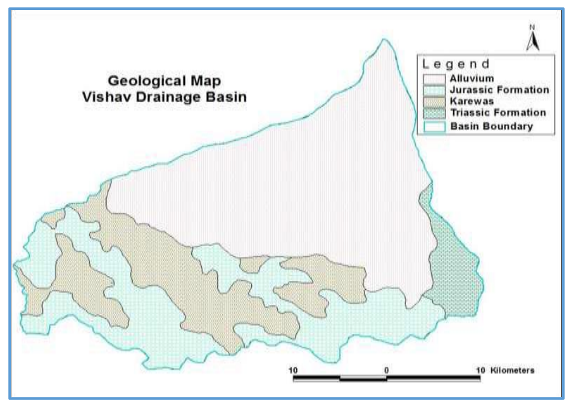
The present study on fish diversity and anthropogenic pressure on the ecology of Vaishav stream in Kashmir Himalayas, India was carried out during the period from November, 2019 to October, 2020.

5.1 Study area

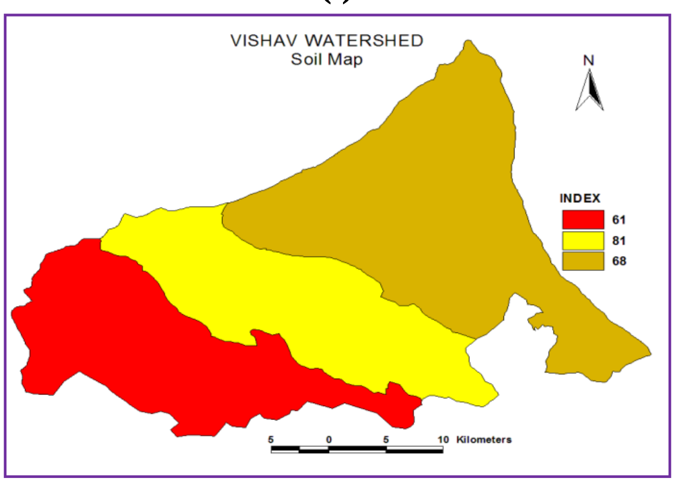
The current study was carried out in Vaishav stream originates from the perennial Oligotrophic Kounsarnag lake and north- western slopes as well as the adjacent glaciers within the mountainous Pir Panjal region of the Kashmir Himalayas, India. Covering an area of about 1.37 km^2 at an elevation of approximately 3840 m.a.s.l., it spans between geographical coordinates of 33°39' to 33°65'N latitude and 74°35' to 75°11'E longitude, ultimately joining the left bank of the River Jhelum at Sangam in the Anantnag district of the Jammu and Kashmir Union Territory (Rather *et al.*, 2022) (Figure 2, Figure 3). Draining a significant portion of the northern face of the Pir Panjal range, the catchment area of stream extends over 1,230 km^2 (Nikhoo *et al*., 2015). The basin itself encompasses 1062.48 km^2 with a stream length of approximately 75 km (Hamid *et al*., 2016). Kounsarnag Lake, located around 30 km from the Aharbal waterfall, remains mostly covered in snow throughout the year. After descending from the Aharbal waterfall, the Vaishav stream branches into various man-made and natural channels before merging with the Jhelum River near Sangam (Raza *et al*., 1978). The study region experiences a moderate environment with cold, wet winters and warm summers. Climatic conditions are widely categorized into four seasons as spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). (Romshoo *et al.*, 2018). To minimize any long-term effects on fish assemblages and after doing a comprehensive site survey for suitability, site selection criteria was used which is a crucial standard for fishing operations (Pouilly et al., 2006). Additionally, the study area witnesses the convergence of several other tributaries originating from the same mountainous terrain, which enhances the volume and velocity of the stream. Throughout its course, the stream receives a continual influx of house hold run off, agricultural runoff and municipal waste which continuously degrade its quality of water quality and subsequently impacting its native flora and fauna (Rather *et al.*, 2022). The study used Survey of India topographic sheets (1972) with the help of Arc-GIS 9.0 software and Landsat 8 OLI satellite data to create a base map for stream course, location, and land use/cover for three selected sites in 2020.



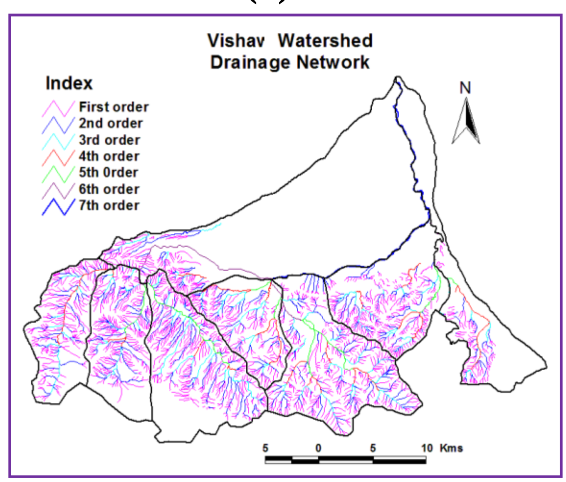
(i)



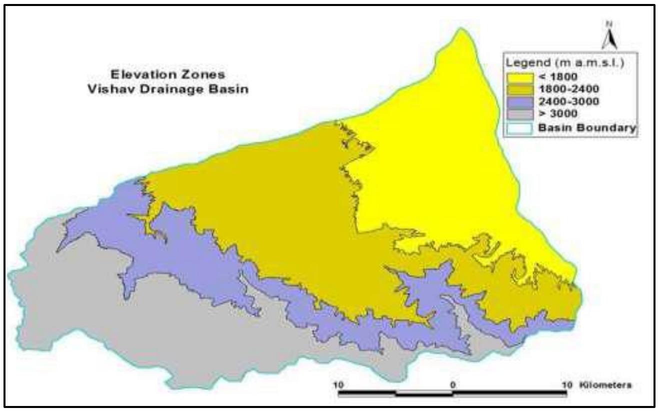
(ii)



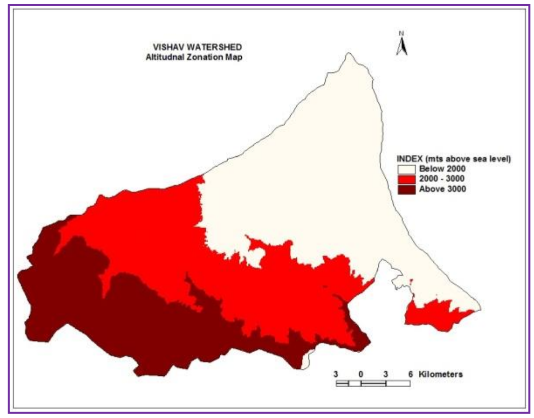
(iii)



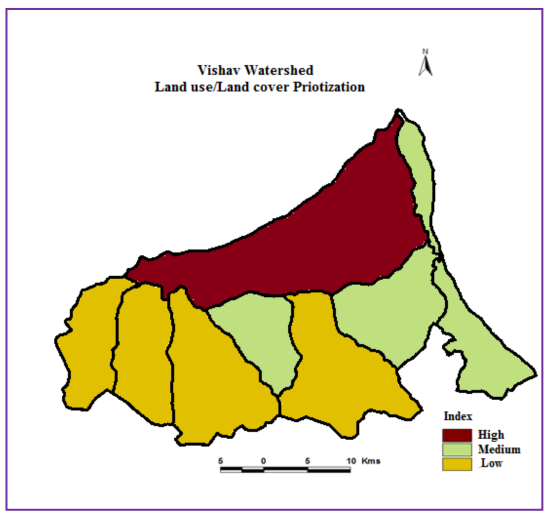
(iv)



(v)



(vi)



(vii)

Figure 2: Showing the topographic features of Vaishav stream (i) Location map (ii) Geology map (iii) Soil map (iv) Drainage Network (v) Elevation map (vi) Altitudinal Zonation map (vii) Prioritization of land use/ cover.

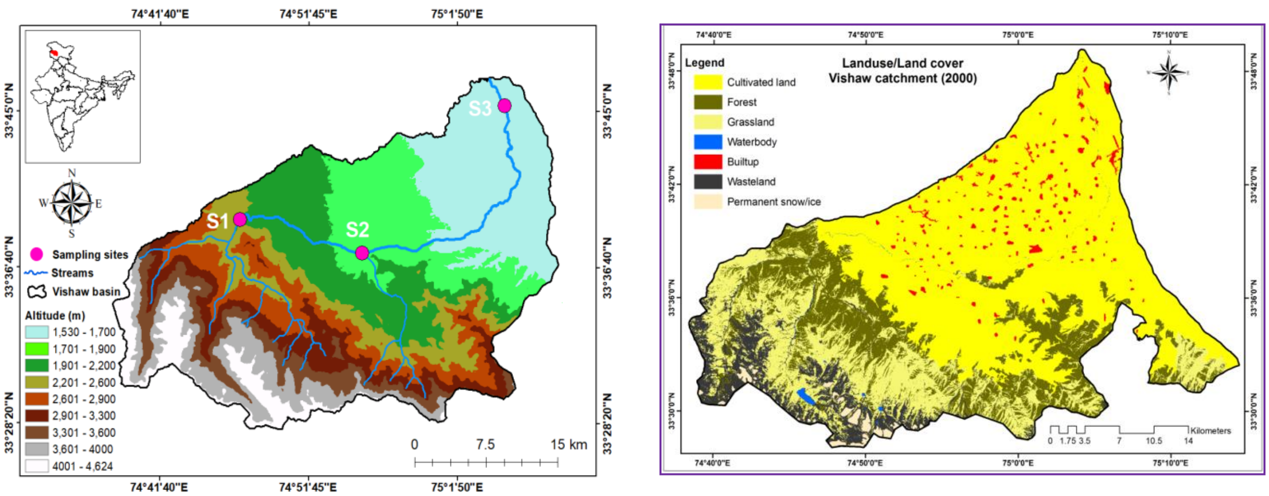


Figure 3: Course and location of sampling sites and land use/cover of Vaishav watershed.

5.2 Description and geographical attributes of Selected Sites

In this study, three specific locations were chosen along the Vaishav stream: Watoo Reshinagri, Kulgam, and Arwani (Figure 4; Table 1). Selection criteria included ecological and topological differences such as elevations, areas of fast flow, slow zones, and human interferences. Sampling was conducted on a monthly basis from November 2019 to October 2020 to consistently monitor and evaluate disturbances in the Vaishav Stream.

5.2.1 Site-1: Watoo Reshinagar

Located approximately 3.5 kilometers downstream from the Aharbal waterfall, this site sits at latitude of 33°39'19 and longitude of 74°47'08", with an altitude of 2266 meters above sea level. Characterized by a highly turbulent stream, the bottom substrate consists of sand, gravel, and stones, with water depths ranging from 1 to 4 meters. Surrounding the area are mountains adorned with coniferous trees.

5.2.2 Site-II: Kulgam

Located approximately 25 kilometers downstream from Aharbal, this site is situated at latitude of 33°37'26" and longitude of 74°55'25", with an altitude of 1882 meters above sea level. The Vaishav stream exhibits a less turbulent flow compared to site-I. Here, the streambed comprises sand, gravel, and stones, with water depths ranging from 1 to 3 meters. The area surrounding this site is characterized by rural settlements and paddy fields. Agricultural effluents from these areas are a significant contributor to the stream's water quality.

5.2.3 Site-III: Arwani Bijbehara

This site is situated close to a bridge, approximately 22 kilometers downstream from site-II, at latitude of 33°45'24" and longitude of 75°02'24", with an altitude of 1534 meters above sea level. The flow of stream water is comparatively slower in contrast to other sites and the streambed primarily consists of sand. Effluents and runoff from Arwani and its neighboring villages are directed into this site.

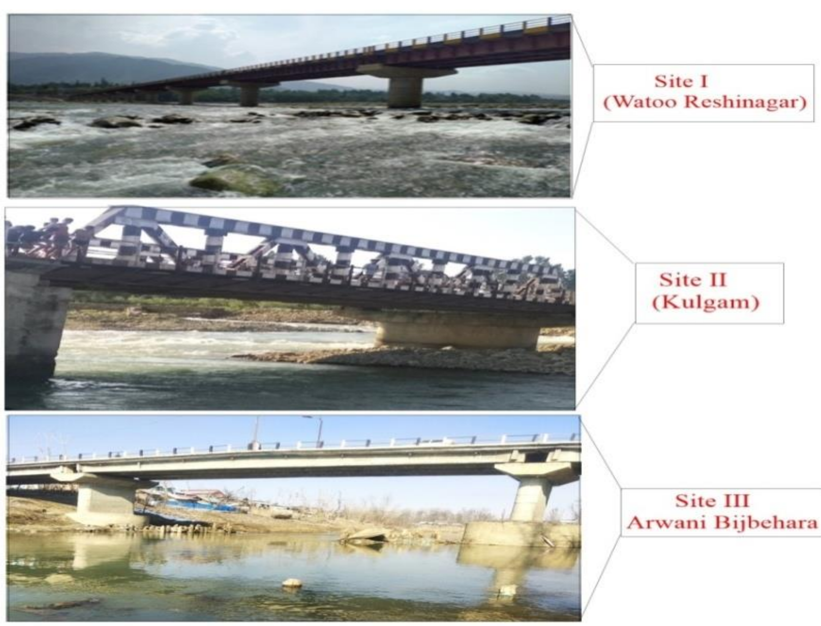


Figure 4: Showing selected sampling sites.

Table 1: Geo-morphological attributes of different sampling sites.

Site	I	II	III
Altitude (masl)	2266	1882	1534
Stream segment	Upstream	Midstream	Downstream
Position	Latitude 33^{0}39’19’N, Longitude 74^0 47’08’E	Latitude 33^{0}37’26’N Longitude 74^0 55’25’E	Latitude 33^0 45’24’N Longitude 75^0 02’24’E
Habitat type	Riffle	Riffle & pool	Pool
Substrate	Sand, gravel, stones, silt & clay	Pebbles, cobbles, boulders	Sand, silt & clay
Riparian vegetation	Salix, Acacia, Popular, pinus, Grass, Orchards	Popular,Acacia ,Salix, Grass, Apple Orchards	Popular,Salix,Acacia, and Grass
Land use	Horticulture, Wastland,Forest	Agriculture, Urban settlements, Horticulture	Urban settlement and Agriculture

5.3 Samplying and analysis of water

The water samples were collected in sterilized plastic bottles from three different sampling sites early in the morning before sunrise because with the sunlight various physic-chemical parameters generally changed. Preservation, transportation, and analysis were completed within 24 hours using the recommended procedures (APHA, 2017). Temperature, TDS, pH, dissolved oxygen and conductivity were assessed at the sampling sites, whereas turbidity, free carbon dioxide, total alkalinity, calcium hardness, total hardness, magnesium hardness, sulfate, nitrate, and total phosphorus were analyzed in the laboratory following the standardized titrimetric procedures outlined by (APHA, 2017).

5.3.1 Air temperature

The ambient air temperature was monitored using a digital thermometer positioned near the sampling site, shielded from direct sunlight to minimize any potential heat bias. After allowing for a stabilization period of 2 to 3 minutes, temperature readings were recorded and reported in degrees Celsius (˚C), adhering to standardized units for temperature measurement.

5.3.2 Water temperature

Water temperature measurements were conducted by submerging a calibrated thermometer into the water sample for approximately two minutes to achieve thermal equilibrium. The resulting temperatures were then recorded and expressed in degrees Celsius (˚C) as a standardized unit for assessing the thermal condition of the water.

5.3.3 Turbidity

Turbidity is an optical phenomenon in water where light is scattered rather than absorbed, causing it to pass through the medium. In this investigation, turbidity was measured using a digital nephelometric turbidity meter model 132 (Systronics). The recorded turbidity values were reported in Nephelometric Turbidity Units (NTU), serving as a standardized measure to evaluate the clarity of the water sample.

5.3.4 Electrical Conductivity

Electrical conductivity indicates the ability of an aqueous solution to conduct electricity, which correlates with the concentration of dissolved ions within the solution. A digital conductivity meter (Labtronics LT-17) was employed to measure electrical conductivity, and the results were uttered in microsiemens per centimeter (µs/cm).

5.3.5 Total dissolved solids (TDS)

Total dissolved solids (TDS) serves as a valuable indicator for delineating the chemical composition of water. It represents the cumulative concentration of dissolved major ions within freshwater. Measurement of total dissolved solids was conducted using a digital TDS meter (Tayser-T3), and the outcomes were reported in milligrams per liter (mg/l).

5.3.6 pH (Hydrogen ion concentration)

pH serves as a critical parameter in assessing water quality as it impacts various processes, including biological and chemical reactions within aquatic environments. The measurement of pH stands as one of the fundamental and commonly employed tests in water chemistry. The concentration of hydrogen ions in water was assessed using a pen-type digital pH meter (PHEP-Hanana). The pH meter underwent standardization with solutions of pH 4.0 and 7.0. Following calibration, the pH of water samples was determined.

5.3.7 Dissolved oxygen (DO)

Dissolved oxygen stands as a vital limnological factor essential for the survival of organisms inhabiting aquatic ecosystems. Its occurrence in natural water is dependent on a range of physical, chemical, and biological processes taking place within the aquatic environment. The assessment of dissolved oxygen levels was carried out using a digital dissolved oxygen meter (Lutron type DO-5510), and the outcomes were measured and presented in milligrams per liter (mg/l) to precisely depict the concentration levels.

5.3.8 Free Carbon-dioxide

Naturally occurring free carbon dioxide (CO_2) exists in various concentrations within water bodies, constituting part of equilibrium involving bicarbonate and carbonate ions. The proportions of these chemical forms rely on the water's pH. To assess the level of free CO_2, a 50 ml water sample underwent treatment with 2-3 drops of phenolphthalein indicator. The absence of any color change in the sample indicated the presence of free CO_2. Subsequently, the sample underwent rapid titration with 0.02272 N Sodium hydroxide (NaOH) until a faint pink color appeared. The quantity of free CO_2 was estimated by using the following formula:

$$\text{Free CO2 mg/l} = \frac{\text{Volume of titrant used}}{\text{Volume of sample used}} \times 1000$$

The results were expressed in mg/l.

5.3.9 Total Alkalinity

Alkalinity refers to the quantitative ability of water to counteract acids. It primarily stems from the presence of bicarbonates, carbonates and hydroxide ions, which form due to the dissolution of carbon dioxide in water. The total alkalinity of the water sample was determined by titrating 50 ml of the sample against a standard 0.01 N HCl solution using phenolphthalein indicator. The endpoint was identified by the disappearance of the pink color. The outcomes were reported in milligrams per liter (mg/l).

The phenolphthalein alkalinity was estimatedby using the following formula:

$$\text{Total Alkalinity mg/l} = \frac{\text{volume of titrant used } \times \text{N } \times 50000}{\text{volume of sample used}}$$

Where, N = normality of titrant

5.3.10 Total Hardness

Total hardness in water refers to the collective concentration of alkaline earth metal cations, primarily calcium (Ca^{2+}) and magnesium (Mg^{2+}). In most freshwater environments, these ions, typically combined with bicarbonates and carbonates, constitute the majority of hardness, resulting in what is termed temporary hardness. Other ions like sulphates, chlorides, and nitrates also contribute to total hardness. Assessing this parameter is crucial for determining water suitability for various applications. Total hardness was evaluated by adding 1 ml of buffer to 25 ml of the sample, which was then diluted to 50 ml. The sample underwent titration against 0.01 N EDTA using Eriochrome black T (1 to 2 drops) as an indicator until the color shifted from a reddish tinge to a blue endpoint. The results were quantified and reported in milligrams per liter (mg/l), calculated using the following formula:

$$\text{Total hardness mg/l} = \frac{\text{ml of titrant used}}{\text{volume of sample used}} \times 1000$$

5.3.11 Calcium Hardness

Calcium is the predominant ion found in natural waters, typically existing in the form of carbonates and sulphates dissolved from limestone and gypsum rocks. To determine Calcium Hardness, 2 ml of 1N NaOH was added to 25 ml of the sample to precipitate magnesium. The resulting solution was titrated against a standard 0.01 N EDTA titrant using 0.1g of eriochrome dark blue as an indicator. The endpoint was signaled by a color transition from red to purple-blue. The findings were then reported in milligrams per liter (mg/l).

The calcium hardness was calculated by the following formula:

$$\text{Calcium hardness mg/l} = \frac{\text{ml of titrant} \times 400.5 \times 1.05}{\text{volume of sample used}}$$

Ca^{2+} was calculated by the following formula=(Calcium hardness)/2.5

5.3.12 Magnesium Hardness

Magnesium is commonly found in natural water sources, primarily as Mg^{2+}, and plays a notable role in water hardness along with calcium. Its presence mainly originates from the breakdown of rocks containing ferromagnesian minerals and certain carbonate rocks. The concentration of magnesium ions in water samples was measured and reported in milligrams per liter (mg/l).

Magnesium hardness was calculated directly by using the formula given below:

$$\text{Magnesium hardness mg/l} = (\text{Total hardness} - \text{Calcium hardness}) \times 0.243$$

Mg^{2+} was calculated by the following formula = (Magnesium hardness)/4.1

5.3.13 Nitrate-Nitrogen (NO_3-N)

Nitrate, the most prevalent and highly oxidized form of nitrogen compounds in aquatic environments, plays a pivotal role in nutrient cycling. Its concentration in freshwater bodies is primarily influenced by inputs from wastewater, agricultural runoff, and groundwater, in addition to autochthonous production. To assess nitrate-nitrogen levels, a method employing phenol disulphonic acid was utilized. Initially, a 25 ml water sample was evaporated to dryness, and the resulting residue was dissolved in 1.5 ml of phenol disulphonic acid. Subsequently, the solution was diluted to 5 ml using ammonia-free distilled water and treated with 1.5 ml of concentrated 12 N KOH, resulting in a yellow coloration with flocs. Following this, the supernatant was carefully extracted, avoiding the flocs, and the intensity of the yellow color was measured at 410 nm using a spectrophotometer (Human Corporation, Japan). The obtained results were then compared with a standard curve and reported in micrograms per liter (µg/l).

5.3.14 Sulphate

Sulphates, which contribute to water hardness, are commonly found in significant concentrations in natural water sources. These sulphate compounds originate from the oxidation of minerals such as Barite, Gypsum, and Epsomite present in sedimentary rocks. To assess sulphate levels, a method involving sequential addition of reagents was employed. Initially, a 50 ml water sample (pre-filtered through Whatman filter paper No. 1) with sulphate concentrations not exceeding 10 mg/l was treated with 10 ml of NaCl-HCl solution and 10 ml of glycerol-ethanol solution. Subsequently, 0.15 g of barium chloride was added, and the mixture was stirred for 30 minutes using a magnetic stirrer. The absorbance of the resulting solution was measured against a distilled water blank on spectrophotometer (Human Corporation, Japan at 420 nm and compared with a standard curve. The sulphate concentration was then quantified and reported in micrograms per liter (µg/l).

5.3.15 Total Phosphorous

Total phosphorus in freshwater encompasses soluble reactive phosphate, polyphosphate, and soluble and insoluble organic phosphorus. The estimation of total phosphorus involved digesting a 25 ml water sample containing 1 ml of concentrated sulphuric acid (H_2SO_4) and 5 ml of concentrated nitric acid (HNO_3) to a 1 ml colorless solution. Upon cooling, 20 ml of distilled water was added. The sample was then titrated with 1N NaOH solution using 0.05 ml (1 drop) of phenolphthalein indicator until a faint pink endpoint was reached. The sample volume was adjusted to 100 ml with distilled water. The pink coloration was neutralized by adding strong acid (a mixture of concentrated H_2SO_4 and HNO_3). After thorough mixing, 4 ml of ammonium molybdate reagent and 0.5 ml of stannous chloride were added. The intensity of the blue color developed after a 10-minute pause was measured using a spectrophotometer (Human Corporation, Japan) at 690 nm and compared with the calibration curve. The results were then expressed in micrograms per liter (µg/l).

Calculation of Water quality index (WQI):

Weighted index method developed by (Horton, 1965) was used for determine the suitability of stream water for drinking purposes.

For computing WQI, three steps were followed.

Initially, each of the 11 parameters was allocated a weight (wi) based on its significance in determining the overall quality of water for drinking purposes. Nitrate received the highest weight of 4 due to its paramount importance in assessing water quality. Magnesium was assigned the lowest weight of 2 since it alone may not pose significant harm.

In the second step, the relative weight (Wi) was computed by the following equation:

$Wi=wi/(\sum ni)$

Where,

W_i = relative weight

w_i =weight of each parameter and

n= number of parameters.

In the third step, a quality rating scale was designated for each parameter by dividing its concentration in each water sample by its corresponding standard as outlined in the BIS guidelines. The outcome was then multiplied by 100.

$q_i=(C_i/S_i)\times 100$

Where,

q_i = quality rating

C_i = concentration of each chemical parameter in each water sample in mg/L, and

S_i = Indian and WHO drinking water standards for each chemical parameter in mg/L.

$SI_i=W_i\times q_i$ $\qquad$ $WQI = \sum SI_i$

SI_i = subindex of ith parameter

q_i = rating based on concentration of ith parameter and

n = number of parameters.

The computed WQI values were classified into five types, “excellent water” to water “unsuitable” for drinking.

Objective 2: To study the current status of fish fauna, by analyzing the species richness, abundance and distribution of Vaishav stream

5.4 Collection and preservation of fishes

Fish sampling was conducted at three distinct study sites, namely Watoo Reshinagar (upper stream), Kulgam (mid stream), and Arwani (down stream), along the course of the study area. The sampling period spanned from November 2019 to October 2020, with collections taking place during the morning hours (6:00 am to 9:00 am) on a monthly basis to mitigate the influence of diurnal variations. Each site was visited once at the end of every month and no specific permits were required for field site access or sampling in this study area as the study was conducted in [publicly accessible lands, non-protected areas, or describe applicable designation. The work followed all relevant regional and national regulations governing research activities in natural water bodies. Skilled local fishermen utilized cast nets equipped with knot-to-knot heavy sinkers to ensure rapid settling at the bottom, following established protocols (Tun, 2014). Cast net fishing leverages the behavioral tendencies of the target fish species (Peterson *et al.*, 2008). The 1.2 meters diameter cast net with a mesh size of 1.3 to 3.0 centimetres is suitable for capturing small to medium-sized fish species in the Himalayan streams of Kashmir Valley (Andrabi *et al.,* 2022). Multiple trials were conducted within a 500-meter segment until the maximum count was attained, enabling the assessment of catch composition. After being left in place for approximately three to five minutes, the net was retrieved, and trapped fish were recovered from its pouches. Fresh fish specimens were photographed and subsequently preserved in jars filled with 10% formalin. The smaller samples were directly immersed in the formalin solution, while larger specimens underwent a ventral incision before preservation. Fish specimens were oriented with the snout facing downward and the caudal region upwards. Each collected sample was meticulously labeled with a serial number, collection locality, date of collection, and local name of the fish to facilitate subsequent research endeavors.

5.5 Identification of fishes

The identification process for collected fish specimens relied on established taxonomic sources, including works authored by Misra (1949), Talwar and Jhingran, (1991), Kullander *et al.,* (1999), and Bhat *et al.,* (2020). Additionally, confirmation of these identifications was cross-referenced with online databases like www.fishbase.org and www.calacademy.org/research/icthology/catalog (Awas *et al.,* 2023). Local fish names were documented in the field with the assistance of local fishermen. Furthermore, to ensure a comprehensive understanding of fish biodiversity, diverse data and information were collected through physical verification and interviews with local fishermen in the study area.

5.6 Biodiversity studies

Species diversity can be measured separately either as species richness or evenness or diversity as a whole. Following indices were used to measure fish biodiversity.

5.6.1 Shannon-Weiner Diversity Index (H): (Shannon and Wiener, 1963)

$$H=-\sum p_i (\ln p_i) \text{ Larger } H = \text{more diversity}$$

Variables associated with the Shannon-Weiner Diversity index:

S = Total number of species in the community (richness)

Pi = Proportion of S made up of the ith species

Hmax = ln(S)

EH = Equitability (evenness; b/t 0 and 1) = H/Hmax

5.6.2 Pielou's Evenness index (E): (Pielou, 1966)

The Pielou Evenness index, formulated by Pielou in 1966, is derived from the Shannon index. It quantifies the ratio of the observed Shannon index value to its maximum attainable value. The resulting index value ranges between 0 and 1. As the value approaches 1, it indicates a more equitable distribution of individuals among species. A value of 1 signifies that all species are equally represented in the sample, whereas a value close to zero suggests domination by one particular species.

$$E = H/ \ln S$$

E: Pielou's evenness index

H: The observed value of Shannon index

lnS: H max

S: Total number of species

5.6.3 Jaccard's similarity index (J):

The Jaccard's index, also known as the Jaccard's similarity coefficient, functions as a measure to evaluate the similarity between two datasets. Ranging from 0 to 1, this index compares the presence or absence of species and is suitable for qualitative data, such as species lists. Originally introduced by Paul Jaccard in 1912 as the "coefficient de communaute," it was independently developed by T. Tanimoto in 1958.

Jaccard's similarity is calculated as follows:

$$J = j/a + b - j$$

Where,

Cj represents the similarity between any two zones,

j is the number of species common to both zones,

a is the number of species in zone.

b is the number of species in zone.

J=1, it indicates complete similarity, while J=0signifies complete dissimilarity. Classification was as follows: J = 0-0.25 (very dissimilar); 0.25-0.50 (dissimilar); 0.50-0.75 (similar); and 0.75-1.0 (very similar) (Chen *et al*., 2018).

Multiplying Jaccard's similarity by 100 yields the percent similarity.

$$Percent\ similarity = Jaccard's similarity \times 100$$

5.6.4 Jaccard's dissimilarity index (JD)

The Jaccard's dissimilarity index measures the difference between two datasets and is calculated by subtracting the Jaccard's similarity from 1. It can be represented as:

$$JD = 1 - Cj$$

This measurement offers an understanding of the distinction between two datasets or their deviation from each other

5.6.5 Relative abundance (RA):

The determination of the relative abundance of fish across the three designated sites was undertaken. Relative abundance, a facet of biodiversity, serves as a gauge of how prevalent or uncommon a species is compared to others within a specific location or community (Hubbell, 2001). It indicates the proportionate composition of a specific organism relative to the total organism count in the area (Hubbell, 2001; McGill *et al.*, 2007). The relative abundance of individual species was calculated using the subsequent equation:

$$RA = (n \times 100 / N)$$

Where,

n=Number of specimens of a particular species

N=Total number of specimens of all species.

Objective 3: To assess the anthropogenic threats and challenges of Vaishav stream.

5.7 Anthropogenic threat

To comprehensively evaluate anthropogenic threats, an extensive dataset was gathered through a combination of primary and secondary sources. Primary data collection involved direct interaction with local communities residing within the study area. This approach facilitated a deeper understanding of the local perspectives and experiences regarding environmental challenges. Additionally, secondary sources such as scientific literature, governmental reports, and archival data were consulted to augment the primary data. By synthesizing information from diverse sources, this study aimed to provide a comprehensive overview of anthropogenic pressures on the ecosystem.

5.8 Study area/ Surveys

The investigation into anthropogenic activities impacting the Vaishav stream, situated in the Kashmir Himalayas, India, encompassed a survey conducted across twenty-five villages within the Kulgam district, situated along the banks of the Vaishav stream (Figure 1). Survey data were meticulously compiled using Survey of India (SOI) Toposheet No. 55 F/14, at a scale of 1:50,000, serving as the basis for delineating survey sites and village locations, a process facilitated by digitalization within ArcGIS software. This method ensured precise mapping and documentation of anthropogenic influences along the stream's vicinity.

5.9 Sampling procedures and Questionnaire survey

Before finalizing the questionnaire for data collection, a preliminary survey was conducted in the proposed study area to systematically document visible and potential anthropogenic threats. Based on these observations, a Likert scale-based questionnaire was formulated. The Likert scale, recognized as a psychometric tool for gauging opinions, attitudes, and preferences (Rai *et al.*, 2024) was chosen for its efficacy in elucidating respondent perspectives. Typically, Likert scales employ a five-point rating system, ranging from "strongly agree" to "strongly disagree," with each response assigned a numerical score (McLeod, 2019). The questionnaire, comprising both open-ended and closed-ended inquiries, was tailored following a comprehensive review of pertinent literature to address identified issues and research objectives.Utilizing a survey-based approach allowed for anonymous participant feedback, minimizing bias and facilitating validity and reliability testing (McLaren, 2013). To ascertain the impacts of anthropogenic activities on the Vaishav stream, a purposive sampling technique was employed to select respondents from the affected areas, aligning with the study's objectives of monitoring anthropogenic threats. Additionally, convenience sampling was utilized to recruit willing participants. A total of 400 respondents across various age groups were sampled for the study, adhering to methods outlined by (Wang *et al.*, 2016). Questionnaires were translated into Kashmiri for illiterate participants, and data collection employed a drop-and-pick survey method (Madyise, 2013), with responses recorded and stored in Excel software for subsequent analysis.

5.10 Field survey

Throughout the survey period, a spectrum of anthropogenic disruptions along the Vaishav stream was documented. Additionally, focused group discussions, employing a qualitative approach method, were conducted within the local populace to gauge their knowledge, attitudes, and awareness regarding anthropogenic activities (Mishra, 2016). Employing a digital camera, photographic evidence of affected areas was captured. To garner primary data, individual interviews were conducted, covering diverse subjects. Key informants were identified and interviewed regarding the primary parameters concerning the investigation of anthropogenic impacts on the Vaishav stream. Each interview was meticulously tailored with structured questions to ensure precise data collection, considering the position and educational background of each participant. Prior consent and appointments were arranged with participants, conducted either in designated offices or their residences. Officers from the Public Health Engineering Department in Kulgam were interviewed within their office premises to assess their understanding of drinking water quality. Individuals directly engaged in anthropogenic activities, such as drivers involved in sand mining, were interviewed at extraction sites. Various government departments, including Fisheries, Public Health, Municipality, Forestry, Geology/Mining, Statistical and Evaluation, Rural Development, and the District Hospital in Kulgam, were visited to gather pertinent information concerning the impacts of anthropogenic activities on the Vaishav stream.

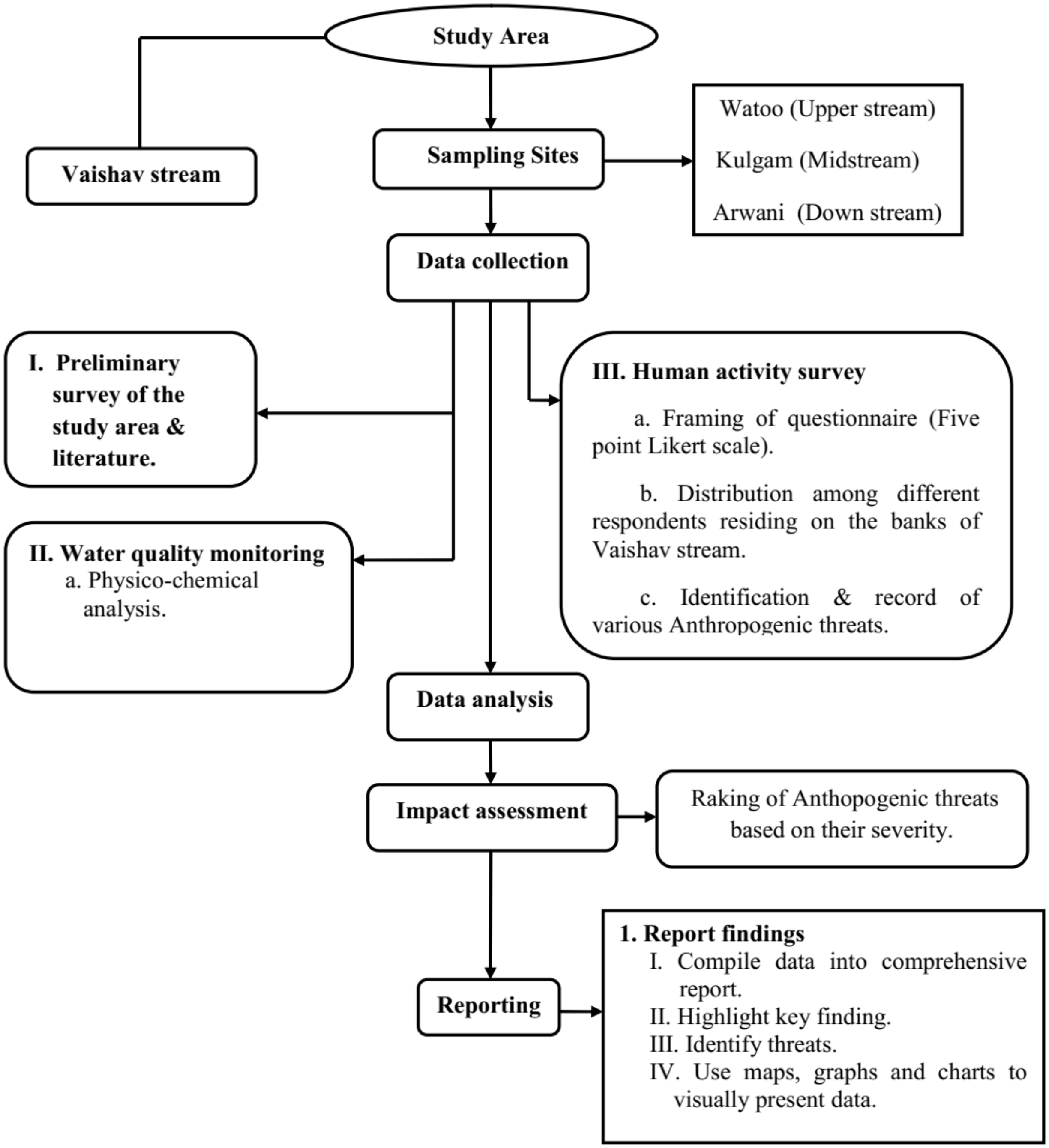


Figure 5: Showing flow chart of methodology of anthropogenic threat.

Table 2: Depicting the contents considered for questionnaire

S.No.	Part	Questionnaire
1.	**Demographic data of respondents**	Questions were meant on demographic data of respondents in the sampled village, collected data described characteristics of sample.
2.	**Water Quality**	Questions were meant for respondents to give their views on various parameters associated with water quality.
3.	**Fish biodiversity**	Respondents were asked to give their views on impacts of sand mining on fish habitat, biodiversity and fish catch as per their experience.
4.	**Mining**	Question was meant on impacts of mining and channelization changing stream morphology.
5.	**Problems associated with mining and awareness**	Subjects inhabiting along the catchment area were asked to rank the problems which are responsible for execution of mining and were also asked about their awareness regarding consequences of heavy mining.
6.	**Anthropogenic thre ats discussed in questionnaire and their validity**	Question was meant for respondents: if the problems asked in said questionnaire are challenges for the public in general and government in particular.

5.11 Questionnaire for assessing the anthropogenic threat of the Vaishav Stream

We are carrying out a survey for which we need to ask you a few questions. The answer that you may provide will be used to generate scientific information in developing the possible management strategies for long lasting sustainability of the Vaishav stream.

1. Respondents Name: Mr./Mrs./Ms…………………………………………………
2. Address: ………………………………………………………………………
3. Gender: ………………………………………………………………………
4. Age: ………………………………………………………………………..
5. Occupation: ……………………………………………………………………
6. Qualification: …………………………………………………………………..
7. Contact: ………………………………………………………………………
8. Email ID:……………………………………………………………..………

[1] The execution of mining, channelization and slit clearance in stream changes its morphology and makes the stream bed uneven which affects the water flow and subsequently hampers the fish abundance, movement and assemblage.

a) Strongly Agree
b) Agree
c) Neither agree nor disagree
d) Disagree
e) Strongly Disagree

[2] Mining is the main threat to fish biodiversity in the stream?

a) Strongly Agree
b) Agree
c) Neither agree nor disagree
d) Disagree
e) Strongly Disagree

[3] How would you rank the following problems which is more responsible for executing of heavy mining in the stream

Problems	Ranking
a) Urbanization	1 2 3 4 5
b) Population growth	1 2 3 4 5
c) Unemployment	1 2 3 4 5
d) Negligence of local administration	1 2 3 4 5
e) Illegal means	1 2 3 4 5

[4] The inhabitants along the catchment area of the said stream are not aware about the consequences of heavy mining in the stream like soil erosion, damaging of residential houses, washing of agricultural and horticulture land, roads bridges and so on?

a) Very aware
b) aware
c) Neither aware nor unaware
d) Unaware
e) Very unaware

[5] Which according to you is the Impact of mining on fish catch of Vaishav stream?

a) High
b) Modrate
c) Less
d) No
e) Strong

[6] Mining is the most important cause for habitat and breeding ground loss of fishes.

a) Strongly Agree
b) Agree
c) Neither agree nor disagree

d) Disagree

e) Strongly Disagree

[7] The stream water is still potable for drinking purpose.

a) Strongly Agree

b) Agree

c) Neither agree nor disagree

d) Disagree

e) Strongly Disagree

[8] To what extent the Vaishav stream is polluted.

a) High

b) Very high

c) Moderately

d) Marginally

e) Not at all

[9] The illegal fishing like (chemicals and electric currents etc) are used for fish capturing in the said stream.

a) Strongly Agree

b) Agree

c) Neither agree nor disagree

d) Disagree

e) Strongly Disagree

[10] How would you rank the following pollutants in terms of threat that the stream is facing according to their order of importance.

a) Important

b) Very important

c) Most important

d) Somewhat important

e) Least important

Problems	Ranking
Mining	
Rampant use of fertilizers & pesticides	
Solid waste	
Illegal fishing(Like electric current & chemicals)	
Household run-off (Sewage)	

[11] How would you rank the following problems in terms of importance which is more responsible for deteriorating the water quality of the said stream?

a) Important
b) Very important
c) Most important
d) Somewhat important
e) Least important

Problems	Ranking
Deforestation	
Solid Waste Pollution e.g. Polythene	
Mining	
Encroachment	
Household run-off (Sewage)	
Illegal fishing	
Pesticides, insecticides and fertilizers	

Washing and bathing	
Stone crushers	
Solid waste dumping	
Built latrines and open defecation on banks	

[12] Which of the following anthropogenic threats is the main cause of decline in fish diversity of the Vaishav stream in order of importance?

a) Important

b) Very important

c) Most important

d) Somewhat important

e) Least important

Problems	**Ranking**
Siltation	
Solid Waste Pollutants like polythenes etc	
Sewage	
Encroachment	
Water diversion	
Mining	
Illegal fishing	
Agricultural Waste like pesticides & fertilizers	

[13] The continuous increase in population growth along the catchment area of the said stream has also increased the anthropogenic disturbances which subsequently deteriorating the water quality and declines in fish diversity.

a) Strongly Agree
b) Agree
c) Neither agree nor disagree
d) Disagree
e) Strongly Disagree

[14] The threats mentioned in the said questionnaire are challenges for the public in general and government in particular

a) Strongly Agree
b) Agree
c) Neither agree nor disagree
d) Disagree
e) Strongly Disagree

5.12 Statistical analysis

The physico-chemical parameter data were presented in the form of mean ± standard deviation. Before commencing the investigation, the entire observation period was divided into four seasons: winter (November, December, and January), spring (February, March, and April), summer (May, June, and July), and autumn (August, September, and October). To assess significant spatio-temporal variations among different sampling sites and seasons for water quality parameters, one-way analysis of variance (ANOVA) was employed, with a significance level set at $p < 0.05$. Additionally, multivariate techniques such as cluster analysis (CA) and principal component analysis (PCA) were applied to the physico-chemical dataset. Before conducting the multivariate analysis, the physico-chemical dataset underwent standardization using z-scale transformation to minimize misclassification arising from differences in data dimensionality (Shrestha and Kazma, 2007; Yang *et al.*, 2010). PCA, based on the correlation matrix of the rearranged data, was performed to unveil the underlying structure of the dataset. CA was executed using hierarchical agglomerative clustering (HAC) based on Ward's method, utilizing Euclidean distances as a measure of similarity (Arafat *et al.*, 2022 and Islam *et al.*, 2023). Correlation and linear regression analysis was undertaken to ascertain the nature (positive or negative) of significant relationships among physico-chemical parameters.

Alpha diversity metrics were applied to the fish dataset to assess community structure by providing insight into ecological community richness (taxonomic group count), evenness (abundance distribution), or both. Given the impact of various disturbances on community alpha diversity, this approach is widely employed to analyze and compare community structures in surveys. T-tests were utilized to determine significance among three sites and four seasons based on 11 fish species and number of individuals (Sheskin, 2011). To assess the connection between fish abundance and environmental factors, a principal component analysis were utilized. The non-metric multidimensional scaling (NMDS) ordination technique was applied to create an ordination based on the similarity or dissimilarity among sites and seasons. Statistical analyses were conducted using R Core 2017, SPSS Version 2019, and MS Excel.

CHAPTER 6

RESULTS AND DISCUSSION

CHAPTER 6 – RESULTS AND DISCUSSION

Objective 1: To analyze the Physico-chemical parameters of Vaishav stream along its longitudinal gradient.

6.1 Physicochemical parameters

During the present study 17 physicochemical parameters were analysed to find out the seasonal variation of Vaishav stream at three different sites.

6.1.1 Air & water temperature

Air temperature has a significant impact on various environmental factors that influence the water temperature and over all content of dissolved oxygen of system (Ahmad *et al*., 2024). During the present study the site wise variation of air temperature with minimum mean valve 8.5±8.6 at site-I and maxium 12±8 at site-III. Similarly the seasonal variation in mean value of air temperatures at three different sites with lowest mean air temperature -5 ± 4.72 °C was recorded at Site-I in winter located at high elevation in comparison to site III with the highest air temperature 19.33± 2.51 °C was recorded in summer season located at low altitude (Table 3&4; Figure 7). Our findings suggest that the mean air temperature tends to decrease may be due to higher elevation, low temperatures, less exposure to the sun, cool air and possibly more influence from the nearby mountainous areas (Khanday *et al.,* 2018). On the other hand, highest temperature at Site-III in summer may be due to bright sun exposure, heat retention, low altitude and possibly warmer air from lower-lying locations that can have impact on the higher temperatures at lower elevations. In mountainous areas, where temperature declines with elevation due to the adiabatic lapse rate, this temperature change with height is a typical occurrence in mountainous streams and temperature fluctuation is also influenced by the topography and its immediate surroundings (Nigrelli *et al.*, 2018).

Water temperature is a critical ecological factor and is mainly responsible for growth and distribution aquatic flora and fauna and substantially impacts the solubility of oxygen in water, metabolic rate and reproductive process of aquatic species (Mir *et al.,* 2023). The observed flucatation in temperature is mainly related with the change in atmospheric temperature, clamatic and topographical conditions (Patel & Datar, 2014; Yu *et al*., 2021; Kattel *et al.,* 2022).In the present study the minimum mean value of water temperature 4.91±3.01 was recorded at site-I and maximum 6.33±3.63 at site-III (Table 3&4; Figure 7). A consistent pattern was observed when analyzing water temperature, with the highest average temperature (10.33±2.51°C) recorded during summer at Site-III, while the lowest average temperature (1.33±0.57°C) was observed during winter at site-I (Table 4, Figure 4a). The seasonal variation in mean value of water temperature may be due to bright solar radiation, warm air temperature, flow patterns, and regional hydrological conditions like flow and depth can be the few reasons that cause seasonal fluctuations. Sampling intervals, plant cover and certain water quality characteristic such as turbidity are responsible for higher water temperature (Patel & Datar, 2014; Yu *et al.,* 2021). In addition to this, the increased water temperature at site III in summer is due to low altitude (Sheikh *et al.,* 2010), less canopy in the riparian area (Garner *et al.,* 2017), velocity of water (Khanday *et al.,* 2018; Sinokrot & Gulliver, 2000). Our study are in confirimity with the studies of (Mir *et al.,* 2023) while studying physico-chemical parameters of Airpal and Watalara streams of Kashmir Himalayas.

6.1.2 Turbidity

During the present study, the lowest mean turbidity value of 3.01±1.5 was recorded at site-I and highest 11.89±1.4 at site-III. Similarly, the seasonal variation in mean values of turbidity at three different sampling sites shows at Site I, the season wise mean turbidity recorded during winter, spring, summer and autumn were 1.54±0.24 NTU, 4±2NTU, 5.13±0.96 NTU and 3.13±0.30 NTU respectively. The minimum mean turbidity at this site was recorded as 1.54±0.24 NTU during winter while the maximum was recorded as 5.13±0.96 NTU during summer. At Site II, the season wise mean turbidity recorded were 5.13±0.06 NTU, 5.38±0.35 NTU, 7.5±0.6 NTU and 6.96±0.26 NTU. The minimum mean turbidity at this site was recorded as 5.13±0.06 NTU during winter while the maximum

7.5±0.6 NTU was recorded during summer. At Site III, the season wise mean turbidity recorded were 10.13±1.45 NTU, 12±0.87 NTU, 13.53±0.51 NTU and 11.92±0.23 NTU. The minimum mean turbidity at this site was recorded as 10.13±1.45 NTU during winter while the maximum was recorded as 13.53±0.51 NTU during summer (Table 3&4; Figure 7).These findings show that the turbidity level at sampling sites varied with seasons. Thus, the increased value of turbidity level reported during the present study in summer season at Site –III may be due to soil erosion, sewage, hydrological conditions, melting of snow and precipitation, flashfloods which erodes silt, mud, dust, wood ashes through surface runoff and agricultural discharge (Mahazar *et al.,* 2013; Muhangane *et al.,* 2017; Lu *et al.,* 2023). Understanding changes in turbidity offers the stream water quality and its possible effects.

6.1.3 Electrical Conductivity

The values obtained while assessing the electrical conductivity at sampling locations (Site I, Site II and Site III), the lowest mean value of 108.91±29.55 at site I and highest mean value of 161.17±44 at site III. Similarly, the seasonal fluctuations in water conductivity along the Vaishav stream in winter, spring, summer, and autumn seasons during which the mean water conductivity were recorded. The mean water conductivity values at Site I were lowest, varying from 74±5.29 µs/cm in the winter to 141.66±4.04 µs/cm in the summer. Similarly, Site II had slightly higher conductivity values, with winter readings of 102.66±7.02 µs/cm and summer readings of 150.66±2.08 µs/cm. The highest mean conductivity values were found at Site III, which varied from 141.66±7.63 µs/cm in winter to 181±3.60 µs/cm in summer (Table 3&4; Figure 7). These results point to geographical differences in water conductivity along the Vaishav stream, which may be influenced by geological formations, mineral composition, and human activities. These findings emphasize how important is to take seasonal variations in water conductivity into account when evaluating the overall water quality and its potential effects on aquatic ecosystems. The higher conductivity at Site-III in summer season may be due to entry of sewage into the stream (Muhangane *et al.,* 2017), excess use of agricultural fertilizers (Mir & Gani, 2019), high nutrient enrichment (Coffin *et al.*, 2021), urban and agricultural land use (Sabha *et al.*, 2019), human settlement (Rather *et al.*, 2016), stream bank erosion, precipitation, influx of ions from urban surface runoffs, sewage effluents and channels (Ahmad *et al.*, 2024). Moreover, addition of epedic and pedogenic factors also contributes in stream electrical conductivity (Bhateria & Jain, 2016). Similar results were observed in other Himalayan Streams of Kashmir Valley, India in Rambaiar stream (Mir *et al.*, 2019) and in Jhelum basin (Khanday *et al.*, 2021) which justifies our results.

6.1.4 Total Dissolved Solids

The current study examined the sitewise and seasonal fluctuations in total dissolved solids (TDS) concentrations at three sampling locations along the Vaishav stream. The minimum mean value of 83.08±9.57 was recorded at site I and maximum value 119.89±15.55 at site III. The seasonal fluctation of TDS concentration at Site I ranged from 48.10 ±3.43 mg/l in the winter to 92.08±2.62 mg/l in the summer, with the summer months showing the highest concentrations. Likewise, TDS levels at Site II fluctuated from 66.73±4.56 mg/l in the winter to 97.93±1.35 mg/l in the summer. TDS levels at Site III ranged from 92.08±4.96 mg/l in the winter to (116.06±3.28) mg/l in the summer (Table 3&4; Figure 7). The findings reveled that there is seasonal variations in TDS along the Vaishav stream and highest concentrations being recorded in the summer. These differences may be linked to many elements, such as geological features (Bhateria & Jain, 2016). Agricultural activities, surface run off, production of particulate matter, discharge of wastes from residential areas, livestock rearing, siltation caused by surface run-off are the major contributors in the downstream area of the stream (Meng *et al*., 2018; Mir & Gani, 2019). Furthermore, in summer, the rising temperature contributes to elevated conductivity by accelerating the ionization process in water, leading to an increase in total dissolved ions (Venkatesharaju *et al*., 2010; Rahmanian *et al*., 2015; Arafat *et al*., 2022). This phenomenon occurs as the total dissolved solids in water are directly propotional to electrical conductivity (Allan, 2004). To better understand the causes of increased TDS level and their potential effects on the aquatic environment and water quality of the Vaishav stream, and further research is necessary. Previous study by (Ahmad *et al*., 2024) yielded a similar result.

6.1.5 pH (Hydrogen ion concentration)

The current study recorded the overall alkaline pH with the lowest mean value of 7.60±0.48 at site I and highest mean value of 8.42±0.51 at site III and seasonal variation in pH were recorded at three sampling sites. At Site I, the pH fluctuated from 7.06±0.11 in the winter to 8.03±0.45 in the summer, with the summer months recording the highest pH. Similarly at Site II was recorded 7.4±0.26 in winter and 8.5±0.25 in summer and at Site III 7.8±0.23 was recorded during winter 8.9±0.52 during summer (Table 3&4; Figure 7).). The results revealed somewhat alkaline conditions and also show small fluctuation in pH over the seasons. Various elements, including dissolved minerals, plants, and human activities, settlement in riparian area can have an impact on these pH changes (Khanday *et al*., 2021 ; Arafat *et al*., 2022). Our results are in conformity with (Mir *et al*., 2019) who analyzed pH fluctuations of two Himalayan streams i.e., Doodhganga and Jhelum respectively. To evaluate the Vaishav stream's water quality and potential effects on aquatic life, it is critical to comprehend the seasonal pH dynamics and is advised to conduct more research to determine the underlying causes of pH changes and their ecological effects on the ecosystem of the Vaishav stream

6.1.6 Dissolved Oxygen

During the present study, the minimum mean value of Dissolved oxygen 8.65±0.66 was recorded downstream at site III while maximum 12.46±0.94 was recorded upstream at site I. The lowest DO value observed at down stream site was due anthropogenic burden, less atmospheric diffusion due at prevailing atmospheric temperature and less water velocity in plane topography result in reduce water recirculation (Ahmad *et al* 2024). The seasonal variation in mean values of Dissolved Oxygen was recorded during winter, spring; summer and autumn were 13.16±1.69 mg/l, 12.7±0.88 mg/l, 12±1.15 mg/l and

12.5±0.2 mg/l respectively. The minimum mean Dissolved Oxygen value at this site-I was recorded as 12±1.15 mg/l during summer while the maximum value was recorded as 13.16±1.69 mg/l during winter. Similarly at Site II, the season wise mean Dissolved Oxygen values recorded during winter, spring, summer and autumn were 10.6±0.2 mg/l, 10.2±0.34 mg/l, 10.16±0.64 mg/l and 10.5±1.01 mg/l respectively. The minimum mean Dissolved Oxygen value at this site was recorded as 10.16±0.64 mg/l during summer while the maximum value was recorded as 10.6±0.2 mg/l during winter (Table 3&4; Figure 7). In the same way the the season wise mean Dissolved Oxygen values recorded at site III, during winter, spring, summer and autumn were 8.96±0.86 mg/l, 8.46±0.30 mg/l, 8.2±0.87 mg/l and 8.86±0.30 mg/l respectively. The minimum mean Dissolved Oxygen value at this site was recorded as 8.2±0.87 mg/l during summer while the maximum value was recorded as 8.96±0.86 mg/l during winter (Figure 4c). The lowest concentration of dissolved oxygen at Site-III is due to increase in temperature as the dissolved oxygen primarily depends on water temperature (Rajwa-Kuligiewicz *et al*., 2015) and regulates the concentration of dissolved oxygen in aquatic environment lower dissolution at higher temperature (Kumar *et al*., 2022), influx from surrounding agricultural land, residential and municipal sewage (Mahmood *et al*., 2017), shallowness and low stream flow leads to deposition of organic matter and its subsequent decomposition by decomposers through utilization of dissolved oxygen (Lukubye and Andama, 2017; Bhat *et al*., 2021). Decomposition of nitrogenous compounds in water can cause oxygen depletion (Mir *et al*., 2019). It was observed that low temperature, low biological activity, high altitude, high turbulence, and little anthropogenic pressure may be the valid reasons for maintaining high dissolved oxygen upstream at Site-I. Our results are in conformity with the statement that high turbulent flow, cold water and low anthropogenic pressure retains more oxygen due to less dispersal of oxygen from water into air (Mir *et al*., 2019). Furthermore, low biological activity and little anthropogenic pressure at upstream site-I may be due to its proximity to the glacier source, forest cover and meadows in the adjacent catchment areas having less anthropogenic stress (Andreolli *et al*., 2015; Sabha *et al*., 2019). Similar results were reported from Haraz River in Iran by (Pirnia *et al*., 2019) and Rambiara stream in Kashmir Himalayas by (Mir *et al*., 2019).

6.1.7 Free Carbon-dioxide

Free carbon dioxide (FCO2) is present in the form of dissolved gas in surface water (Mir *et al*., 2023).The level of FCO_2 is mostly regulated by metabolic activities, i.e respiration and photosynthesis apart from atmospheric diffusion (Arafat *et al.,* 2022). In the present study, the FCO_2 depicted site variation with highest mean value of 6.41±2.36 down stream at site I while as the lowest mean value of 4.36±2.31 was recorded upstream at site I. Similarly the season-wise mean value of free CO_2 at Site I, during winter, spring, summer and autumn were 1.5±0.5 mg/l, 4±0.2 mg/l, 7.3±0.26 mg/l and 4.6±0.52 mg/l respectively with lowest mean free CO_2 value of 1.5±0.5 mg/l in winter while the highest value of 7.3±0.26 mg/l was recorded during summe. Similarly, at Site II, the mean free CO2 values observed during winter, spring, summer, and autumn were 2.33±0.76 mg/l, 5.33±1.15 mg/l, 7.53±0.50 mg/l, and 5.66±1.52 mg/l, respectively. The lowest mean free CO2 value at this site was recorded as 2.33±0.76 mg/l during winter, while the highest value was noted as 7.53±0.50 mg/l during summer (Table 3&4; Figure 7). At Site III, the seasonal mean free CO2 values during winter, spring, summer, and autumn were 3.5±1 mg/l, 7±1 mg/l, 8.63±0.35 mg/l, and 8.23±1.18 mg/l, respectively. The lowest mean free CO2 value at this site occurred during winter at 3.5±1 mg/l, whereas the highest was observed during summer at 8.63±0.35 mg/l (Figure 4c). The increased free carbon dioxide levels at Site III during summer could potentially be attributed to wastewater discharge, sewage effluents, and fertilizers from agricultural areas (Singh *et al*., 2020). Moreover, the rising trend of free carbon dioxide downstream (Site III) might be due to the introduction of carbon-loaded materials, as a significant portion of carbon originates from organic compounds of deceased terrestrial plants and animals, as well as groundwater leaching from rocks (Jayaraman and Brindha, 2024).Free carbon dioxide concentration in water bodies is influenced by the atmospheric diffusion, decomposition processes and through the inflow of groundwater which is continuously loaded with carbon dioxide due to the catchment soil respiration (Allan, 2004; Mir *et al* 2023).

6.1.8 Total Alkalinity

During the present study, the lowest mean value of total alkalinity was 56.42±5.51 at site I and highest 111.33±15.01 at site III. The season wise mean value of total alkalinity recorded at Site I were 52.33±5.03 mg/l, 52±4 mg/l, 61±3 mg/l and 60.66±2.08 mg/l respectively with minimum value was recorded as 52.33±5.03 mg/l during winter while as the highest value was recorded as 61±3 mg/l during summer (Figure 4c).The season wise mean alkalinity values recorded at Site II were 66.66±9.86 mg/l, 79.66±5.03 mg/l, 84±3.60 mg/l and 79.66±3.05 mg/l respectively The with minimum mean alkalinity at this site was recorded as 66.66±9.86 mg/l during winter respectively while the maximum was recorded as 84±3.60 mg/l during summer. The season wise mean alkalinity values recorded at Site III were 99±3 mg/l, 99.33±17.92 mg/l, 126.66±3.51 mg/l and 120.33±9.60 mg/l respectively with minimum value at this site was recorded as 99±3 mg/l during winter respectively while the maximum was recorded as 126.66±3.51 mg/l during summer (Table 3&4; Figure 7).The seasonal variation in alkalinity values at different sampling sites may be due to the discharge emanating from agricultural activities, domestic sewage, surface run-off, mining, and other inorganic and organic ions discharge into streams through waste (Patel & Datar, 2014; Khanday *et al*., 2021).

6.1.9 Total Hardness

The mean total hardness values varied from upstream site I to downstream site III with minimum mean value of 67.58±13.74 at site I and maximum mean value of 112.08±16.15 at site III. The down stream increase in total hardness may be due to waste in put from point and non- point sources (Arafat *et al* 2022). The seasonally mean total hardness values varied at three different sites. At Site I, the values were 48±5.29 mg/l (winter), 65.33±11.01 mg/l (spring), 81±3 mg/l (summer), and 76±4 mg/l (autumn). The minimum recorded hardness at Site I was 48±5.29 mg/l during winter, while the maximum was 81±3 mg/l during summer (Figure 4d). At Site II, the mean values were 68.66±6.11 mg/l (winter), 76.66±12 mg/l (spring), 94±2 mg/l (summer), and 88.66±4.04 mg/l (autumn). The lowest hardness at Site II was 68.66±6.11 mg/l in winter, and the highest was 94±2 mg/l in summer (Figure 4d). At Site III, the mean values were 92±13.11 mg/l (winter), 106±12.48 mg/l (spring), 127±3 mg/l (summer), and 123.33±6.65 mg/l (autumn). The minimum recorded hardness at Site III was 92±13.11 mg/l during winter, while the maximum was 127±3 mg/l during summer (Table 3&4; Figure 7).The increasing trend in hardness concentration from Site I to Site III indicates a downstream rise likely influenced by surface wastewater discharge affecting stream hydrochemistry (Xiao *et al*., 2022). The higher hardness at Site III during summer may be attributed to inputs from both point and non-point sources of waste, geological characteristics such as carbonate-silicate rocks in the basin, agricultural and domestic waste contributions (Khanday *et al*., 2021), rising temperatures (Atwebembeire *et al*., 2018), increased mobilization rates of calcium and magnesium from surface water, and influx of municipal waste from the catchment area (Hussain, 2011; Mir *et al* 2016; Ahmad *et al* 2024).

6.1.10 Calcium Hardness

During the present study, the concentration of calcium hardness increased from upstream site I to down stream site III with minimum mean value of 35.83±9.23 at site I while maximum mean value of 70.83±14.62 at site III. Similarly for season-wise mean values recorded during winter, spring, summer and autumn were 24±2 mg/l, 34.66±10 mg/l, 46.33±1.52 mg/l and 38.33±4.16 mg/l at site I respectively. The minimum mean calcium hardness value at this site was recorded as 24±2 mg/l during winter whereas the maximum value was obtained as 46.33±1.52 mg/l during summer (Table 3&4; Figure 7).At Site II, the season wise mean calcium hardness values recorded during winter, spring, summer and autumn were 38.3±3.51 mg/l, 41.66±12.58 mg/l, 57.66±1.52 mg/l and 51±4.35 mg/l respectively. The minimum mean calcium hardness value at this site was recorded as 38.3±3.51 mg/l during winter while the maximum value was recorded as

57.66±1.52 mg/l during summer. At Site III, the season wise mean calcium hardness values recorded during winter, spring, summer and autumn were 54.33±9.71 mg/l, 65.33±16.04 mg/l, 85.66±2.51 mg/l and 78±8 mg/l respectively. The minimum mean calcium hardness value at this site was recorded as 54.33±9.71 mg/l, during winter while the maximum value was recorded as 85.66±2.51 mg/l during summer. Similarly the season wise mean Ca^{2+} values recorded at Site I were 9.6±0.8 mg/l, 13.86±4.02 mg/l, 18.53±0.61 mg/l and 15.33±1.66 mg/l respectively. The minimum mean Ca^{2+} at this site was recorded as 9.6±0.8 mg/l during winter respectively while the maximum was recorded as 18.53±0.61mg/l during summer. The season wise mean Ca^{2+} values recorded at Site I were 15.33±1.40 mg/l, 16.66±5.03mg/l, 23.06±0.61 mg/l and 20.4±1.74 mg/l respectively. The minimum mean Ca^{2+} at this site was recorded as 15.33±1.40 mg/l during winter respectively while the maximum was recorded as 23.06±0.61 mg/l during summer (Table 3&4; Figure 7).The season wise mean Ca^{2+} values recorded at Site I were 21.73±3.88 mg/l, 26.13±6.41 mg/l, 34.26±1 mg/l and 31.06±3.23 mg/l respectively. The minimum mean Ca^{2+} at this site was recorded as 21.73±3.88 mg/l during winter respectively while the maximum was recorded as 34.26±1 mg/l during summer (Figure 4e). Seasonal changes in calcium levels could be attributed to human activities and waste materials, particularly substances rich in calcium such as bones and dairy products from slaughtered animals (Usman *et al*., 2022), as well as the geological composition of the catchment area (Jaiswal *et al*., 2019).

6.1.11 Magnesium Hardness

During the present study, the concentration of magnesium hardness increased from upstream site I to down stream site III with minimum mean value of 7.97±1.18 at site I while maximum mean value of 9.78±0.87 at site III and the season wise mean magnesium hardness values recorded during winter, spring, summer and autumn were 6.88±1.88 mg/l, 7.49±0.27 mg/l, 9.15±0.27 mg/l and 8.41±0.37 mg/l at site I respectively. The minimum mean magnesium hardness value at this site was recorded as 6.88±1.88 mg/l during winter while the maximum value was recorded as 9.15±0.27 mg/l summer.

At Site II, the season wise mean magnesium hardness values recorded during winter, spring, summer and autumn were 7.77±1.04 mg/l, 8.5±0.19 mg/l, 9.15±0.27 mg/l and 8.82±0.14 mg/l respectively. The minimum mean magnesium hardness value at this site was recorded as 7.77±1.04 mg/l during winter while the maximum value was recorded as 9.15±0.27 mg/l during summer (Figure 4e). At Site III, the season wise mean magnesium hardness values recorded during winter, spring, summer and autumn were 8.91±0.56 mg/l, 9.19±0.06 mg/l, 11.01±0.50 mg/l and 10.04±0.11 mg/l respectively. The minimum mean magnesium hardness value at this site was recorded as 8.91±0.56 mg/l during winter while the maximum value was recorded as 11.01±0.50 mg/l during summer. Similar season-trend was recorded in Mg^{2+} values were 1.67±0.46 mg/l, 1.81±0.06 mg/l, 2.20±0.08 mg/l and 2.05±0.14 mg/l respectively recorded at Site I. The minimum mean Mg^{2+} at this site was recorded as 1.67±0.46 mg/l during winter respectively while the maximum was recorded as 2.20±0.08 mg/l during summer (Figure 4e). The season wise mean Mg^{2+} values recorded at Site II were 2.05±0.25 mg/l, 2.07±0.06 mg/l, 2.22±0.06 mg/l and 2.15±0.03 mg/l respectively. The minimum mean Mg2+ at this site was recorded as 2.05±0.25 mg/l during winter respectively while the maximum was recorded as 2.22±0.06 mg/l during summer (Figure4e).The season-wise mean Mg2+ values recorded at Site III were 2.17±0.13 mg/l, 2.24±0.01 mg/l, 2.68±0.12 mg/l and 2.32±0.13 mg/l respectively. The minimum mean Mg^{2+} at this site was recorded as 2.17±0.13 mg/ during winter respectively while the maximum was recorded as 2.68±0.12 mg/l during summer (Table 3&4; Figure 7). The fluctuation in average magnesium levels across various sites and seasons is likely influenced by human activities such as discharge from households, agricultural runoff containing fertilizers, which significantly contribute to elevated magnesium levels in streams and rivers (Jaiswal *et al*., 2019). Furthermore, higher temperatures in summer also play a role in affecting magnesium concentrations. Additionally, different rock types serve as primary sources of magnesium in natural water (Mir *et al*., 2019).

6.1.12 *Nitrate-Nitrogen (NO_3-N)*

During the present study, the concentration of nitrate nitrogen increased from upstream site I to down stream site III with minimum mean value of 128.25±23.85 at site I while maximum mean value of 178.58 ±29.94 at site III (Table 3,Figure 4e). The season-wisemean value of nitrate nitrogen was recorded at Site I 97±7 µg/l, 123±16.70 µg/l, 153±9.64 µg/l and 140±19 µg/l respectively. The minimum mean nitrate nitrogen at this site was recorded as 97±7 µg/l during winter respectively while the maximum was recorded as 153±9.64 µg/l during summer.The season-wise mean nitrate nitrogen values recorded at Site II were 120.66±9.29 µg/l, 145±20.95 µg/l, 170±4.04 µg/l and 149±18.55 µg/l respectively. The minimum mean nitrate nitrogen at this site was recorded as 120.66±9.29 µg/l during winter respectively while the maximum was recorded as 170±4*.04 µg/l* during summer (Figure4e).The season-wise mean nitrate nitrogen values recorded at Site III were 140.66±9.45 µg/l, 176±33.86 µg/l, 211±7 µg/l and 186±15.94 µg/l respectively. The minimum mean nitrate nitrogen at this site was recorded as 140.66±9.45 µg/l during winter respectively while the maximum was recorded as 211±7 µg/l during summer (Table 3&4; Figure 7).Seasonal changes in nitrate levels across different sampling sites can be attributed to inputs from diverse non-point sources. These include agricultural and horticultural activities where nitrate-containing fertilizers are used, as well as contributions from domestic sewage, runoff from washing activities, open garbage disposal, and fecal matter (Mir *et al* 2023). Additionally, higher temperatures and increased organic matter decomposition are factors that contribute to elevated nitrate nitrogen levels in water (Hamid *et al*., 2020; Hamid *et al*., 2016). Previous study by (Arafat *et al.*, 2022) obtained similar results.

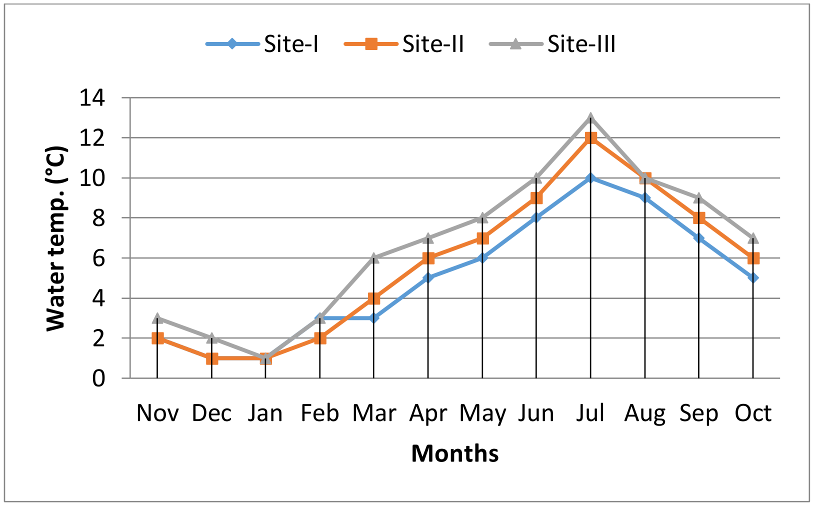
6.1.13 Sulphate

In the present study, the concentration of sulphate increased from upstream site I to down stream site III with minimum mean value of 5.03±1.09 at site I while maximum mean value of 8.87±1.52 at site III and the mean value of sulphate at Site I were recorded during winter, spring, summer and autumn were 3.7±0.81 mg/l, 4.63±0.570 mg/l, 6.13±0.45 mg/l and 5.66±0.66 mg/l respectively. The minimum mean sulphate value at this site was recorded as 3.7±0.81 mg/l during winter while the maximum value was recorded as 6.13±0.45 mg/l during summer. Similarly, at Site II, the season wise mean sulphate values recorded during winter, spring, summer and autumn were 5.16±0.76 mg/l, 6.46±0.95 mg/l, 7.73±0.20 mg/l and 6.83±0.55 mg/l respectively. The minimum mean sulphate value at this site was recorded as 5.16±0.76mg/l during winter while the maximum value was recorded as 7.73±0.20 mg/l during summer (Figure 4f).and at Site III, the season wise mean sulphate values recorded during winter, spring, summer and autumn were 7±1 mg/l, 8.36±1.06 mg/l, 10.56±0.56 mg/l and 9.56±0.50 mg/l respectively. The minimum mean sulphate value at this site was recorded as 7±1 mg/l during winter while the maximum value was recorded as 10.56±0.56 mg/l during summer (Table 3&4; Figure 7). The seasonal and site variation in sulphate concentration may be due to the discharge of sulphate-rich ions from commercial and domestic sewage, as well as the increased usage of fertilizers (Hussain, 2011; Ahmad *et al*., 2024). In addition to this, the geological features of stream are also contributing sulphate in the stream (Mahmood *et al*., 2017). Previous study by (Mir *et al.*, 2023) obtained similar results.

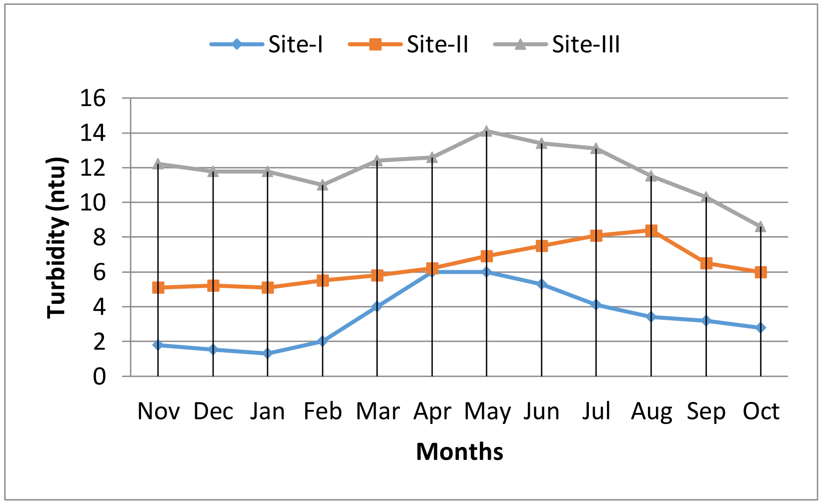
6.1.14 Total Phosphorus

In the present study, the concentration of total phosphrous increased from upstream site I to down stream site III with minimum mean value of 90.66±11.29 at site I while maximum mean value of 235.08±31.97 at site III and the seasonal mean total phosphorus concentrations varied across different sites. At Site I, values were 76±2 µg/l (winter), 88±6 µg/l (spring), 103.33±7.02 µg/l (summer), and 95.33±8.32 µg/l (autumn), with the lowest recorded during winter and the highest during summer (Figure 4f). At Site II, values were 131.33±4.16 µg/l (winter), 155.33±7.02 µg/l (spring), 179.33±10.06 µg/l (summer), and 168±11.59 µg/l (autumn), with the lowest observed in winter and the highest in summer. Similarly, at Site III, values were 192±6 µg/l (winter), 223.33±13.01 µg/l (spring), 270±13.11 µg/l (summer), and 255±18.52 µg/l (autumn), with the minimum during winter and the maximum during summer (Table 3 & 4; Figure 7).The variations in mean values of total phosphorus indicate the presence of anthropogenic pollutants (Bhat *et al*., 2014). Earlier works also indicate that domestic sewage and application of fertilizers in surrounding agricultural land area and leaching of nutrients are possible factors that enhance phosphorous concentration in stream waters (Dodds and Smith, 2016). Other factors include regeneration and subsequent release of phosphate from the decaying sediment into water column (Huang *et al*., 2021) and excess use of detergents in summer for domestic use (Adeyemo *et al*., 2008). Previous study by (Mir *et al.*, 2023) obtained similar results.

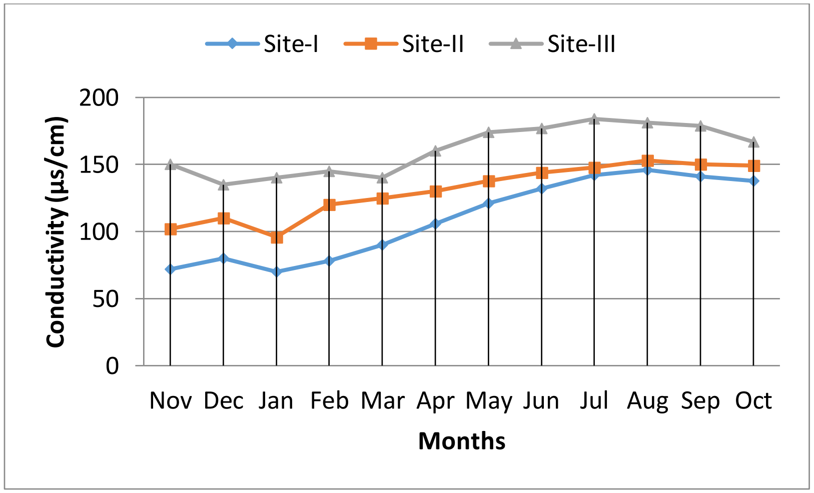
•



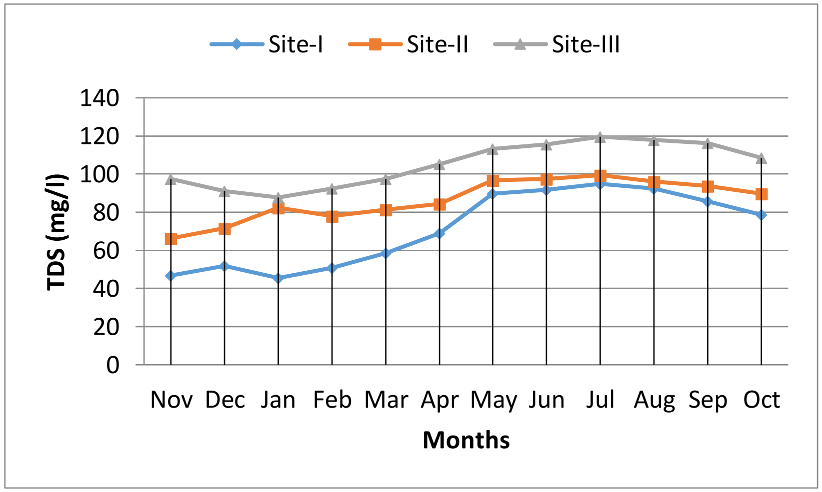
Site-I
Site-II
Site-III
Water temp. (°C)
14
12
10
8
6
4
2
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months



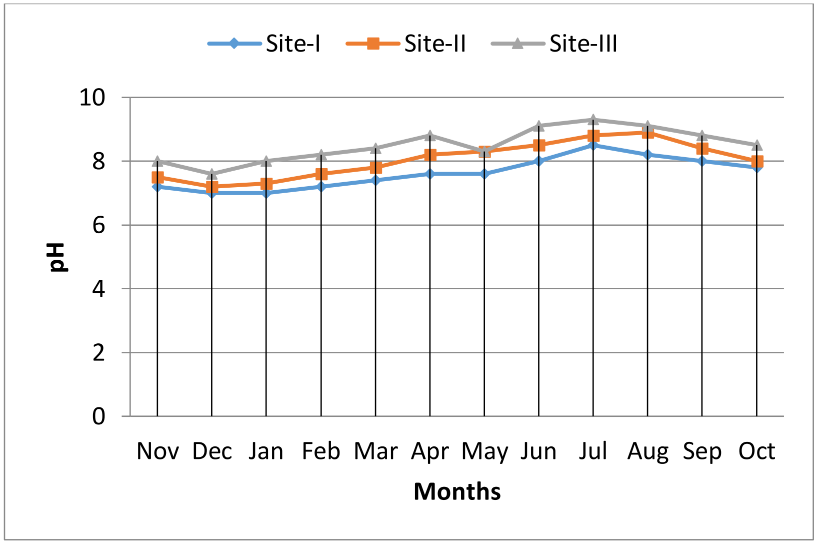
Site-I
Site-II
Site-III
Turbidity (ntu)
16
14
12
10
8
6
4
2
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months

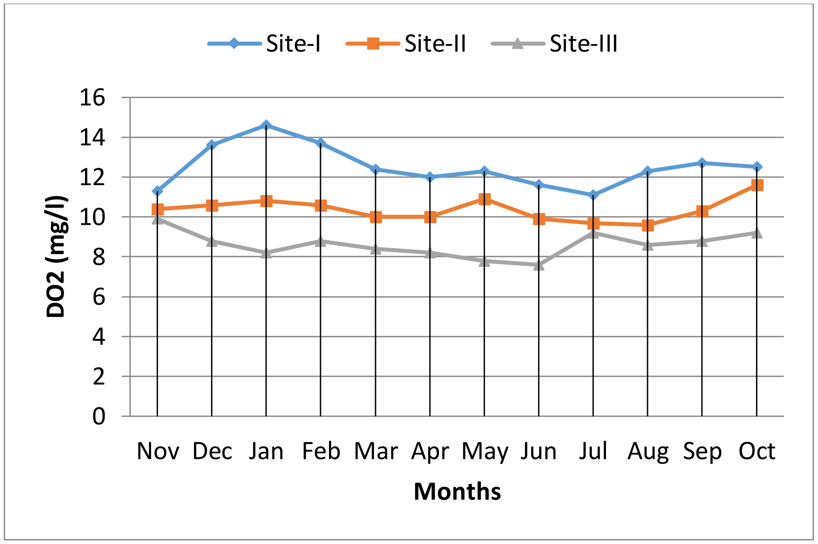


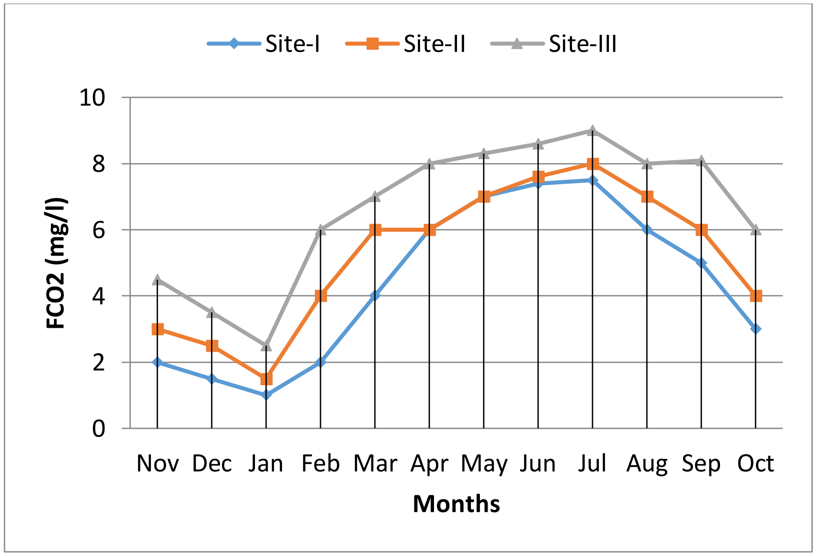
Site-I
Site-II
Site-III
Conductivity (µs/cm)
200
150
100
50
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months

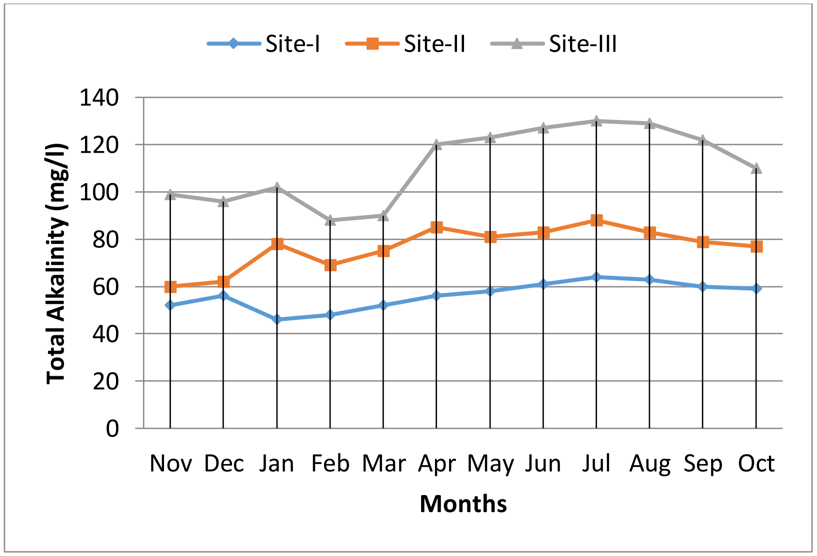


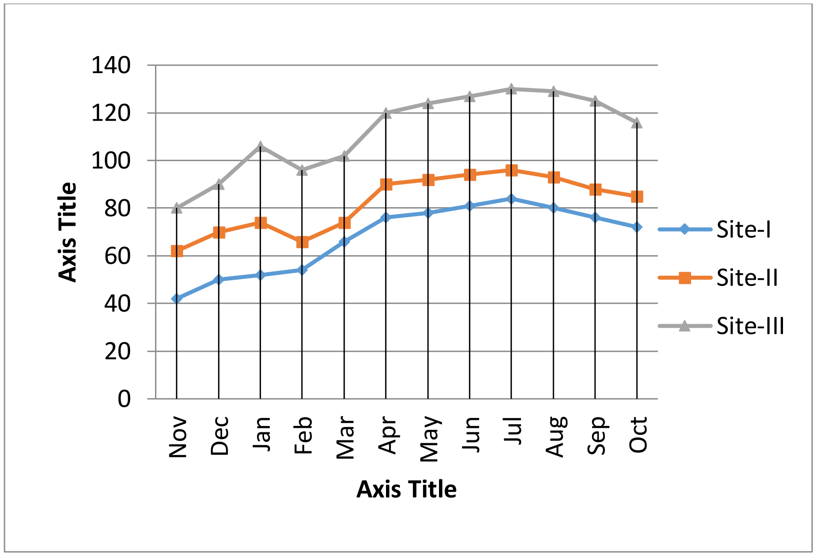
Site-I
Site-II
Site-III
TDS (mg/l)
140
120
100
80
60
40
20
0
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months


Site-I
Site-II
Site-III
10
8
6
4
2
0
pH
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months

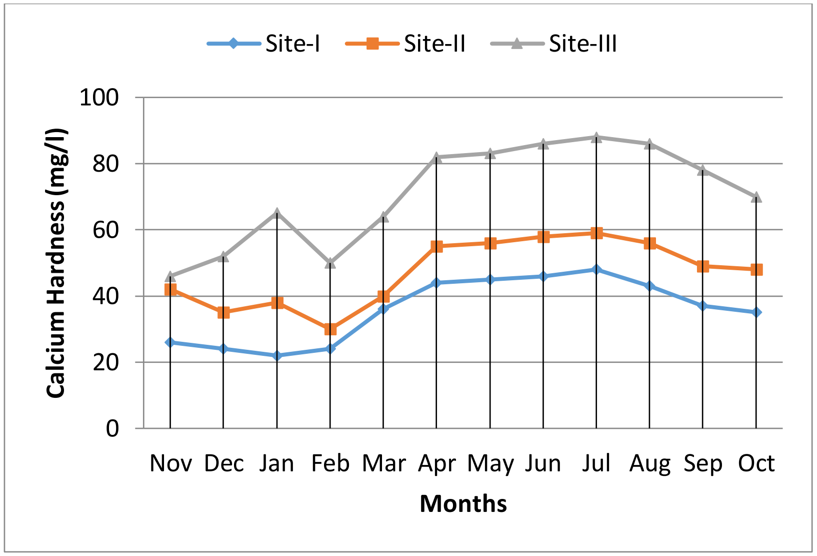

Site-I
Site-II
Site-III
16
14
12
10
8
6
4
2
0
DO2 (mg/l)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months


Site-I
Site-II
Site-III
10
8
6
4
2
0
FCO2 (mg/l)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months

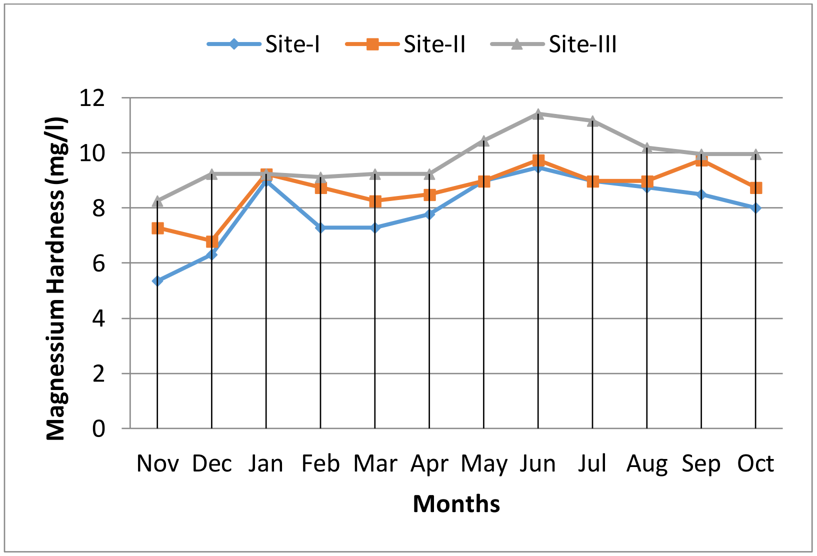

Site-I
Site-II
Site-III
140
120
100
80
60
40
20
0
Total Alkalinity (mg/l)
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Months



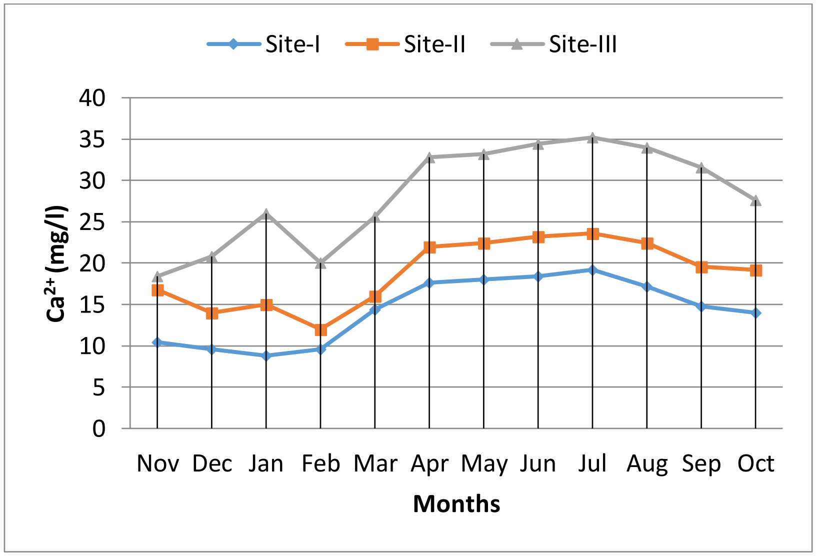
140
120
100
80
60
40
20
0
Axis Title
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Axis Title
Site-I
Site-II
Site-III



Site-I
Site-II
Site-III
100
80
60
40
20
0
Calcium Hardness (mg/l)
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Months



Site-I
Site-II
Site-III
12
10
8
6
4
2
0
Magnesium Hardness (mg/l)
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Months



Site-I
Site-II
Site-III
40
35
30
25
20
15
10
5
0
Ca^{2+} (mg/l)
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Months

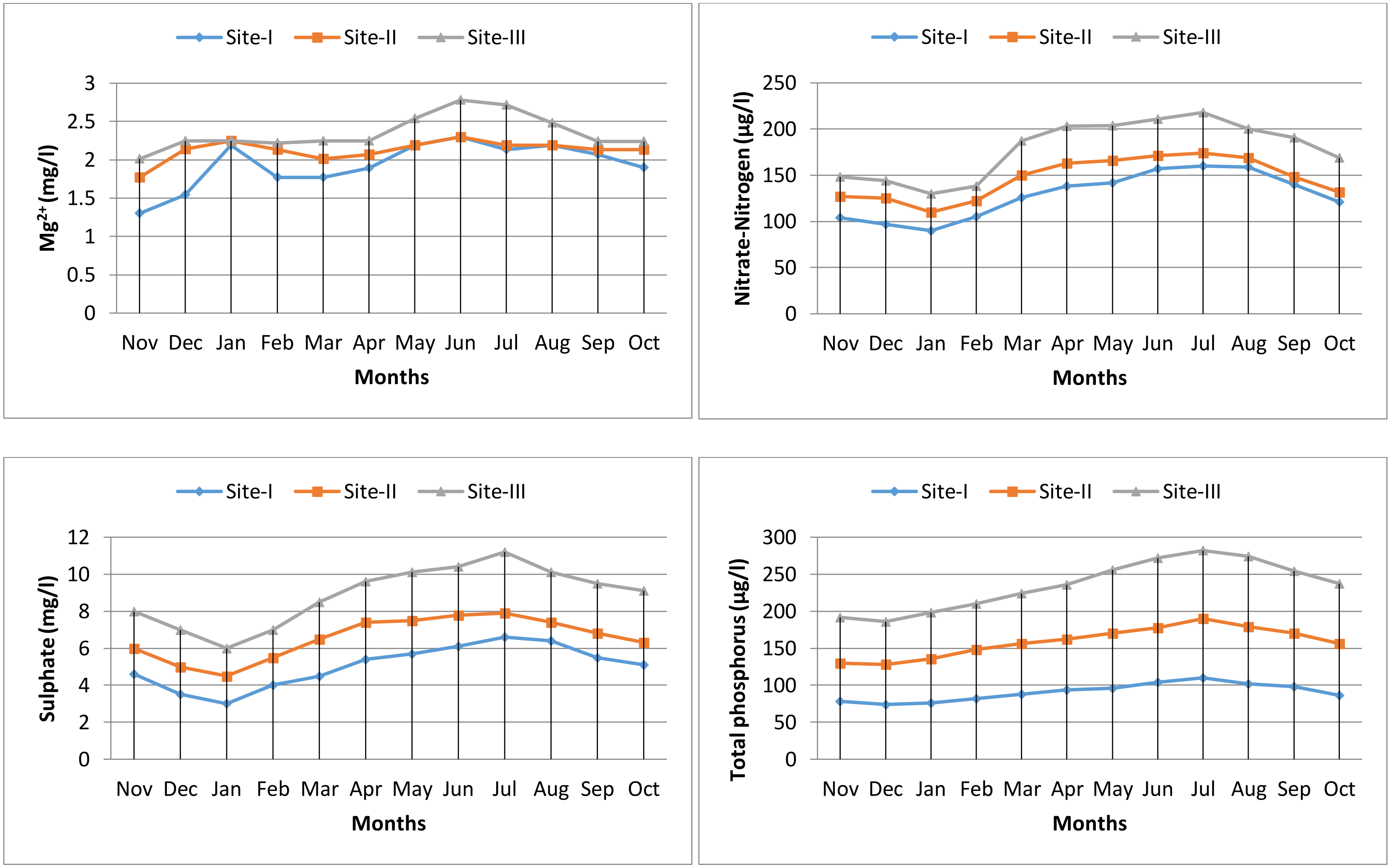


Figure 6: Showing monthly variations in Physico-chemical parameters from November, 2019 to October, 2020 at three different sites of Vaishav stream.

Table 3: Monthly variations in Physico-chemical parameters from November, 2019 to October, 2020 at three different sites of Vaishav stream and the superscripts are added on top of the values showing significance at $p<0.05$, those having different superscripts are significantly different at $p<0.05$ as indicated by Fishers LSD pairwise multiple comparision test.

Parameters	**Site**								
	Mean±SD			**Min./Max.**					
	I	**II**	**III**	**I**		**II**		**III**	
Air Temp. (°C)	8.5±8.6^{a}	10.41±7.77^{a}	12±8^{a}	-8	19	-5	20	-4	22
Water Temp. (°C)	4.91±3.01^{a}	5.66±3.54^{a}	6.33±3.63^{a}	1	10	1	12	1	13
Turbidity	3.01±1.5 ^{a}	6.35±1.09^{b}	11.89±1.4^{c}	1.31	6	5.10	8.4	8.6	14.1
Conductivity (µs/cm)	108.91±29.55^{b}	130.41±19.01^{ab}	161.17±0.44^{a}	70	146	96	153	135	184
TDS (mg/l)	83.08±9.57^{b}	94.02±8.04^{ab}	119.89±15.55^{a}	45.5	94.9	62.4	99.45	87.75	119.6
pH	7.60±0.48^{b}	8.04±0.55^{ab}	8.42±0.51^{a}	7	8.5	7.2	8.9	7.6	9.3
Free CO_2(mg/l)	4.36±2.31^{a}	5.09±2.2^{a}	6.41±2.36^{a}	1	7.5	1.5	8	2.5	9
Dissolved Oxygen (mg/l)	12.46±0.94^{a}	10.38±0.54^{b}	8.65±0.66^{c}	11.1	12.7	9.6	10.9	2.5	9
Total Alkalinity (mg/l)	56.41±5.51^{a}	76.66±8.45^{b}	11.33±15.01**c**	46	64	60	88	88	130
Total Hardness (mg/l)	67.58±13.74^{b}	82±11.53^{b}	112.08±16.15**a**	42	84	62	96	80	130
Calcium Hardness (mg/l)	35.83±9.23^{b}	47.16±9.5^{b}	70.83±14.62^{a}	22	48	30	59	46	88

Magnesium Hardness (mg/l)	7.97±1.18[a]	8.56±0.74[a]	9.78±0.87[a]	5.35	9.47	6.81	9.47	8.26	11.42
Ca^{2+} (mg/l)	14.33±3.69[b]	18.86±3.8[b]	28.3±5.83[a]	8.8	19.2	12	23.60	18.4	35.20
Mg^{2+} (mg/l)	1.93±0.28[b]	2.08±0.18[ab]	2.36±0.21[a]	1.30	2.30	1.77	2.30	2.01	2.78
Nitrate-Nitrogen (µg/l)	128.25±23.85[b]	146.58±21.57[ab]	178.58±29.94[a]	90	160	110	174	130	218
Sulphate (mg/l)	5.03±1.09[b]	6.55±1.07[ab]	8.87±1.52[a]	3	6.6	4.5	7.9	6	11.2
Total Phosphorus (mg/l)	90.66±11.29[a]	158.58±19.23[b]	235.08±31.97[c]	74	110	128	190	186	282

Table 4: Seasonal variations in Physico-chemical parameters from November, 2019 to October, 2020 at three different sites of Vaishav stream and the superscripts are added on top of the values showing significance at $p<0.05$, those having different superscripts are significantly different at $p<0.05$ as indicated by Fishers LSD pairwise multiple comparision test.

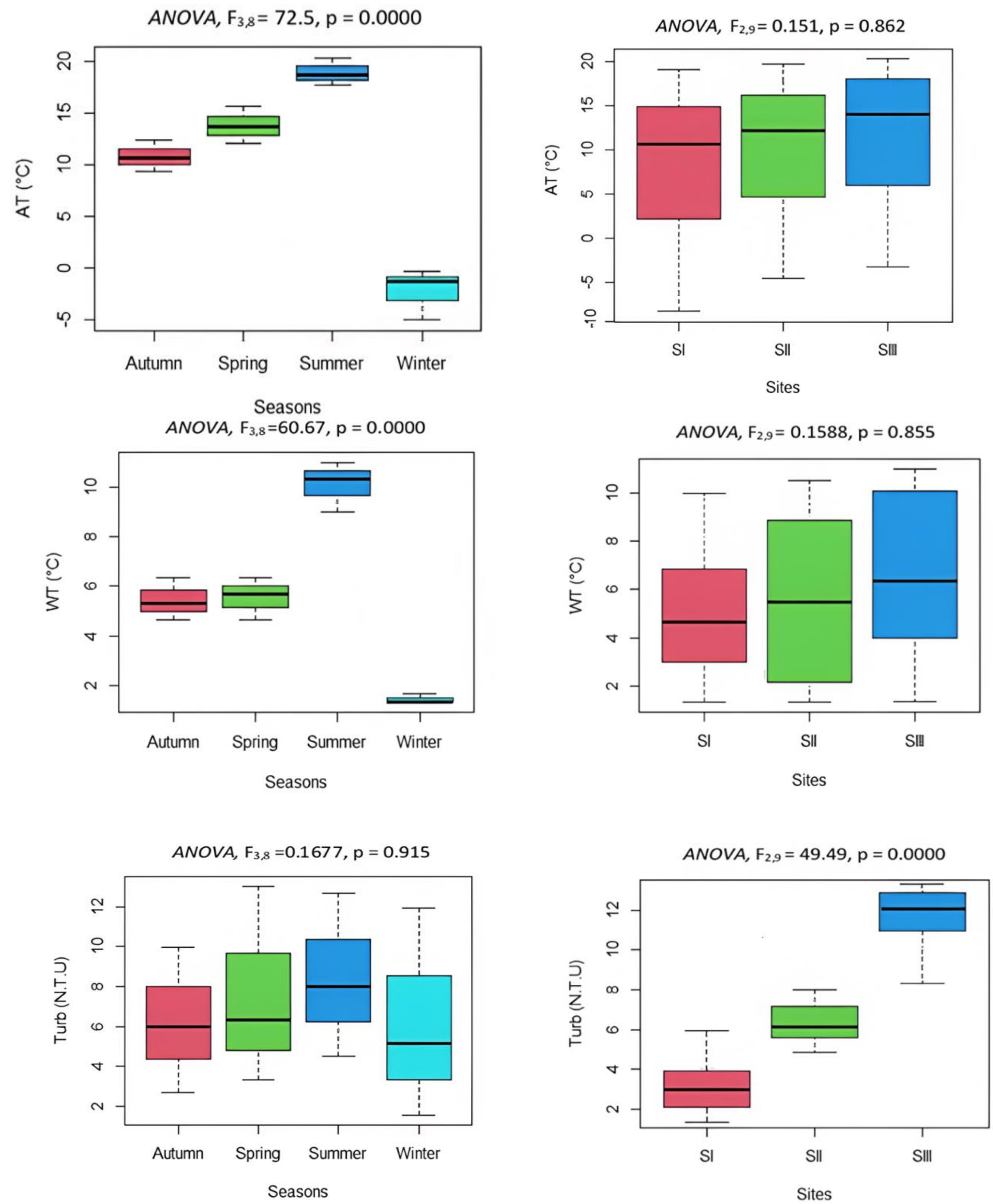
Parameters	Site	Winter	Spring	Summer	Autumn	Minimum	Maximun
Air Temp. (°C)	**I**	**-5±4.72^{a}**	9±3.60^{b}	16.33±2.51^{c}	13.66±4.04^{b}	-5±4.72	16.33±2.51
	II	-1.33±4.72^{a}	11±3.60^{b}	17.33±2.51^{b}	14.66±3.78^{b}	-1.33±4.72	17.33±2.51
	III	-0.33±4.72^{a}	13.33±3.05^{a}	**19.33±2.51^{a}**	15.33±3.78^{a}	-0.33±4.72	19.33±2.51
Water Temp. (°C)	**I**	**1.33±0.57 ^{a}**	3.66±1.15^{b}	8±2^{c}	7±1.63^{b}	1.33±0.57	8±2
	II	1.34±0.57^{a}	4±2^{b}	9.33±2.51^{c}	8±2^{b}	1.33±0.57	9.33±2.51
	III	2±1^{a}	5.33±2.08 ^{b}	**10.33±2.51^{c}**	8.66±1.52^{b}	2±1	10.33±2.51
Turbidity (NTU)	**I**	**1.54±0.24^{a}**	4±2^{bc}	5.13±0.96^{bc}	3.13±0.30^{a}	1.54±0.24	10.33±2.51
	II	5.13±0.06 ^{a}	5.83±0.35^{bd}	7.5±0.6^{b}	6.96±1.26 ^{cd}	5.13±0.06	5.13±0.96
	III	10.13±1.45^{a}	12±0.87^{a}	**13.53±0.51^{a}**	11.92±0.23^{b}	10.13±1.45	7.5±0.6
Conductivity (μs/cm)	**I**	**74±5.29 ^{a}**	91.33±14.04^{ae}	141.66±4.04^{ce}	131.66±10.50^{de}	74±5.29	141.66±4.04
	II	102.66±7.02^{a}	125±5^{bef}	150.66±2.08^{ce}	143.33± 5.03^{df}	102.66±7.02	150.66±2.08
	III	141.66±7.63 ^{a}	151.33±10.06 af	**181±3.60^{be}**	173.33±6.02^{cef}	141.66±7.63	181±3.60
Total Dissolved Solids	**I**	**48.10±3.43^{a}**	59.36±9.13^{be}	92.08±2.62^{ce}	85.58±6.82^{de}	48.10±3.43	92.08±2.62

(mg/l)	**II**	66.73±4.56^{af}	81.25±3.25^{bcf}	97.93±1.35^{af}	93.16±3.27^{acf}	66.73±4.56	97.93±1.35
	III	92.08±4.96^{a}	98.36±6.54^{bc}	**116.06±3.28^{ac}**	114.11±5.03^{ac}	92.08±4.96	116.06±3.28
pH	**I**	**7.06±0.11^{a}**	7.40±0.2^{a}	8.03±0.45^{b}	8±0.2^{a}	7.40±0.2	8.03±0.45
	II	7.4±0.26^{a}	7.8±0.30^{bc}	8.5±0.25^{c}	8.4±0.45^{ac}	7.4±0.26	8.5±0.25
	III	7.8±0.23^{a}	8.4±0.30^{a}	**8.9±0.52^{b}**	8.8±0.3^{a}	7.8±0.23	8.9±0.52
Dissolved oxygen (mg/l)	**I**	**13.16±1.69^{a}**	12.7±0.88^{a}	12±1.15^{a}	12.5±0.2^{a}	12±1.15	13.16±1.69
	II	10.6±0.2^{a}	10.2±0.34^{a}	10.16±0.64^{a}	10.5±1.01^{a}	10.16±0.64	10.6±0.2
	III	8.96±0.86^{a}	8.46±0.30^{a}	**8.2±0.87^{a}**	8.86±0.30^{a}	8.2±0.87	8.96±0.86
Free CO_2 (mg/l)	**I**	**1.5±0.5^{a}**	4±0.2^{b}	7.3±0.26^{c}	4.6±0.52^{a}	1.5±0.5	7.3±0.26
	II	2.33±0.76^{a}	5.33±1.15^{b}	7.53±0.50^{c}	5.66±1.52^{d}	2.33±0.76d	7.53±0.50
	III	3.5±1^{a}	7±1^{be}	**8.63±0.35^{ce}**	8.23±1,18^{de}	3.5±1	8.63±0.35
Total alkalinity (mg/l)	**I**	**52±5.03^{ac}**	52.33±4^{ac}	61±3^{bc}	60.66±2.08^{ac}	52.33±5.03	61±3
	II	66.66±9.86^{a}	79.66±5.03^{a}	84±3.60^{a}	79.66±3.05^{a}	66.66±9.86	84±3.60
	III	99±3^{a}	99.33±17.92^{a}	**126.66±3.51^{b}**	120.33±9.60^{a}	99±3	126.66±3.51
Total hardness (mg/l)	**I**	**48±5.29^{a}**	65.33±11.01^{be}	81±3^{ce}	76±4^{be}	48±5.29	81±3
	II	68.66±6.11^{a}	76.66±12^{be}	94±2^{ce}	88.66±4.04^{ae}	68.66±6.11	94±2
	III	92±13.11^{a}	106±12.48 ^{be}	**127±3^{ce}**	123.33±6.65^{ae}	92±13.11	127±3

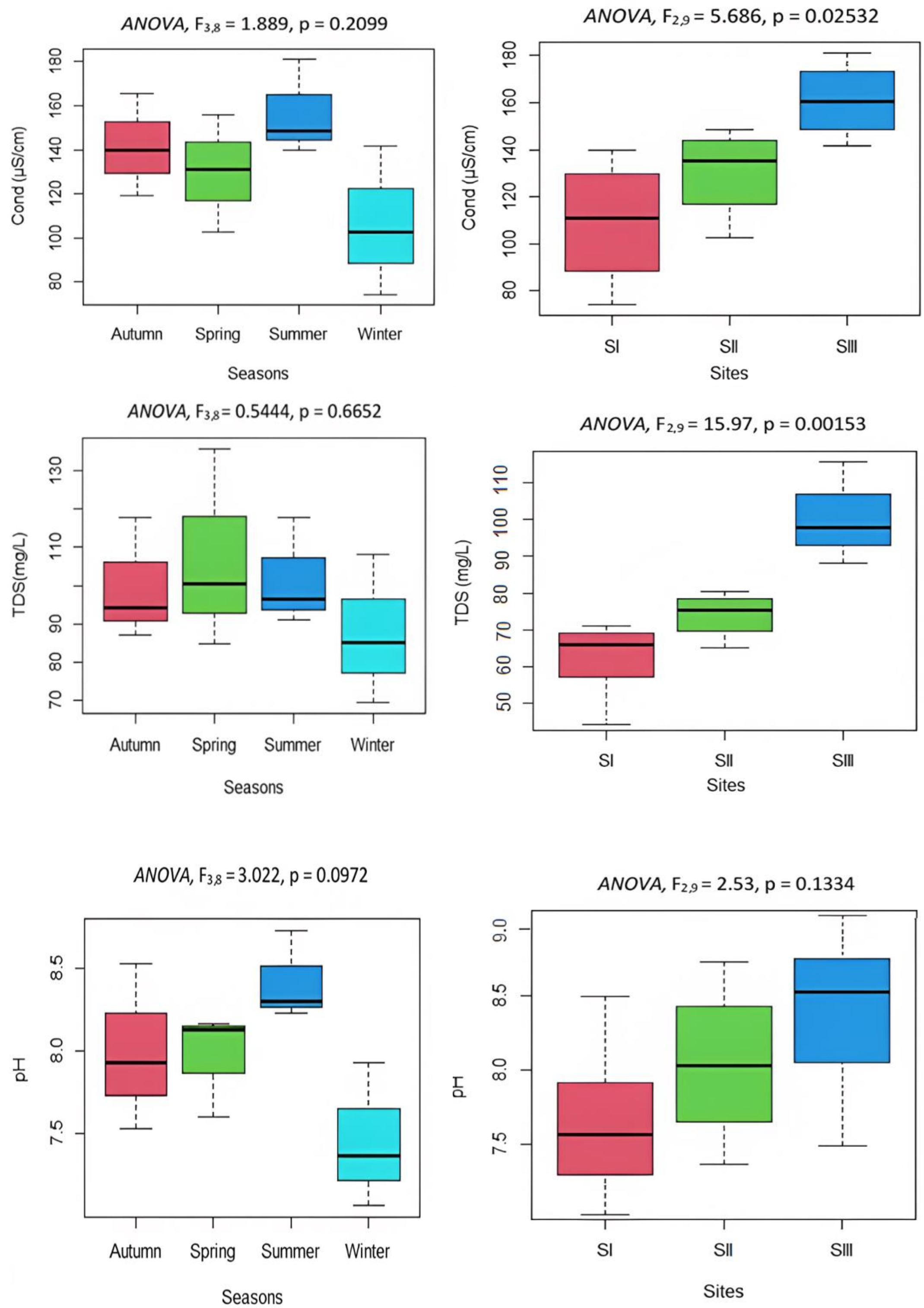
Calcium hardness (mg/l)	I	**24±2**[a]	34.66±10[bd]	46.33±1.52[cd]	38.33±4.16[aa]	24±2	46.33±1.52
	II	38.3±3.51[ac]	41.66±12.58[ac]	57.66±1.52[bc]	51±4.35[ac]	38.3±3.51	57.66±1.52
	III	54.33±9.71[a]	65.33±16.04[bd]	**85.66±2.51**[cd]	78±8 [ad]	54.33±9.71	85.66±2.51
Magnesium hardness (mg/l)	I	**6.88±1.88**[a]	7.49±0.27[a]	9.15±0.27[a]	8.41±0.37[a]	6.88±1.88	9.15±0.27
	II	7.77±1.04[a]	8.5±0.19[a]	9.15±0.27[a]	8.82±0.14[d]	7.77±1.04	9.15±0.27
	III	8.91±0.56 [a]	9.19±0.06[a]	**11.01±0.50**[a]	10.04±0.13[a]	8.91±0.56	11.01±0.50
	I	**9.6±0.8**[a]	13.86±4.02[bd]	18.53±0.61[cd]	15.33±1.66[a]	9.6±0.8	18.53±0.61
Ca^{2+} (mg/l)	II	15.33±1.40[a]	16.66±5.03[a]	23.06±0.61[b]	20.4±1.74[a]	15.33±1.40	23.06±0.61
	III	21.73±3.88[a]	26.13±6.41[be]	**34.26±1.00**[ce]	31.06±3.23[de]	21.73±3.88	34.26±1.00
	I	**1.67±0.46**[a]	1.81±0.06[a]	2.20±0.08[a]	2.05±0.14[a]	1.67±0.46	2.20±0.08
Mg^{2+} (mg/l)	II	2.05±0.25[a]	2.07±0.06[a]	2.22±0.06[a]	2.15±0.03[b]	2.05±0.25	2.22±0.06
	III	2.17±0.13[a]	2.24±0.01[a]	**2.68±0.12**[a]	2.32±0.13[a]	2.17±0.13	2.68±0.12
Nitrate nitrogen (µg/l)	I	**97±7**[a]	123±16.70[bc]	153±9.64[ce]	140±19d[e]	97±7	153±9.64
	II	120.66±9.29[a]	145±20.95[bd]	170±4.04[cd]	149±18.55[a]	120.66±9.29	170±4.04
	III	140.66±9.4 [a]	176±33.86[bd]	**211±7**[cd]	186±15.94[a]	140.66±9.45	211±7
	I	**3.7±0.81**[a]	4.63±0.70[bd]	6.13±0.45[d]	5.66±0.66[ad]	3.7±0.81	6.13±0.45
Sulphate (mg/l)	II	5.16±0.76[a]	6.46±0.95[bd]	7.73±0.20[cd]	6.83±0.55[ad]	5.16±0.76	7.73±0.20

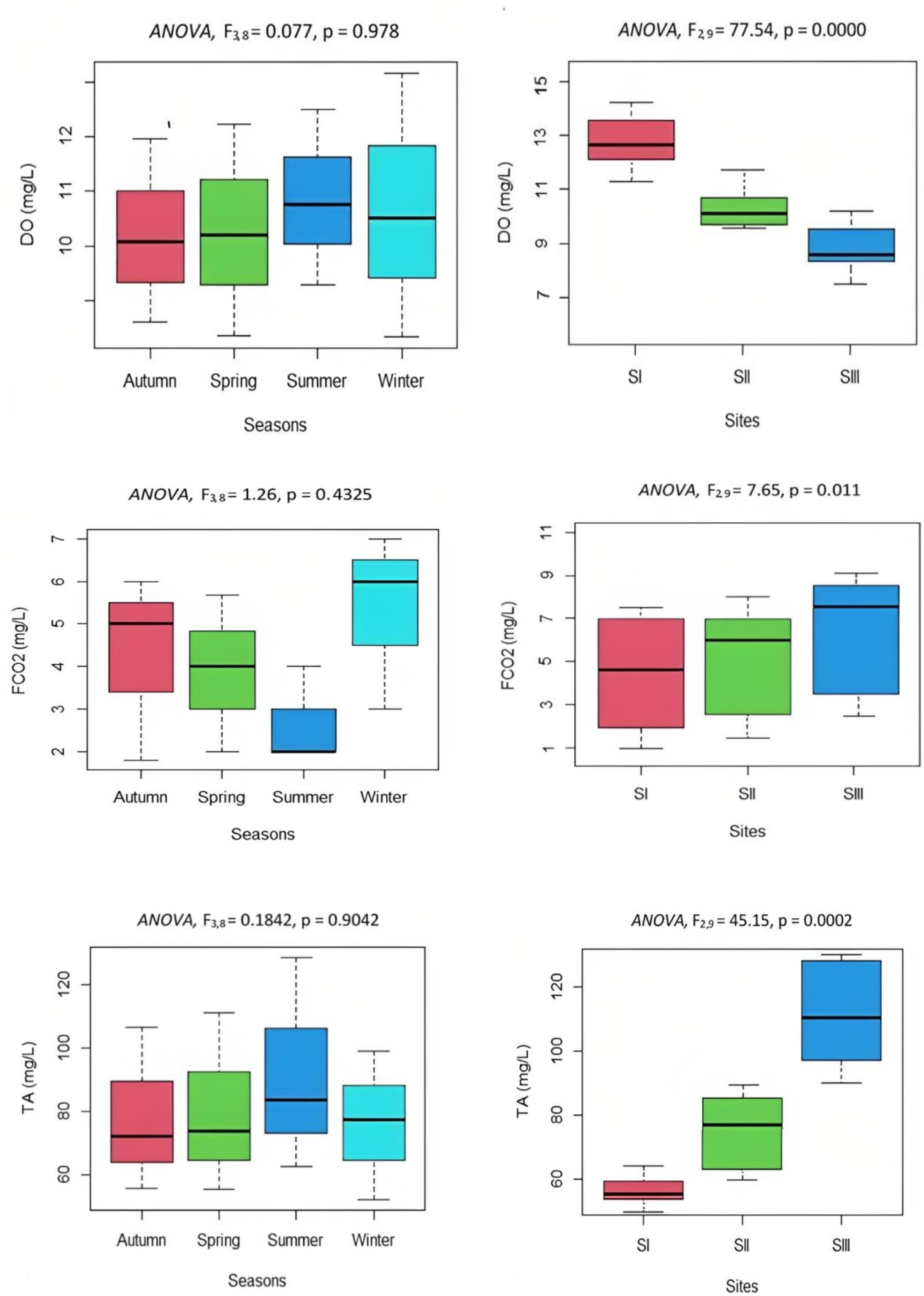
	III	7±1[a]	8.36±1.06[bd]	**10.56±0.50**[cd]	9.56±0.50**ad**	7±1	10.56±0.50
Total phosphorus (µg/l)	I	**76±2**[a]	88±6[bc]	103.33±7.02[ce]	95.33±8.32[de]	76±2	103.33±7.02
	II	131.33±4.16 [a]	155.33±7.02[be]	179.33±10.06[ce]	168±11.59[de]	131.33±4.16	179.33±10.06
	III	192±6 [a]	223.33±13.01[be]	**270±13.11**[ce]	255±18.52[de]	192±6	270±13.11

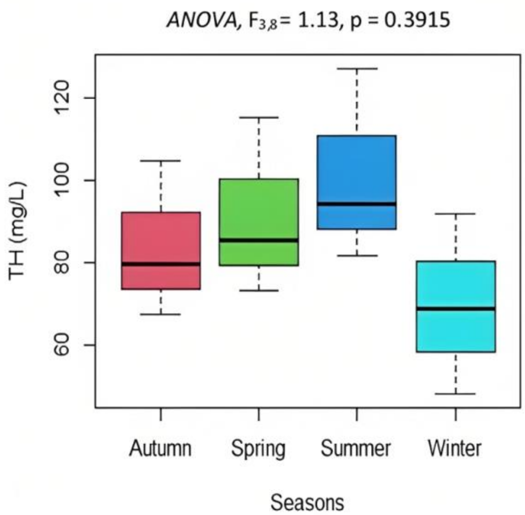
Values are expressed as MEAN±SD

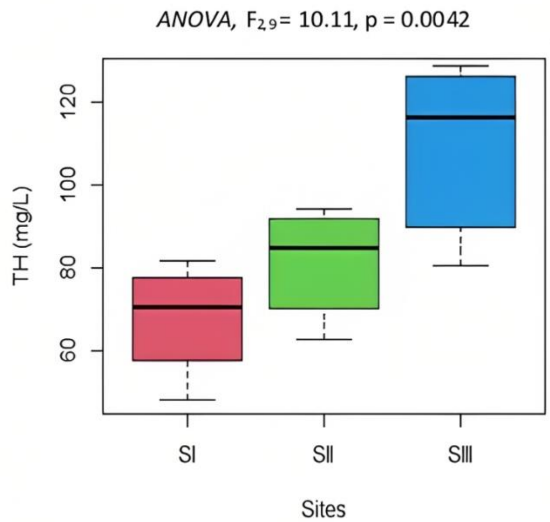


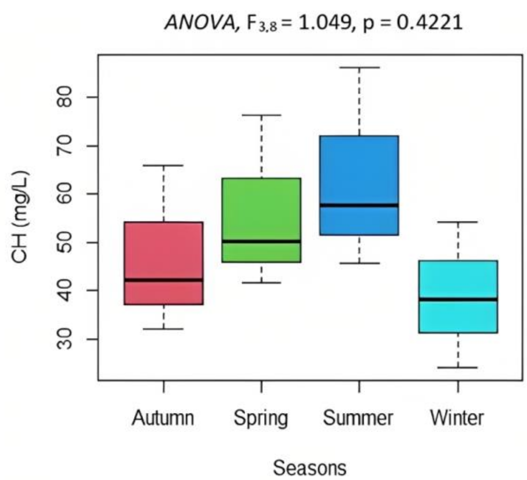
ANOVA, $F_{3,8}$= 72.5, p = 0.0000
AT (°C)
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$= 0.151, p = 0.862
AT (°C)
SI SII SIII
Sites
ANOVA, $F_{3,8}$=60.67, p = 0.0000
WT (°C)
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$= 0.1588, p = 0.855
WT (°C)
SI SII SIII
Sites
ANOVA, $F_{3,8}$ =0.1677, p = 0.915
Turb (N.T.U)
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$= 49.49, p = 0.0000
Turb (N.T.U)
SI SII SIII
Sites

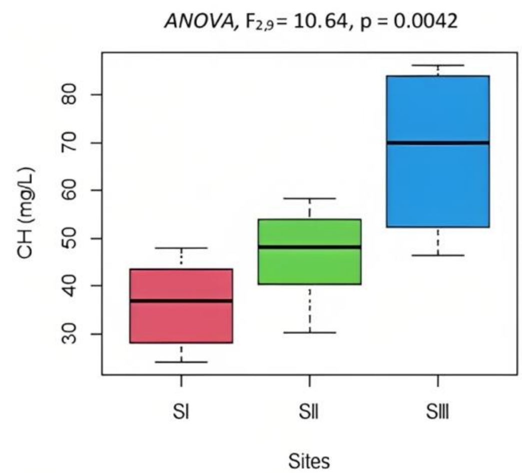

ANOVA, $F_{3,8}$ = 1.889, p = 0.2099
Cond (µS/cm)
180
160
140
120
100
80
Autumn
Spring
Summer
Winter
Seasons
ANOVA, $F_{2,9}$ = 5.686, p = 0.02532
Cond (µS/cm)
180
160
140
120
100
80
SI
SII
SIII
Sites
ANOVA, $F_{3,8}$= 0.5444, p = 0.6652
TDS(mg/L)
130
110
90
80
70
Autumn
Spring
Summer
Winter
Seasons
ANOVA, $F_{2,9}$ = 15.97, p = 0.00153
TDS (mg/L)
110
100
90
80
70
60
50
SI
SII
SIII
Sites
ANOVA, $F_{3,8}$ = 3.022, p = 0.0972
pH
8.5
8.0
7.5
Autumn
Spring
Summer
Winter
Seasons
ANOVA, $F_{2,9}$ = 2.53, p = 0.1334
pH
9.0
8.5
8.0
7.5
SI
SII
SIII
Sites

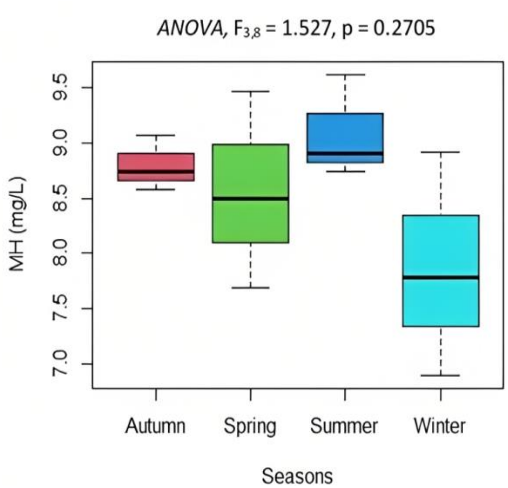

ANOVA, F3,8 = 0.077, p = 0.978
DO (mg/L)
10
11
12
Autumn
Spring
Summer
Winter
Seasons
ANOVA, F2,9 = 77.54, p = 0.0000
DO (mg/L)
7
9
11
13
15
SI
SII
SIII
Sites
ANOVA, F3,8 = 1.26, p = 0.4325
FCO2 (mg/L)
2
3
4
5
6
7
Autumn
Spring
Summer
Winter
Seasons
ANOVA, F2,9 = 7.65, p = 0.011
FCO2 (mg/L)
1
3
5
7
9
11
SI
SII
SIII
Sites
ANOVA, F3,8 = 0.1842, p = 0.9042
TA (mg/L)
60
80
100
120
Autumn
Spring
Summer
Winter
Seasons
ANOVA, F2,9 = 45.15, p = 0.0002
TA (mg/L)
60
80
100
120
SI
SII
SIII
Sites

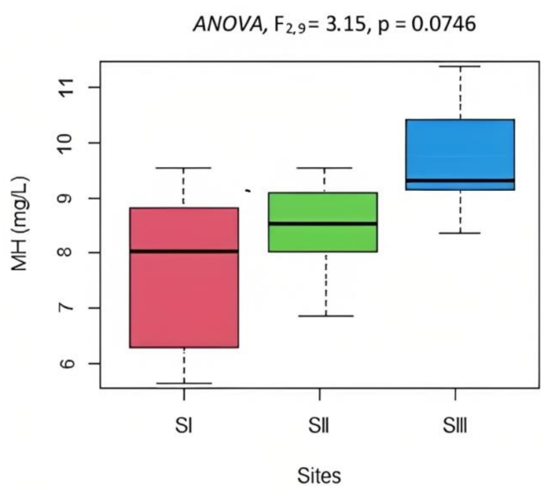

ANOVA, F3,8 = 1.13, p = 0.3915
TH (mg/L)
60
80
100
120
Autumn
Spring
Summer
Winter
Seasons

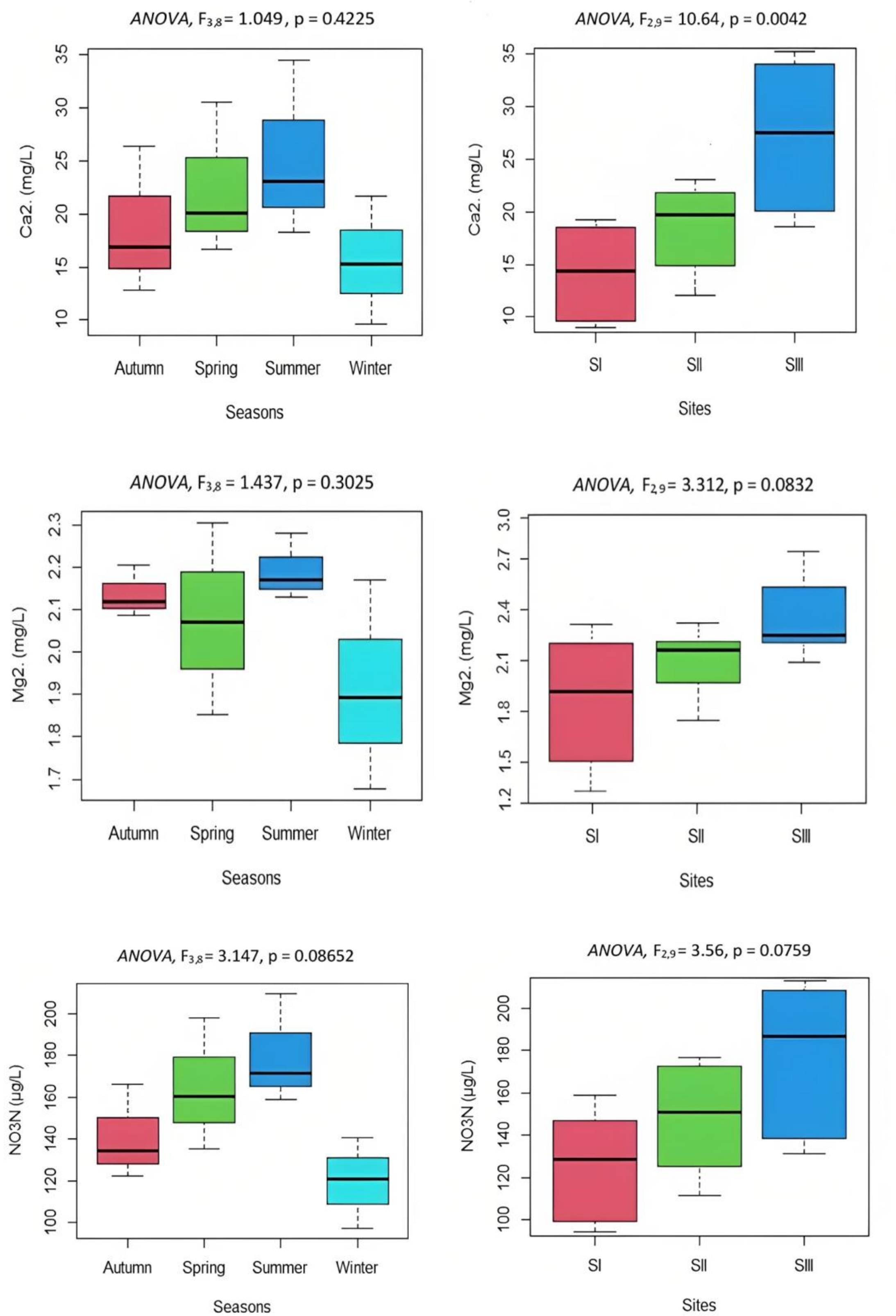

ANOVA, F2,9 = 10.11, p = 0.0042
TH (mg/L)
60
80
100
120
SI
SII
SIII
Sites


ANOVA, F3,8 = 1.049, p = 0.4221
CH (mg/L)
30
40
50
60
70
80
Autumn
Spring
Summer
Winter
Seasons


ANOVA, F2,9 = 10.64, p = 0.0042
CH (mg/L)
30
40
50
60
70
80
SI
SII
SIII
Sites


ANOVA, F3,8 = 1.527, p = 0.2705
MH (mg/L)
7.0
7.5
8.0
8.5
9.0
9.5
Autumn
Spring
Summer
Winter
Seasons


ANOVA, F2,9 = 3.15, p = 0.0746
MH (mg/L)
6
7
8
9
10
11
SI
SII
SIII
Sites


ANOVA, $F_{3,8}$ = 1.049, p = 0.4225
Ca2. (mg/L)
10 15 20 25 30 35
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$ = 10.64, p = 0.0042
Ca2. (mg/L)
10 15 20 25 30 35
SI SII SIII
Sites
ANOVA, $F_{3,8}$ = 1.437, p = 0.3025
Mg2. (mg/L)
1.7 1.8 1.9 2.0 2.1 2.2 2.3
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$ = 3.312, p = 0.0832
Mg2. (mg/L)
1.2 1.5 1.8 2.1 2.4 2.7 3.0
SI SII SIII
Sites
ANOVA, $F_{3,8}$ = 3.147, p = 0.08652
NO3N (µg/L)
100 120 140 160 180 200
Autumn Spring Summer Winter
Seasons
ANOVA, $F_{2,9}$ = 3.56, p = 0.0759
NO3N (µg/L)
100 120 140 160 180 200
SI SII SIII
Sites

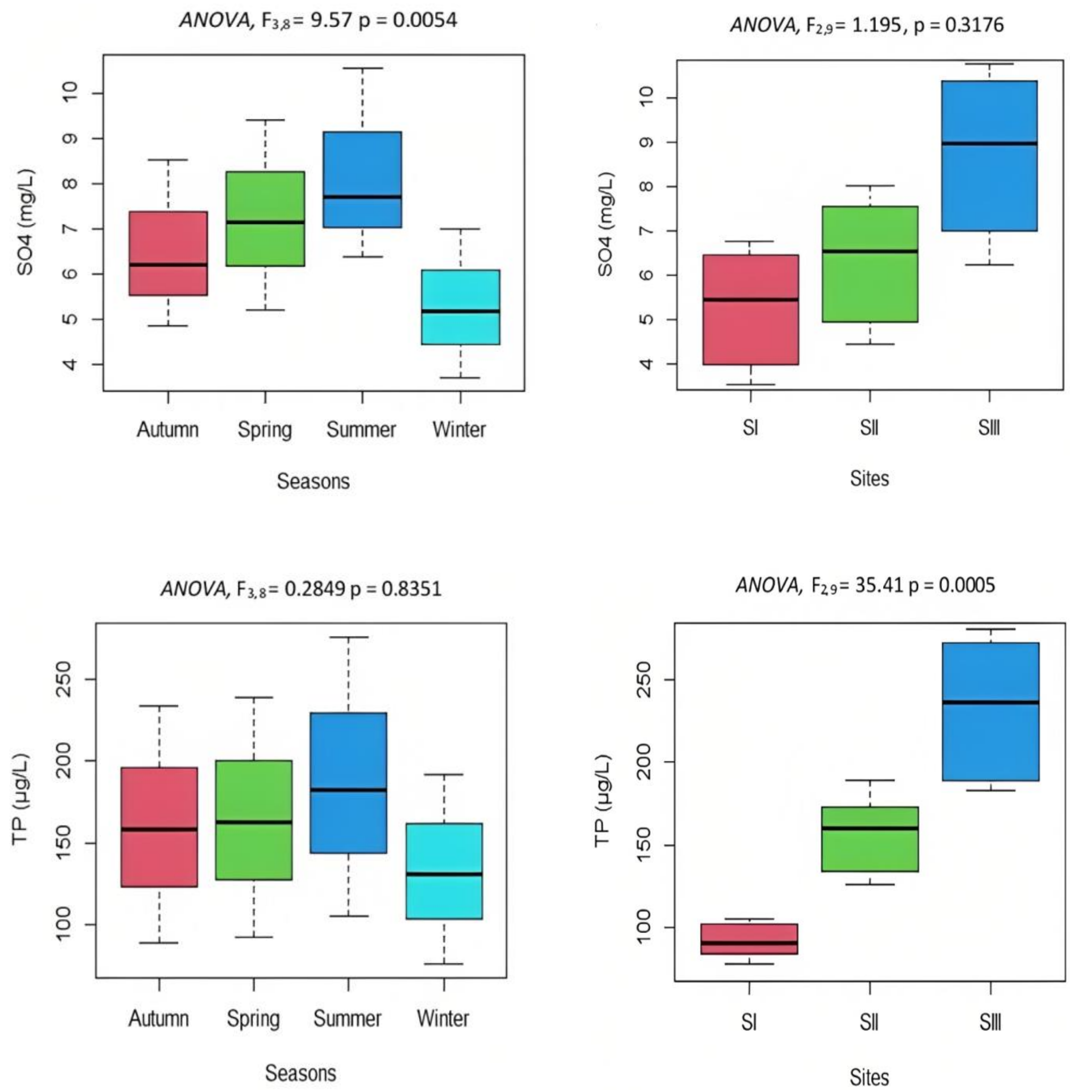


Figure 7: Parametric ANOVA test and Tukey's HSD pairwise-comparisons between sites and seasons based on physico-chemical characteristics from 3 sites of Vaishav stream.

6.2 Correlation analysis:

This study demonstrates the complex interconnections among the physico-chemical parameters observed (as shown in Table 5). Pearson's test revealed a significant positive correlation between pH and total hardness ($r = 0.833$, $p < 0.05$), water temperature (WT) and NO_3-N ($r = 0.835$, $p < 0.05$), WT and TDS ($r = 0.490$, $p < 0.05$), and WT and electrical conductivity (EC) ($r = 0.490$, $p < 0.05$). Electrical conductivity also showed a significant positive correlation with TDS ($r = 1.00$, $p < 0.05$), total hardness ($r = 0.897$, $p < 0.05$), and sulfate ($r = 0.917$, $p < 0.05$), while nitrate positively correlated with sulfate ($r = 0.947$, $p < 0.05$). Positive correlations are often observed when two parameters are influenced by similar external factors. For instance, the positive correlation of water temperature with conductivity, TDS, total alkalinity, total hardness, and nutrients arises due to the dissolution of minerals from streambeds and sediments, increasing the concentration of dissolved ions (such as Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^{2-}, SO_4^{2-}, PO_4^{3-}) in the aquatic environment. Additionally, higher temperatures accelerate decomposition by microbial activity, releasing nutrients like nitrogen and phosphorus into the water, while surface runoff during warmer months further increases nutrient levels (Hamid *et al*., 2020). The positive correlation between conductivity, nitrate, and sulfate likely results from agricultural runoff, which introduces salts and nutrients into the stream (Islam *et al*., 2024). Conversely, the negative correlation between water temperature and dissolved oxygen reflects the physical property of water, as warmer water retains less dissolved oxygen than cooler water (Kumar *et al.*, 2022*)*. Similarly for CO_2 and pH is due to respiration by aquatic organisms releases more carbon dioxide which makes water more acidic (Mahmood *et al.,* 2017). The DO_2 shows negative correlation with water temperature (r=-0.396, p<0.05), total alkalinity (r=-0.843, p<0.05) and sulphate (r=-0.902, p<0.05) respectively. The various water parameters interplay led to postive negative correlation reflects a complex dynamics within aquatic enviroment (Ahmad *et al.,* 2024). It is important to aknowledge that correlation exhibit a certain level of variablity depending upon local circumstances,specfic geographical area human factor and temporal fluactutions are also applicable to the current study. It is imperative to mention that in relation to this study comparable results have been documented previously by (Arafat *et al.*, 2022; Mir *et al.*, 2023). The postive negative relations among the studied physicochemical parameters also indicate dynamic spatial and temporal variations in water quality parameters due to natural as well as anthropogenic activities (Ahmad *et al.*, 2024).

Table 5: Correlation between different Physico-chemical Parameters

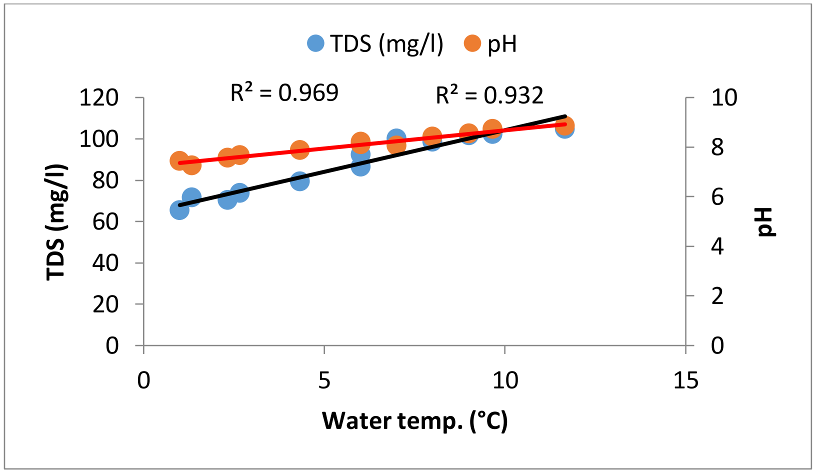
	WT	Turb.	EC	TDS	pH	DO	FC	TA	TH	CH	MH	Ca^{2+}	Mg^{2+}	NO_3-N	SO_4^{2-}
WT	1														
Turb.	0.297	1													
EC	.490*	.928**	1												
TDS	.490*	.928**	1.000**	1											
pH	.520*	.769**	.844**	.844**	1										
DO	-0.369	-.903**	-.894**	-.894**	-.695**	1									
FC	.927**	0.44	.639**	.639**	.659**	-.479*	1								
TA	0.304	.919**	.853**	.853**	.681**	-.843**	0.368	1							
TH	.575*	.868**	.897**	.897**	.833**	-.746**	.672**	.867**	1						
CH	.646**	.831**	.850**	.850**	.787**	-.766**	.684**	.867**	.961**	1					
MH	0.264	.662**	.647**	.647**	.622**	-0.434	0.392	.594**	.734**	.601**	1				
Ca^{2+}	.638**	.838**	.852**	.852**	.787**	-.771**	.676**	.873**	.961**	1.000**	.603**	1			
Mg^{2+}	0.264	.663**	.647**	.647**	.621**	-0.434	0.391	.596**	.735**	.601**	1.000**	.604**	1		
NO_3-N	.835**	.731**	.826**	.826**	.731**	-.761**	.848**	.700**	.842**	.886**	.482*	.885**	.483*	1	
SO_4^{2-}	.693**	.859**	.917**	.917**	.777**	-.902**	.750**	.807**	.839**	.877**	.504*	.879**	.504*	.947**	1

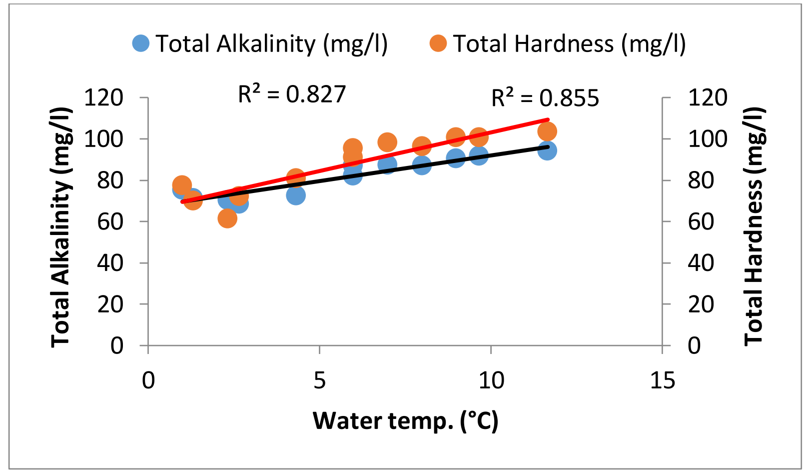
*Correlation is significant at **0.05** level

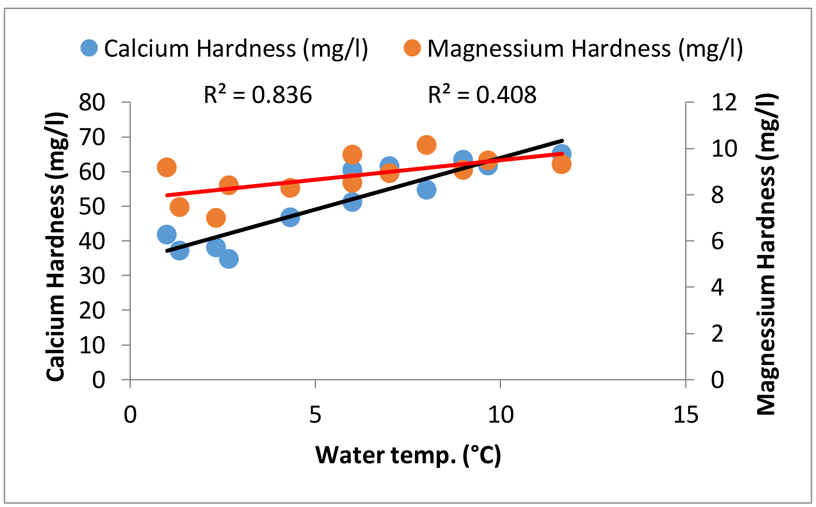
WT: Water temperature,**Turb:**Turbidity**, EC:**Electricalconductivity**, DO:**Dissolvedoxygen**, FC:**Freecarbondioxide**, TA:**Totalalkalinity**,** **TH:**Total hardness, **CH:** Calcium hardness **.MH**: Magesium hardness

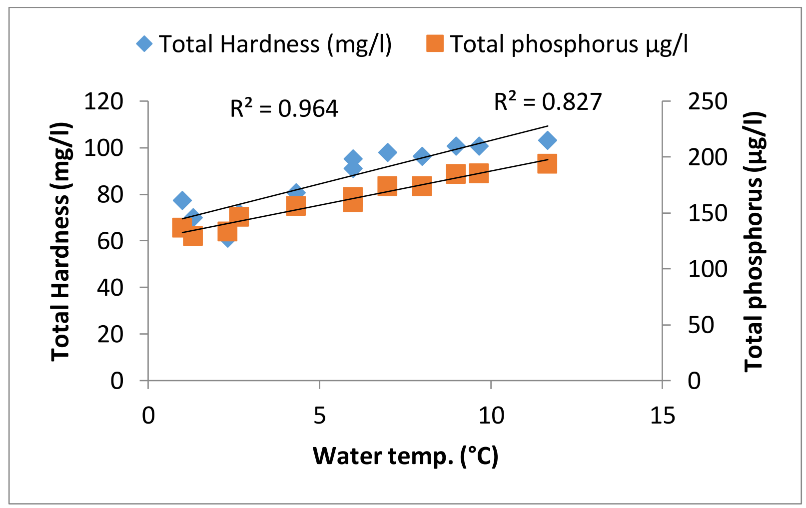
6.3 Linear Regression analysis

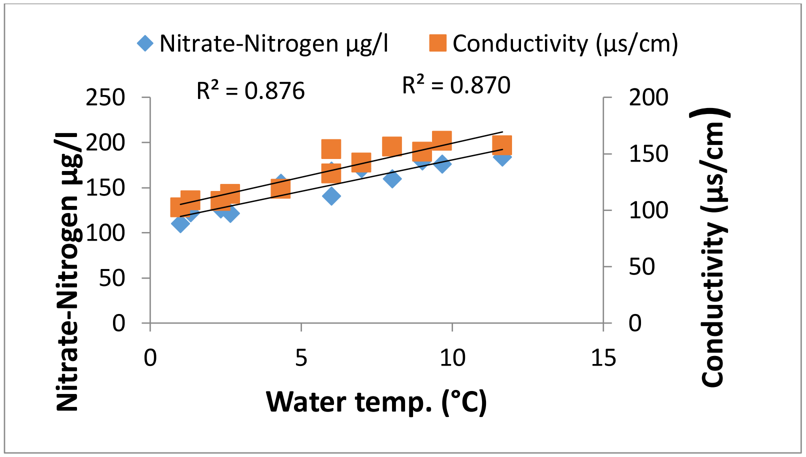
The interconnectedness of various physic chemical parameters play an important role in in forwarding information which can be more efficiently examined by linera regression analysis (Ahmad *et al.*, 2024). The regression cofficent (r^2) represents the amount of variation elucidated by independent parameter thereby indicating a significant proportion of changes taking place in dependent variable. All the relationships in the present study were found significant ($p < 0.05$). The findings of the regression analysis for various Vaishav stream water quality metrics are shown in Figure 5. According to the study on water quality measures, WT and pH, TH, TDS, EC, TP, NO_3-N, and free CO_2 had strong positive associations (Figure 8). These results are consistent with other studies conducted in the Kashmir Himalayas by (Arafat *et al*., 2022), who achieved comparable results from the Sukhnag and Vaishav streams. Temperature was found to affect the chemistry of water, particularly conductivity and hardness (Ramachandra & Solanki, 2007). The temporal link between conductivity and water temperature is often very strong. Additionally, it was discovered that conductivity and water temperature were significantly correlated with total dissolved solids (Allan, 2004). Higher phosphorus concentrations promote greater cellular metabolism, which reduces dissolved oxygen as a result (Hickman and Gray, 2010). As calcium and magnesium levels rise, so does the total hardness of the water (Boyd *et al*., 1998). Due to their shared origin and the dissolution of limestone, total alkalinity and hardness also exhibit a strong correlation. The study found that conductivity strongly correlated with total dissolved solids, total hardness, total phosphorus, and nitrate. This shows that these dissolved chemicals, which have common sources including home sewage and agricultural runoff, are responsible for the increase in stream water conductivity (Hamid *et al*., 2020). Water's ability to transmit electrical current is directly influenced by electrical conductivity, which depends on the quantity of ions dissolved in the liquid. According to a generic linear regression model, water temperature, dissolved oxygen, electrical conductivity, total dissolved solids, nitrate, and total phosphorus were found to fluctuate and predict overall water quality. Additionally, a substantial inverse relationship between dissolved oxygen (DO), water temperature (WT), total phosphate (TP), total hardness (TH), and nitrate nitrogen (NO_3-N) was found in the study. The increase in water temperatureincreases also promotes the decomposition of organic matter in the form of plant and animal residue leading to substantial release of nutrients like nitrogen, phosphrous into the aquatic medium and enhances its concentration and lowers dissolved oxygen through its utilization (Arafat *et al.*, 2022; Mir *et al.*, 2023) may be the cause of this negative association. Water temperature and dissolved oxygen have an inverse connection in the natural world because colder water can contain more of it (Lone *et al.*, 2021).


TDS (mg/l) pH
R² = 0.969
R² = 0.932
TDS (mg/l)
pH
Water temp. (°C)

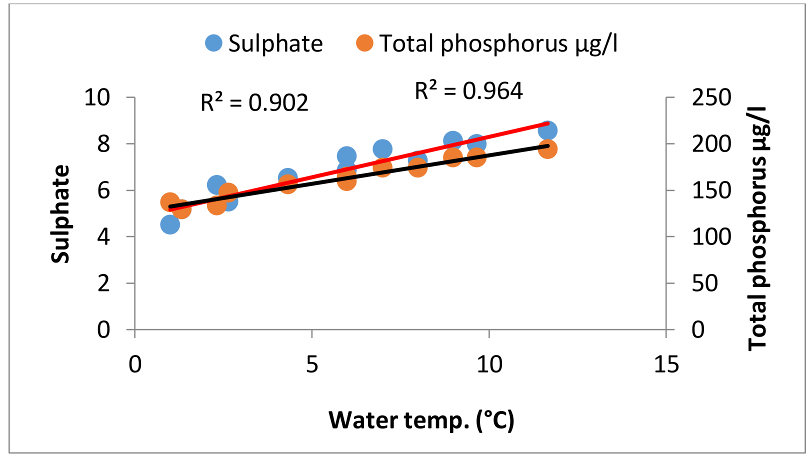

Total Alkalinity (mg/l) Total Hardness (mg/l)
R² = 0.827
R² = 0.855
Total Alkalinity (mg/l)
Total Hardness (mg/l)
Water temp. (°C)


Calcium Hardness (mg/l) Magnessium Hardness (mg/l)
R² = 0.836
R² = 0.408
Calcium Hardness (mg/l)
Magnessium Hardness (mg/l)
Water temp. (°C)

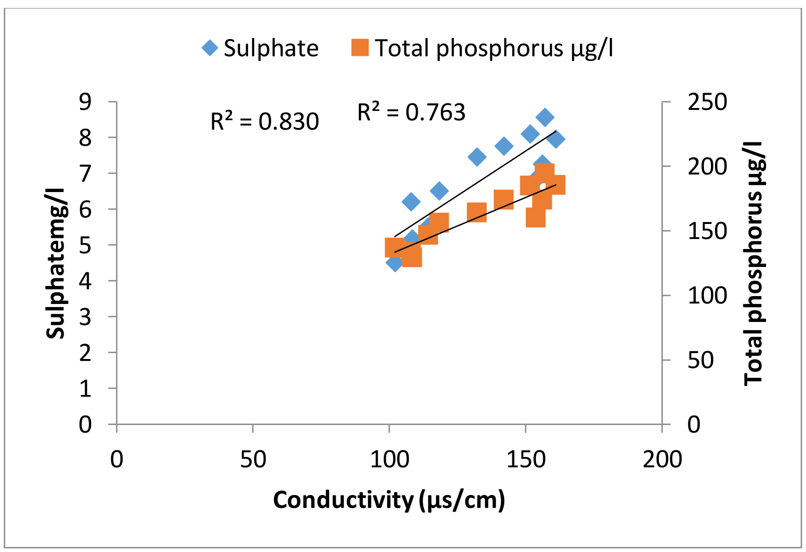

Total Hardness (mg/l) Total phosphorus µg/l
R² = 0.964
R² = 0.827
Total Hardness (mg/l)
Total phosphorus (µg/l)
Water temp. (°C)



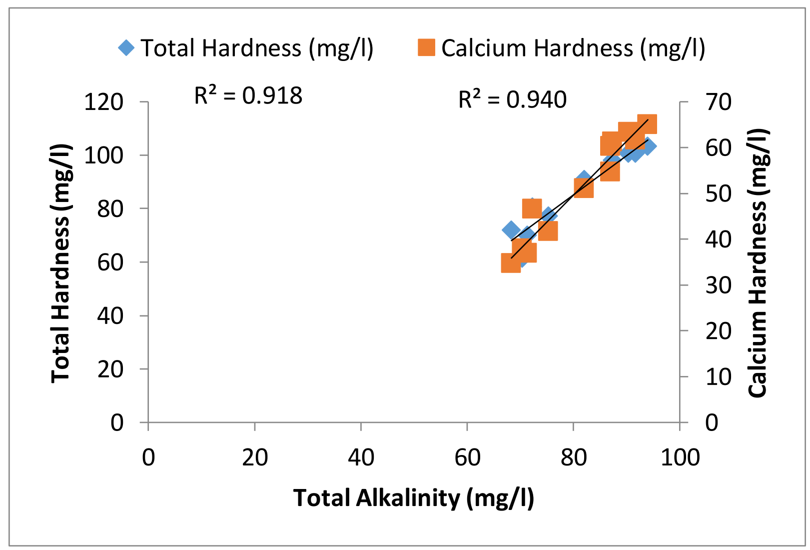
Nitrate-Nitrogen µg/l
Conductivity (µs/cm)
R² = 0.876
R² = 0.870
Nitrate-Nitrogen µg/l
Conductivity (µs/cm)
Water temp. (°C)



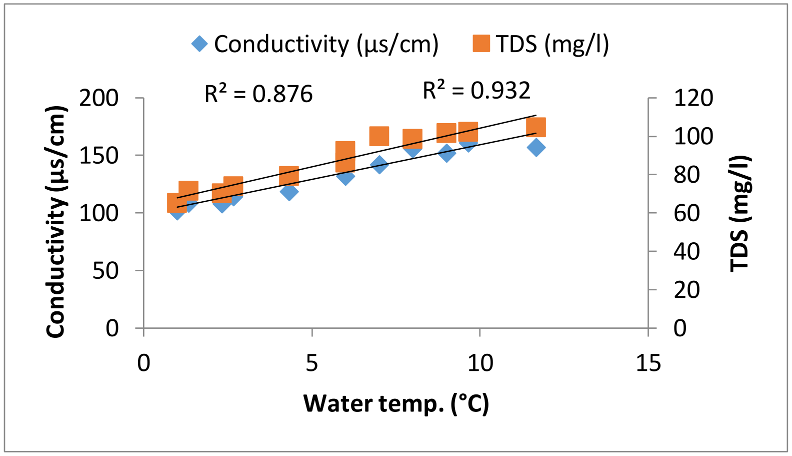
Sulphate
Total phosphorus µg/l
R² = 0.902
R² = 0.964
Sulphate
Total phosphorus µg/l
Water temp. (°C)



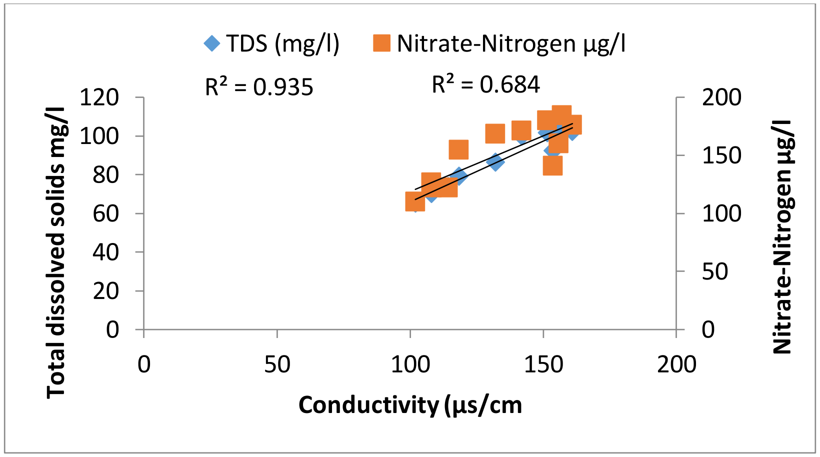
Sulphate
Total phosphorus µg/l
R² = 0.830
R² = 0.763
Sulphatemg/l
Total phosphorus µg/l
Conductivity (µs/cm)



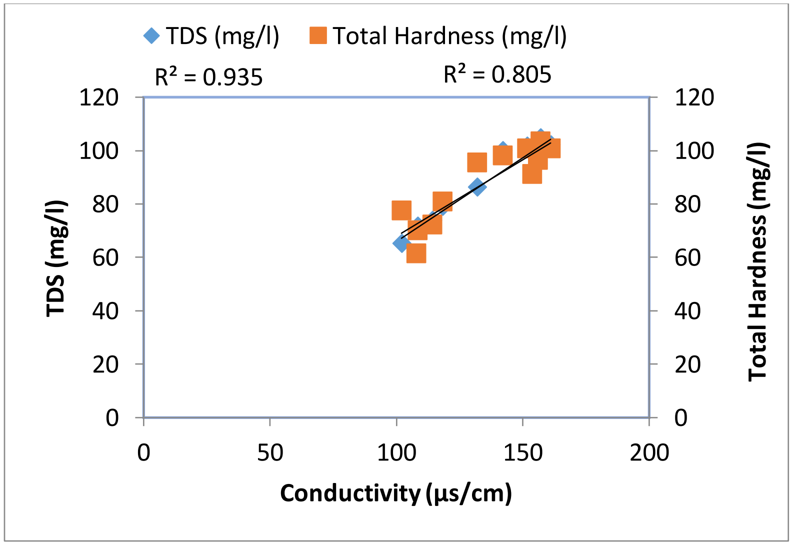
Total Hardness (mg/l)
Calcium Hardness (mg/l)
R² = 0.918
R² = 0.940
Total Hardness (mg/l)
Calcium Hardness (mg/l)
Total Alkalinity (mg/l)



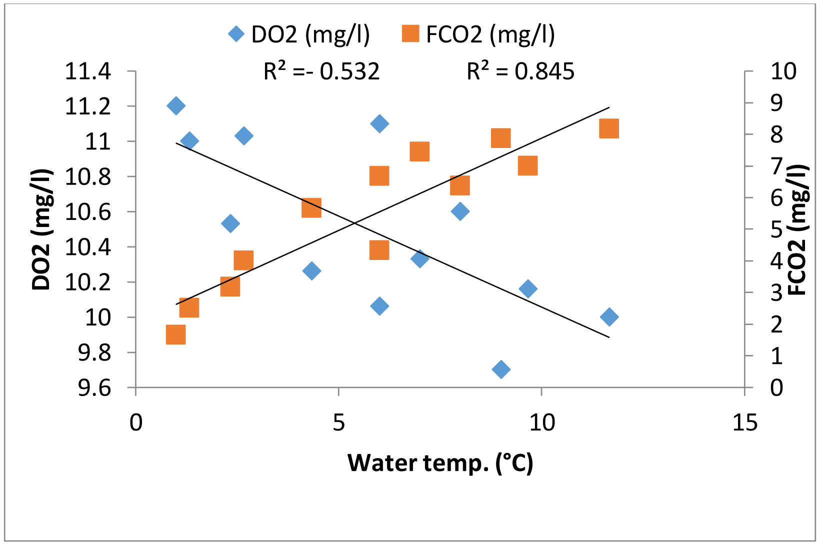
Conductivity (µs/cm)
TDS (mg/l)
R² = 0.876
R² = 0.932
Conductivity (µs/cm)
TDS (mg/l)
Water temp. (°C)



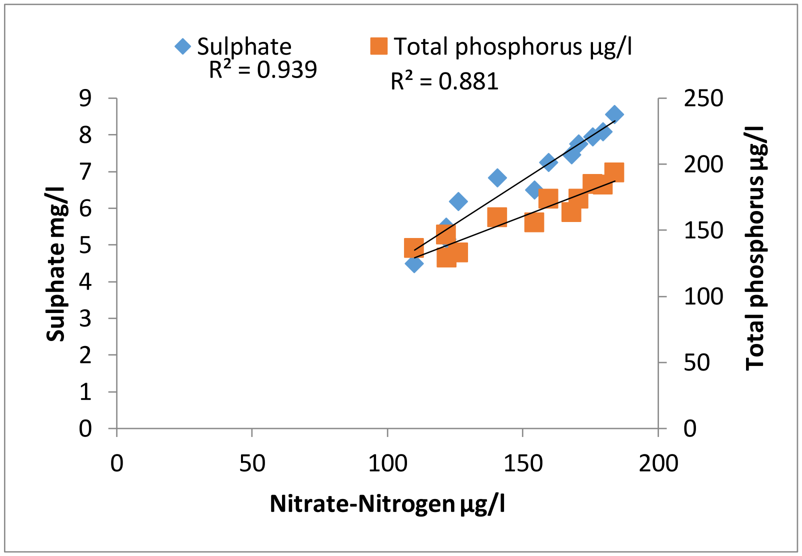
TDS (mg/l)
Nitrate-Nitrogen µg/l
R² = 0.935
R² = 0.684
Total dissolved solids mg/l
Nitrate-Nitrogen µg/l
Conductivity (µs/cm

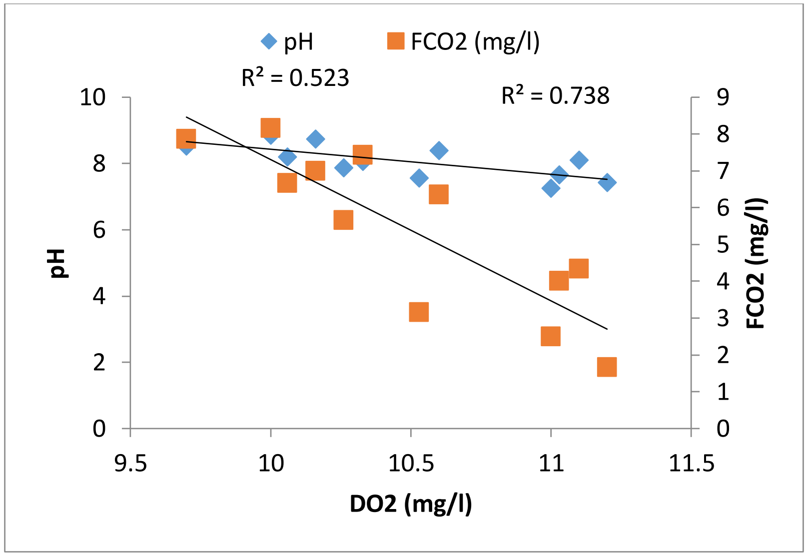


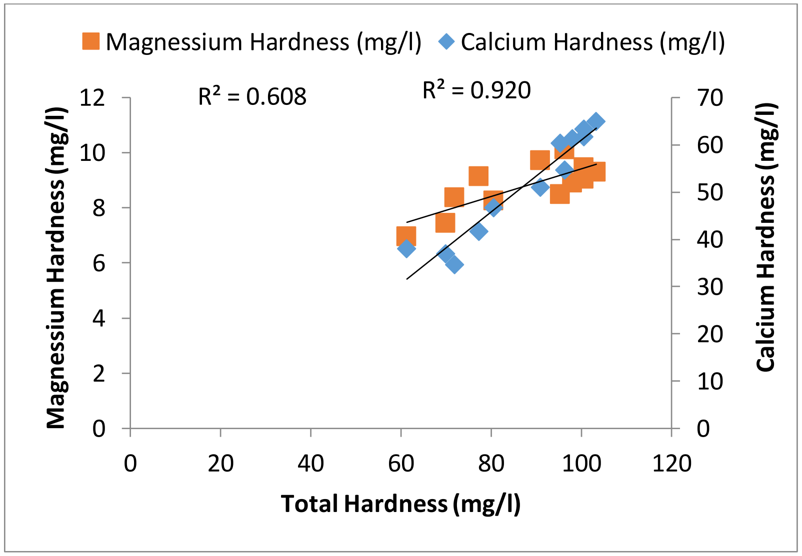
TDS (mg/l)
Total Hardness (mg/l)
R² = 0.935
R² = 0.805
TDS (mg/l)
Total Hardness (mg/l)
Conductivity (µs/cm)

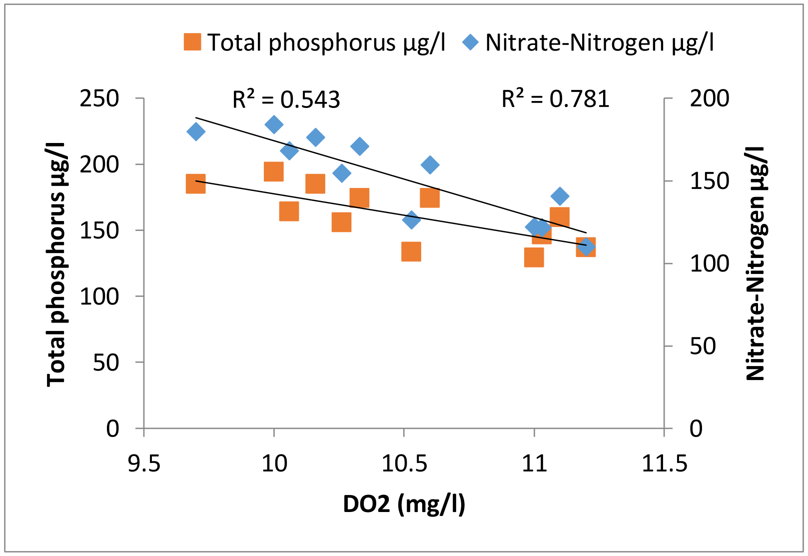


DO2 (mg/l)
FCO2 (mg/l)
R² =- 0.532
R² = 0.845
DO2 (mg/l)
FCO2 (mg/l)
Water temp. (°C)


Sulphate
R^2 = 0.939
Total phosphorus µg/l
R^2 = 0.881
Sulphate mg/l
Total phosphorus µg/l
Nitrate-Nitrogen µg/l


pH
FCO2 (mg/l)
R^2 = 0.523
R^2 = 0.738
pH
FCO2 (mg/l)
DO2 (mg/l)


Magnessium Hardness (mg/l)
Calcium Hardness (mg/l)
R^2 = 0.608
R^2 = 0.920
Magnessium Hardness (mg/l)
Calcium Hardness (mg/l)
Total Hardness (mg/l)


Total phosphorus µg/l
Nitrate-Nitrogen µg/l
R^2 = 0.543
R^2 = 0.781
Total phosphorus µg/l
Nitrate-Nitrogen µg/l
DO2 (mg/l)

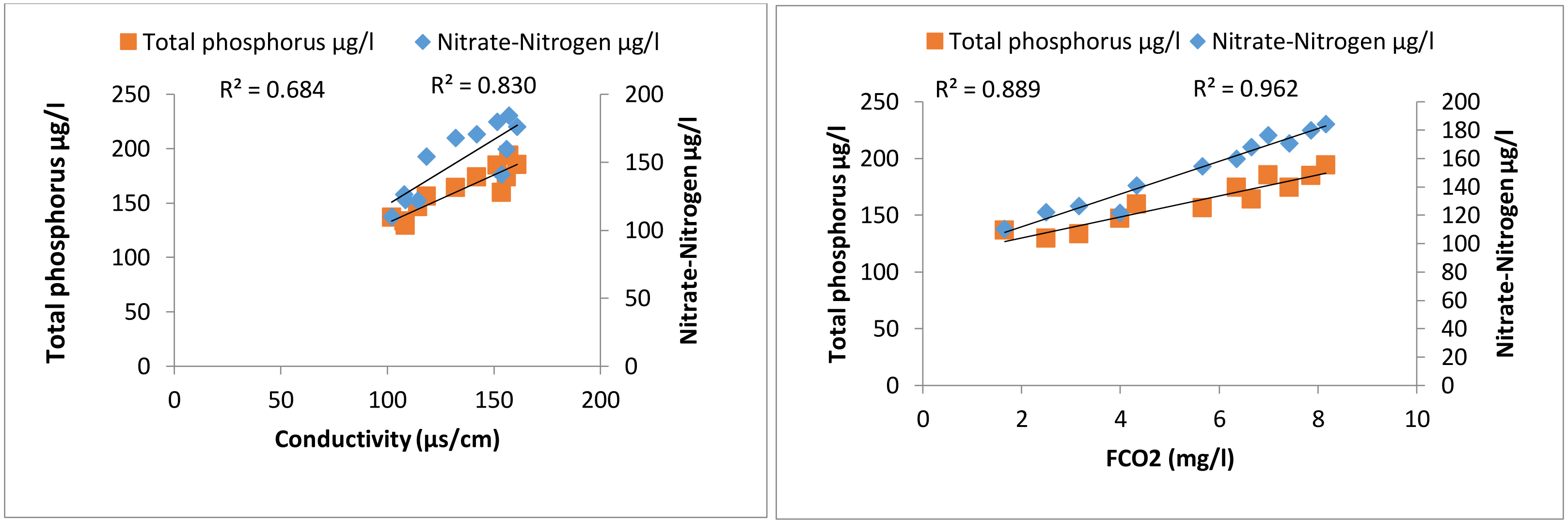


Figure 8: The linear regression model delineates the nature and magnitude of the relationship among the physicochemical parameters of the Vaishav stream

6.4 Hierarchical cluster analysis (HCA)

The Hopkins test was used to evaluate the clustering tendency and viability of constructing meaningful clusters before clustering analysis on water quality information from three different sites along the Vaishav stream (Lawson and Jurs, 1990). For hierarchical agglomerative clustering on 17 water quality indicators, Ward's Method employing Eclidean distances was used (Shrestha and Kazama, 2007). The most important physicochemical factors for site clustering were determined by Wilks' lambda test (Wilks, 1932). Total dissolved solids, turbidity, and total phosphorus were factors that were highlighted during the clustering process. The research divided the sites into two clusters, with Cluster-I (Sites I and II) indicating upstream areas with superior water quality and reduced sensitivity to human activity. The downstream locations in Cluster II (Site III) had relatively lower water quality as a result of habitation, and agricultural, and urban land use (Figure 9). These results support other research on Kashmir's Himalayan streams (Hamid *et al*., 2020; Arafat *et al*., 2022; Mir *et al*., 2023; Ahmad *et al.*, 2023) that indicate how agricultural practices, erosion, and lithological and geological factors affect water quality. Hierarchical cluster analysis is useful for accurately classifying surface waters and can help with the construction of optimized sample methods for assessing the water quality in particular clusters. In conclusion, the study supports the value of cluster analysis in guiding future sampling procedures while lowering costs and hazards. It also highlights its relevance in explaining differences in surface water quality

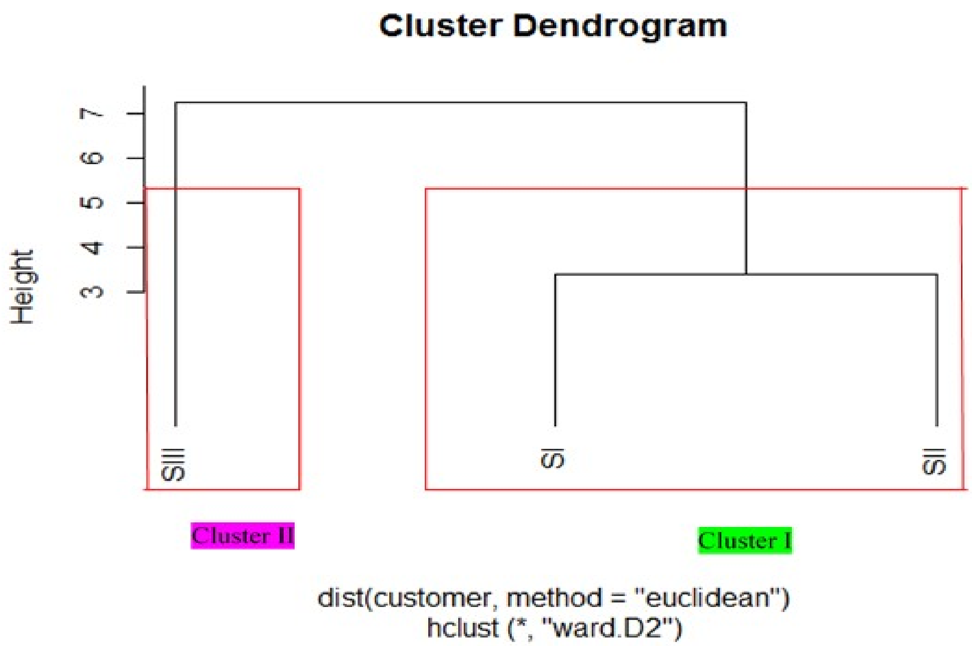
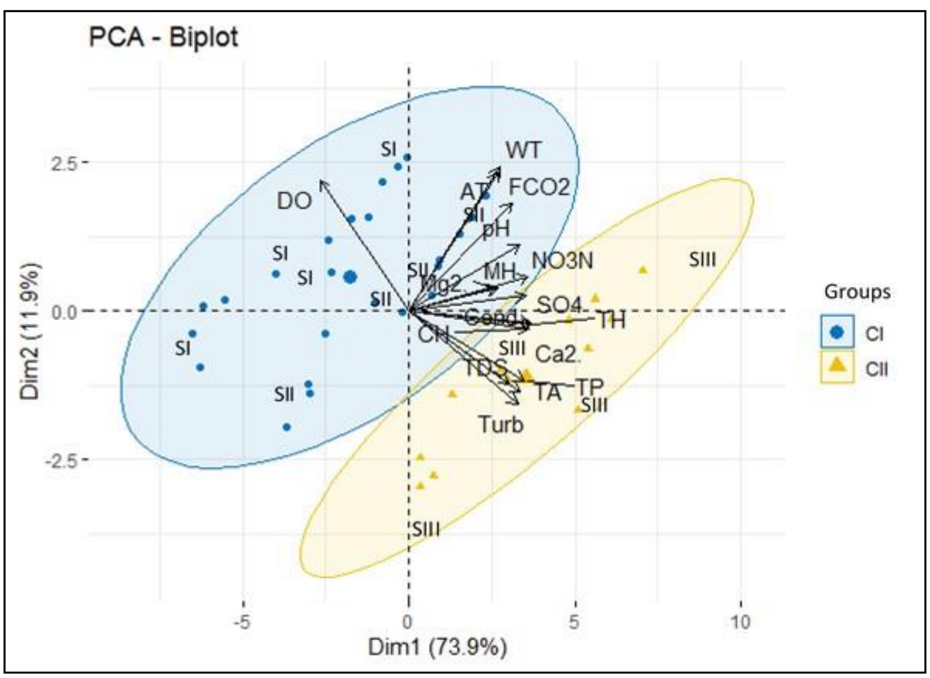


Figure 9: Dendogram highlighting two clusters (1, 2) of all Vaishav stream sites based on physicochemical parameters.

6.5 Principal component analysis (PCA)

PCA was executed on the whole WQ dataset to recognize the main factors responsible for causing significant variation in the water quality of the Vishav stream (Mir *et al.,* 2023). Two principal components (PC1 and PC2) accounted 85.78% of the total variation, according to the research. The parameters air temperature, water temperature, turbidity, conductivity, pH, total dissolved solids, total alkalinity, calcium hardness, total hardness, calcium, magnesium, free CO_2, sulphate, nitrate nitrogen, and total phosphorus all showed strong positive loadings in PC1 (explaining 73.9% of the variance). It showed a significant negative loading for dissolved oxygen, though. According to this, dissolved oxygen levels are negatively impacted by environmental factors like urbanization, influx of household waste, and agriculture runoff as well as, climate factors like flashfoods, heavy rainfall,erosion and inorganic nutrients leads to surface runoff. Postive loading of water temperature and negative loading of dissolved oxygen can be explained by the fact that as the temperature increases organic matter rapidly decomposes by consuming more and more dissolved oxygen (Islam *et al.*, 2023; Mir *et al.*, 2023). The substantial positive loadings for air temperature, water temperature, free CO_2 and dissolved oxygen were seen in PC1 (explaining 11.9% of the variation), while the significant negative loadings for turbidity, total dissolved solids, total alkalinity, and total phosphorus were seen. By showing increases in turbidity, conductivity, and TDS as a result of home sewage, agricultural runoff, and geological characteristics, this demonstrates the influence of watersheds and climate conditions on water quality. The results also showed that dissolved oxygen concentrations and water temperature are inversely correlated, with warm water having lower concentrations of dissolved oxygen than cold water (Lone *et al.*, 2021). The PCA analysis overall indicated the major determinants of water quality in the Vaishav stream, including human activities, inorganic nutrients, climatic variables, and geological characteristics (Arafat *et al.*, 2022; Ahmad *et al.*, 2024) (Figure 10). These fidings highlights the significance of these charactristics in assessing and understanding the over all water quality of Vishav stream, Nevertheless,the physico chemical parameters associateed with PC2 exhabited less importance than those associated with PC1.



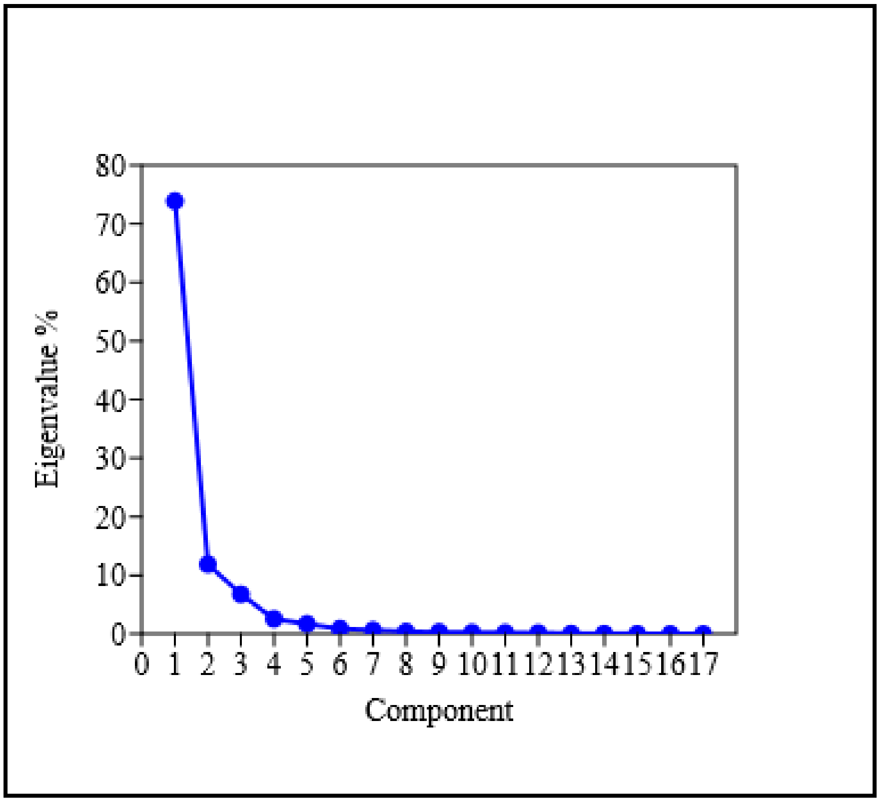


Figure 10: Principle component analysis to recognize the main factors responsible for causing significant variation in the water quality and Scree plot of eigen values versus principal component of physicochemical parameters of Vaishav stream.

6.6 Water Quality Index (WQI)

This method is a systematic approach that involves comparing water's physicochemical parameters against regulatory standards. Water Quality Index (WQI) is determined by assigning weights to these parameters based on their significance for human consumption purposes. It serves as a robust tool for evaluating and determining water quality, offering insights into its suitability for various uses, including drinking (Cude, 2001; Atulegwu and Njoku, 2004). This technique facilitates comparisons of water quality parameters against BIS/WHO standards (Khan *et al*., 2003). Nitrate-nitrogen and turbidity are given the highest weights of 5 and 4, respectively, due to their significant impact on human health, while magnesium is assigned a lower weight of 2, reflecting its lesser harm to humans (Khanday *et al*., 2018) (Table 6). The WQI was calculated using eleven parameters aligned with BIS/WHO criteria. WQI values ranged from a minimum of 41.50 at Site I to a maximum of 177.70 at Site III. Based on these calculations, Site I and Site II fall under Category I, indicating water suitable for drinking, while Site III falls under Category II, indicating water unsuitable for drinking (Table 7). The quality of water in Kashmir streams varies significantly due to various factors, ranging from pristine conditions in higher elevation streams to degradation influenced by urbanization and land use changes in lowland areas (Rather *et al*., 2016).

The higher WQI value observed at Site III may be attributed to runoff from extensive agricultural fields, open garbage dumping, sewage influx along the riparian areas directly affecting the stream, and severe anthropogenic pressures (Khanday *et al.,* 2021). Conversely, the lower WQI value at Site I could be attributed to its proximity to glacial sources, forest cover, meadows in the surrounding areas, and reduced anthropogenic impact (Kanth and Hassan, 2012; Yaseen *et al*., 2015; Islam *et al*., 2023). The water quality of Vaishav stream falls within the excellent of class I & II category, thus makes it appropriate utilization for drinking and irrigation purposes (Hamid *et al*., 2013). Our results coincides with the results of Aripal Stream in Tral Kashmir Valley, India (Shah *et al*., 2020), Dagwan stream, an important tributary of Dal Lake, Kashmir Himalaya (Sabha *et al*., 2019), Rambiarrah watershed of Kashmir Himalayas (Mir *et al*., 2019, Islam *et al.*, 2023) and upper Jhelum basin of the Kashmir Himalaya (Ganaie *et al.*, 2022).

Table 6: Relative weight of water quality parameters.

Physico-chemical Parameters	**BIS/WHO Standards (2012)**	**Weight (w_i)**	**Relative weight (RW_i)**
pH	6.5–8.5	4	0.1000
Turbidity (N.T.U)	1	5	0.1250
TDS (mg/L)	500 mg/L	4	0.1000
Total Alkalinity (as $CaCO_3$mg/L)	200 mg/L	3	0.0750
Total Hardness (as $CaCO_3$ mg/L)	200 mg/L	3	0.0750
Calcium Hardness (as $CaCO_3$mg/L)	200 mg/L	2	0.0500
Magnesium Hardness (as $CaCO_3$ mg/L)	200 mg/L	2	0.0500
Calcium as Ca^{2+}mg/L	75 mg/L	3	0.0750
Magnesium as Mg^{2+} mg/L	30 mg/L	4	0.1000
Sulphate (as SO_4^{2-} mg/L)	200 mg/L	4	0.1250
Nitrate (as NO_3^- µg/L)	45 mg/L	5	0.1250
		$\sum Wi = 41$	$\sum Wi = 1$

Table 7: Presenting the water quality classification of various sites based on the Water Quality Index (WQI)

WQI	**Water Quality**	**Class**	**Suitability**	**Site-I**	**Site-II**	**Site-III**
<50	Excellent	Class1	Absolutely clean	**41.50**	-	-
50-100	Good	Class1	Slightly unclean	-	84.70	-
100-200	Poor	Class2	Moderately unclean	-	-	**177 .70**
200-300	Very poor	Class2	Extremely unclean	-	-	-
>300	Unsuitable	Class3	Severely unclean	-	-	-

Objective 2: To study the current status of fish fauna, by analyzing the species richness, abundance and distribution of Vaishav stream.

6.7 Taxonomy of the fishes of Vaishav stream

6.6.1 Schizothorax plagiostomus

The body of the fish is moderately elongated, spindle-shaped, and laterally compressed towards the rear beyond the pelvic fins. The head is triangular, tapering, and rounded internally, with a flattened ventral surface and a short snout. The ventral surface of the head and the anterior part of the body are somewhat flattened, short, cone-shaped, and blunt. The mouth is wide, inferior, and slightly arched, with fleshy and continuous lips that are sharply attenuated at the margin. The lower lip is edged with firm, hard horny cartilage, and there is a strip of papillae on the labial plate under the chin. Behind the lower lip, there is a pad of papillae that acts as a sucker, while the upper lip is smooth and less fleshy. The space between the eyes (interorbital space) is broad and flat. The fish has two pairs of short barbells, maxillary and mandibular, with the maxillary pair being smaller. The nostrils are separated by a transverse flap. The eyes are large and located nearly midway on the head, slightly dorsolaterally. The dorsal profile of *Schizothorax plagiostomus* is convex, gradually rising from the tip of the snout to the origin of the dorsal fin, and then slopes almost horizontally to the base of the caudal fin. The ventral profile is also slightly convex anteriorly, extending to the beginning of the pelvic fin. The body trunk is thick and muscular, covered with variously shaped small scales. The body coloration is grey, darker on the dorsal side and lighter on the ventral side, with the belly being yellowish-white. The fins are well-developed; the single dorsal fin has a strong serrated spine, with the remaining fin rays bifurcated. The caudal fin is homocercal, and the anal fin lacks a spine. The pectoral fins are large, more or less triangular with a narrow base. Pharyngeal teeth are arranged in three rows. The snout is usually smooth, covered with warys in males. The dorsal fin is positioned opposite to the pelvic fins. The caudal fin is deeply emarginated (Heckel, 1838) (Figure 11).

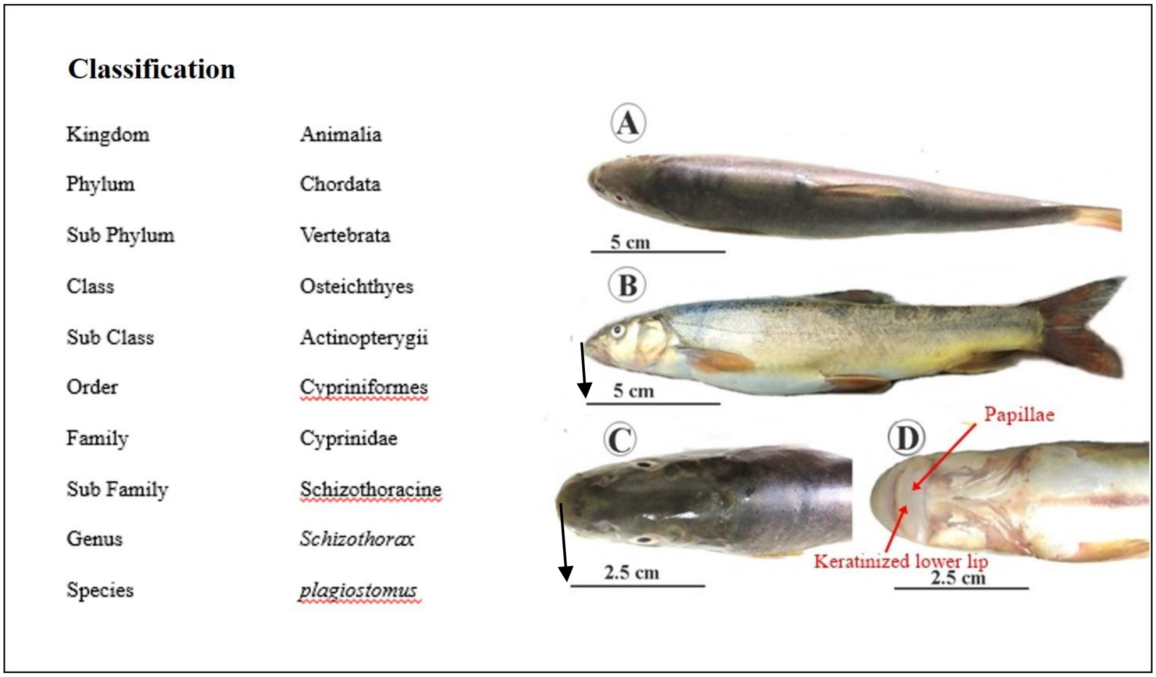


Figure 11:*Schizothorax plagiostomus:* A) Habitus, in dorsal view; B) Habitus, in lateral view;C) Head, in frontal view; D) Head, in ventral view.

6.6.2 Schizothorax curvifrons

The body shape is elongated and fusiform, characterized by a short and blunt upper jaw that protrudes slightly. The mouth is crescent-shaped and positioned inferiorly, similar to that of *S. labiatus*. The lower lip has a sharp edge, is non-keratinized, and not expanded. The upper lip is smooth, thin, less fleshy, and does not extend into wide folds. The body is laterally compressed with minimal variation in body depth along its girth. Along the base of the anal fin, there is a series of elongated scales. Pharyngeal teeth are arranged in three rows, with the first tooth in the main row being smaller, conical, and recurved, while the second teeth are larger, somewhat swollen at the apex, with a truncate tip (Heckel,1838) (Figure 12).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Schizothorax*
Species	*curvifrons*

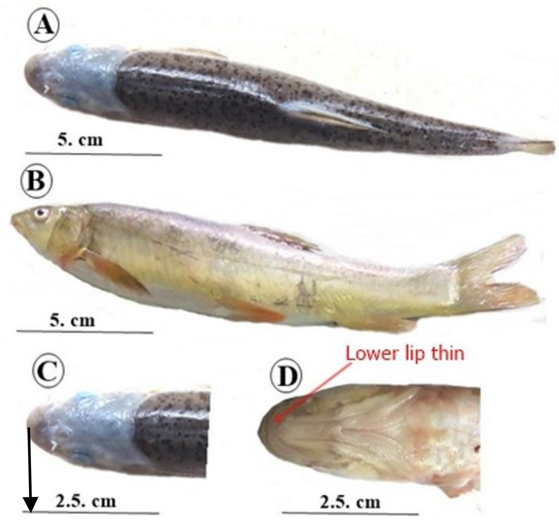


Figure 12: *Schizothorax curvifrons*:A) Habitus, in dorsal view; B) Habitus, in lateral view;C) Head, in frontal view; D) Head, in ventral view

6.6.3 Schizothorax labiatus

S. labiatus is characterized by its elongated, fusiform body shape with a prognathous upper jaw. The lower jaw features wide lip folds typically separated by a distinct raised pad. The lower jaw itself is rounded, with a narrow-keratinized margin, and the lips extend into wide lateral flaps with a moderately expanded, fleshy lower lip. Unlike other *Schizothorax* species, *S. labiatus* exhibits a more pronounced body depth. Pharyngeal teeth are arranged in three rows, with the first tooth in the main row being smaller, conical, and recurved, while the second tooth is the largest, somewhat swollen at the apex, and recurved at the tip. The mouth is positioned sub-inferiorly. Along the base of the anal fin, there is a series of enlarged scales. The dorsal fin has 7 (13) branched rays, while the pectoral fins have 17, the ventral fins have 10, and the anal fin has 7 (25) branched rays (McClelland and Griffth, 1842; Kullander *et al.*, 1999) (Figure 13).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Schizothorax*
Species	*labiatus*

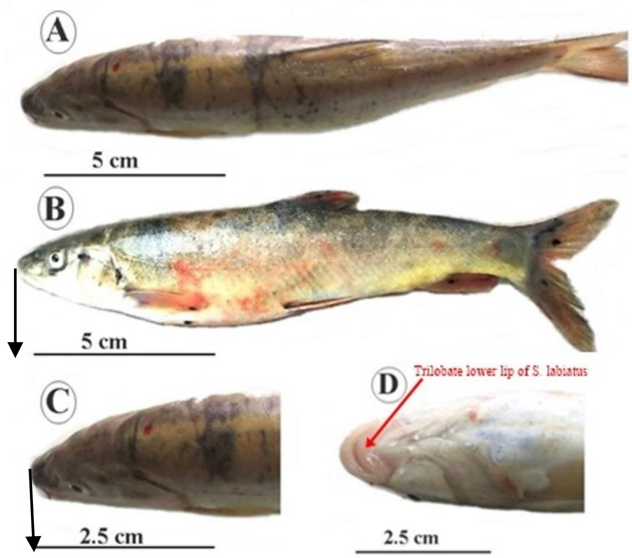


Figure 13:*Schizothorax labiatus,* A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view.

6.6.4 Schizothorax esocinus

Schizothoraxesocinus can be distinguished from other members of the genus by its elongated jaws, lacking enlarged lips or tuberculate pads. The fish has a silvery appearance with numerous small, irregular dark spots on the back and flanks of its body. The fins are silvery-grey with similar dark spots, more concentrated at their bases. The color pattern typically features a light base color contrasted with prominent black spots on most individuals. Its body is streamlined, with a tapered head and a long snout longer than that of other Schizothorax species. The mouth is terminal, wide, and horseshoe-shaped, with a deep cleft. The upper lip is less fleshy compared to the lower lip, which forms less prominent folds interrupted in the middle. The fish possesses two pairs of barbells, with the rostral pair approximately 1.5 times longer than the diameter of the eye and the maxillary pair slightly shorter. The dorsal fin is positioned slightly closer to the base of the caudal fin. The scales on *S.esocinus* are very small. The fin ray arrangement includes 9 dorsal (D), 17 pectoral (P), 10 ventral (V), 7 anal (A), and 29 caudal (C) rays (Heckel, 1838; Kullander *et al.*, 1999) (Figure 14).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Schizothorax*
Species	*esocinus*

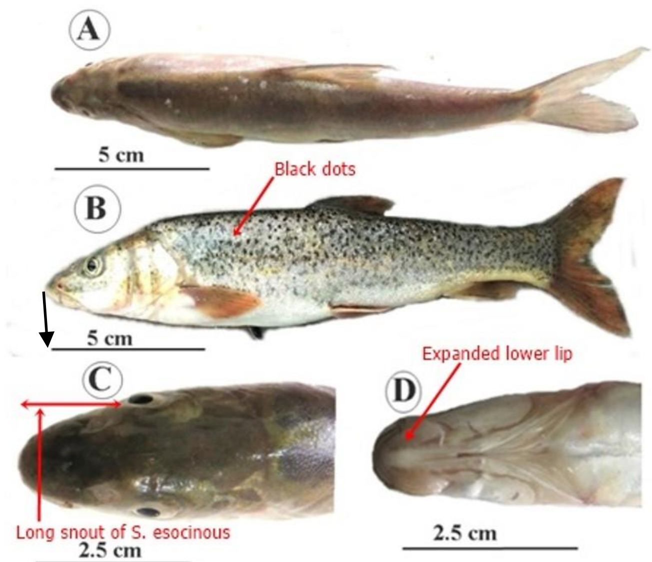


Figure 14: *Schizothorax esocinus*, A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view.

6.6.5 Schizothorax niger

The fish has an elongated spindle-shaped body, slightly compressed in the middle. Its dorsal profile is convex, gradually rising from the snout to the origin of the dorsal fin, and then gradually declining towards the base of the caudal fin. Pharyngeal teeth are arranged in three rows, with the first tooth in the main row smaller, conical, and pointed, and the second tooth the largest, somewhat swollen at the apex, with a semi-curved tip. The ventral profile is convex from the snout to the origin of the pelvic fin, straightening to the origin of the anal fin, and sharply rising to the base of the caudal fin. *Schizothorax niger* has a triangular head, with the upper jaw slightly longer than the lower jaw. It possesses two pairs of barbels (maxillary and mandibular), with the maxillary barbel larger than the mandibular one. The dorsal fin is short with ten fin rays, while the anal fin is narrower and shorter than the pectoral fin. The dorsal fin has 6 (9) branched rays and 7 (1) unbranched rays, and the anal fin has 5 (10) branched rays.The muscular trunk of *Schizothorax niger* is covered with small cycloid scales of varying shapes. Fish inhabiting dense vegetation are darker on the dorsal side compared to those in open waters. The diagnostic fin count formula for *S. niger* is D10 P20 V10 A8 C22 (Heckel, 1838) (Figure 15).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Schizothorax*
Species	*niger*

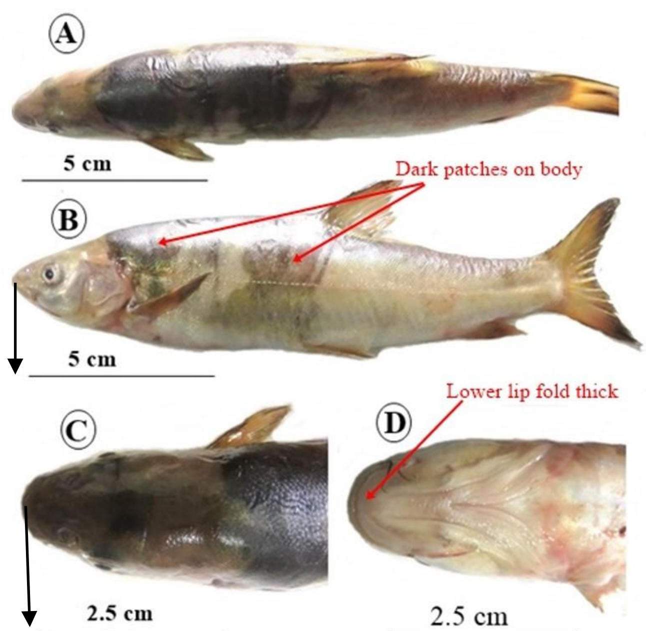


Figure 15: *Schizothorax niger*,A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view

6.6.6 Triplophysa marmorata

Triplophysamarmorata is pale yellowish or whitish in colour with elongated body having short caudal peduncle. Body marking consists of brownish or grayish blotches of different sizes scattered over the dorsum, sides and head. The blotches on the head are smaller compared to those on the sides and back. The eyes are positioned high on the head, and the mouth is located inferiorly. There are no scales present on the body. The fish has two pairs of barbells-two rostral and one maxillary pair. The dorsal fin rays are branched. The origin of the dorsal fin is equidistant between the tip of the snout and the base of the caudal fin in most species. The distance from the snout to the dorsal fin origin (pre-dorsal distance) is notably shorter. Anal fin rays are branched. Pelvic fin inserted slightly posterior to vertical form dorsal fin origin reaching to vent, but never to anal fin origin. The caudal fin is slightly emarginated, with upper lobe slightly longer. The lateral line short usually extending only halfway between its origin vertical form dorsal fin origins and always terminating well anterior to the latter. The arrangement of the rays in various fins is as -D9 P17 V10 A7 C29 (Kullander *et al.*, 1999) (Figure 16).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Schizothorax*
Species	*marmorata*

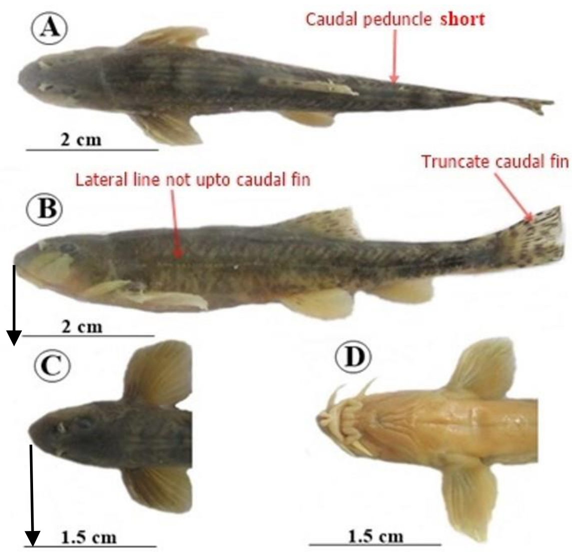


Figure 16: *Triplophysa marmorata*, A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view

6.6.7 *Triplophysa kashmirensis*

Body is elongated, and possess long and slender caudal peduncle without scales. Colour is pale brownish yellow on lateral sides and silvery greenish on ventral side. Dark blotches are found scattered all over the body, three rows of wide dark blotches anterior to dorsal are observed. Both dorsal and caudal fine possess three rows of dark spots. Dorsal fin origin about equidistant between tip of snout and caudal fin base. Caudal fin is forked or emarginated.Body shape notably variable, especially with regard to the degree of elongation and form of the head. Eyes are positioned high on the head and are completely lateral in position having less interorbital length. The fish has an inferior mouth with thick lips. It possesses three pairs of barbels, including two rostral pairs and one maxillary pair. The lateral line runs the entire length to the base of the caudal fin. The fin ray distribution is as follows: dorsal fin with 9 rays, pectoral fin with 17 rays, ventral fin with 10 rays, anal fin with 7 rays, and caudal fin with 29 rays (Kullander *et al*., 1999) (Figure 17).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	*Nemacheilidae*
Genus	*Triplophysa*
Species	*kashmirensis*

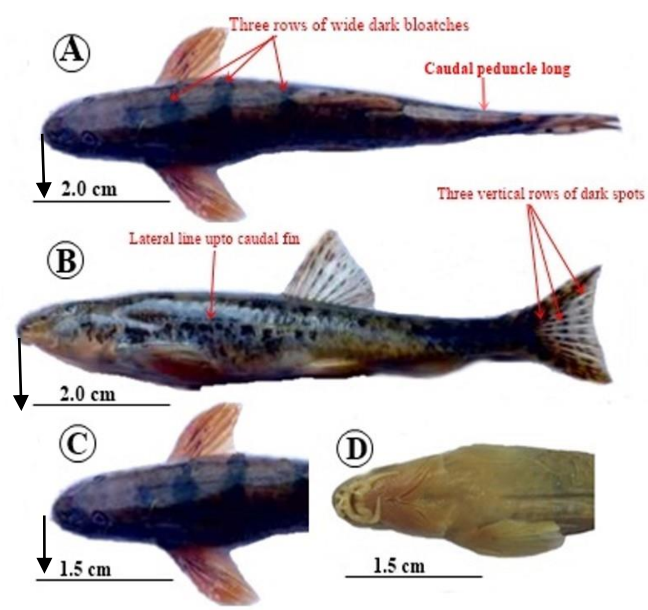


Figure 17: *Triplophysa kashmirensis*:A) Habitus, in dorsal view; B) Habitus, in lateral view;C) Head, in frontal view; D) Head, in ventral view

6.6.8 Crossocheilus diplochilus

The body is fusiform, elongated, with a rounded abdomen covered in scales except on the dorsal side. The coloration is silvery-brownish on the dorsal and lateral sides, transitioning to silvery-whitish on the ventral side. Dark spots are present on both the body and fins. The dorsal profile is more convex than the ventral profile, which is either horizontal or slightly curved.The head is small, with a broad, slightly curved upper surface. The snout is prominent, obtusely pointed, smooth, and overhangs the mouth with a pendulous at the angle of the eye. The mouth is inferior or ventral, and the eyes are large and situated behind the middle of the head. The upper and lower lips are not continuous. The lower lip lacks a suctorial disc and has a horny covering, with a continuous but not highly developed lip fold. The upper lip is fleshy, smooth, thin, and indented along the edge.The fish has a pair of maxillary and rostral barbels. The dorsal fin is inserted midway between the pectoral and pelvic fins, close to the tip of the snout, and lacks any spine. The caudal fin is deeply forked, and the lateral line is continuous (Kullander *et al*., 1999). The fin ray distribution is as follows: dorsal fin with 10-11 rays, pectoral fin with 15 rays, ventral fin with 10 rays, anal fin with 7 rays, and caudal fin with 19 rays (Figure 18).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	*Nemacheilidae*
Genus	*Crossochelius*
Species	*diplochilus*

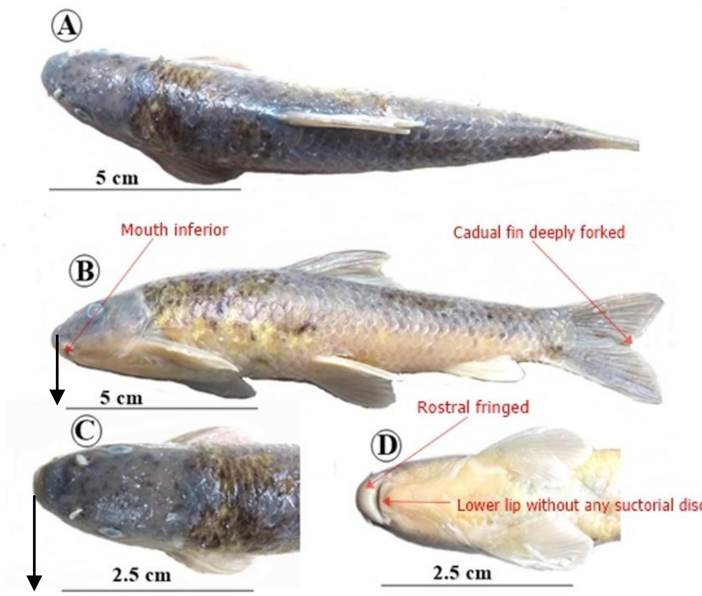


Figure 18:*Crossocheilus diplocheilus,* A) Habitus, in dorsal view; B) Habitus, in lateral view;C) Head, in frontal view; D) Head, in ventral view

6.6.9 Cyprinus carpio communis

The fish has a deep, fusiform body that is laterally compressed and covered with prominent scales. The head is relatively small and short, with a very convex dorsal profile and a bulky, rounded abdomen. The dorsal and lateral sides of the fish are brownish, while the ventral side is whitish. The body is laterally compressed, and the snout is rounded. The mouth is strongly curved and sub-terminal, with thick lips. Short rostral and maxillary barbels are present.The scales are arranged in a lateral series. The dorsal fin has 18-20 branched rays, while the anal fin has 5 branched rays. The lateral line is typically complete, although the development of canals varies, sometimes only being developed on the anterior scales. The last unbranched dorsal and anal fin rays are strong and scattered along the posterior margin.The distribution of rays in the various fins is as follows: dorsal fin with 9 rays, pectoral fin with 17 rays, ventral fin with 10 rays, anal fin with 7 rays, and caudal fin with 29 rays **(**Linnaeus,1758; Talwar and Jhingran, 1991) (Figure 19).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Cypriniformes
Family	*Cyprinidae*
Genus	*Cyprinus*
Species	*carpio*

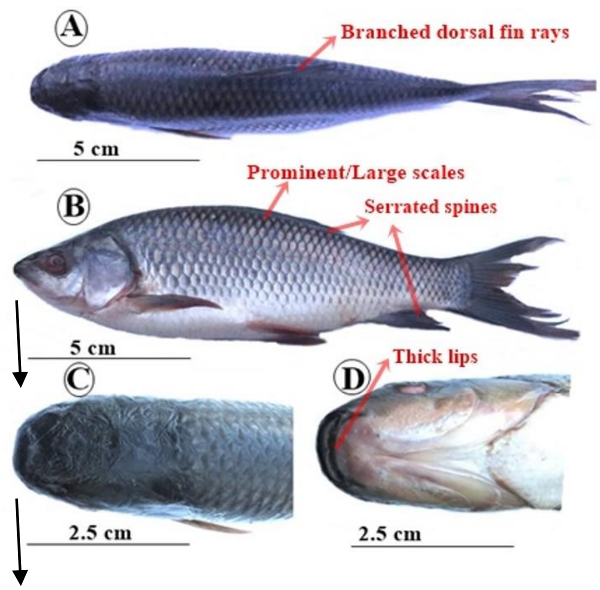


Figure 19: *Cyprinus carpio communis,* A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view:

6.6.10 Glyptosternon reticulatum

The body of the fish is elongated and dorso-ventrally flattened, compressed towards the pelvic fins, and lacks scales, with a complete lateral line. The head is compressed and wide, and the body depth remains uniform from the head to the caudal fin. The eyes are small, located dorsally, and subcutaneous. The lips are thick, fleshy, and papillate. The head is short, wide, and depressed, with a broadly rounded snout. The mouth is wide and inferior.The body and parts of the paired fins are covered with small tubercles. There are four pairs of barbels: one pair of nasal barbels, maxillary barbels, and two pairs of mental barbels. The mental barbels are thick at the base, sub-basally connected to the cheek by membrane, and taper distally. The ventral aspect of the proximal part has folded skin forming an adhesive surface.The dorsal, anal, and caudal fins are short and truncate, without forks, while the adipose fin is long. The paired fins are broad, with the pectoral fin having an unbranched ray that is wide and has transverse striations on the ventral aspect, forming an adhesive surface. The pelvic fin also has an unbranched wide ray, with the first and second rays having transverse striations on the ventral aspect, forming an adhesive surface.Teeth in both jaws are pointed, and post-labial grooves are present. The gill openings extend to the outer side (venter), and there is a low adipose fin. The pectoral and pelvic fins are broad, with no thoracic adhesive organ present between the pectoral fins (McClelland and Griffith, 1842; Kullander*et al.*, 1999) (Figure 20).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Siluriforms
Family	*Sisoridae*
Genus	*Glyptosternon*
Species	*reticulatum*

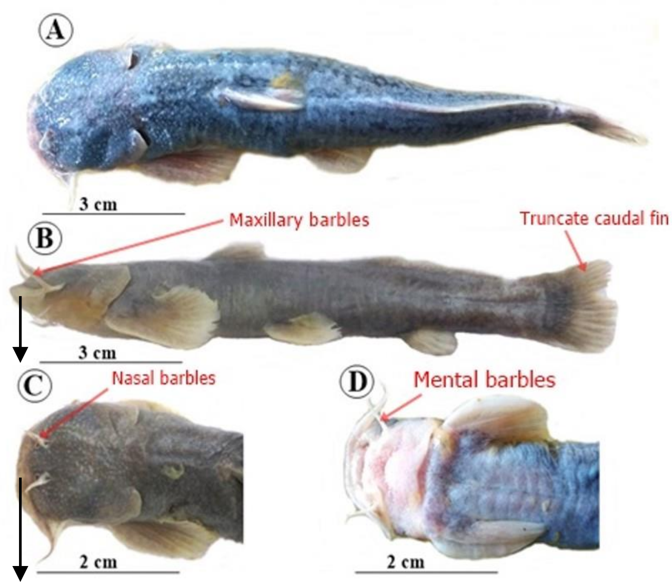


Figure 20:*Glyptosternon reticulum,* A) Habitus, in dorsal view; B) Habitus, in lateral view;C) Head, in frontal view; D) Head, in ventral view

6.6.11 Oncorhynchus mykiss

Oncorhynchus mykiss features a streamlined body, an adipose fin, and a large mouth where the upper jaw extends just beyond the rear margin of the eye. Adults typically exhibit blue-green or olive-green coloring with dense black spotting throughout the body length. A broad reddish stripe runs along the lateral line from the gills to the tail. The caudal fin is square-shaped and slightly forked. It can be distinguished from the Brown Trout by the presence of numerous small black spots on the caudal fin as well as on the back and sides of the body (Walbaum, 1792) (Figure 21).

Classification

Kingdom	Animalia
Phylum	Chordata
Sub Phylum	Vertebrata
Class	Osteichthyes
Sub Class	Actinopterygii
Order	Salmoniformes
Family	*Salmonidae*
Genus	*Oncorhynchus*
Species	*mykisis*

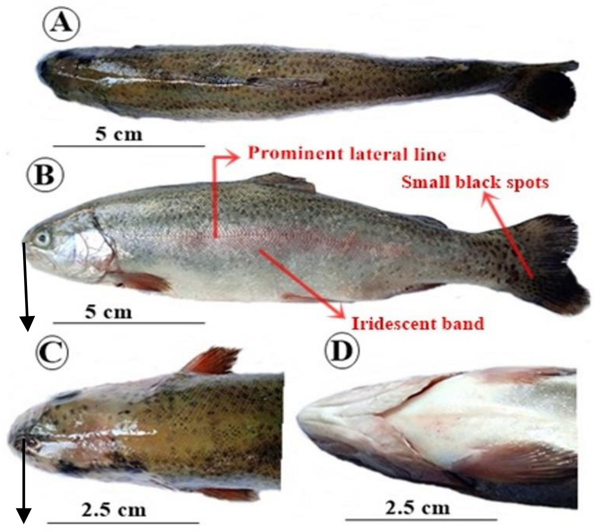


Figure 21:*Oncorhynchus mykiss:* A) Habitus, in dorsal view; B) Habitus, in lateral view; C) Head, in frontal view; D) Head, in ventral view

6.7 Fish collection and identification

The biodiversity of Himalayan Rivers is characterized by a high degree of endangerment and endemism, compared to temperate rivers in Europe and North America, these rivers have not received as much attention (Jun *et al*., 2016). Habitat degradation is predominantly caused by anthropogenic activities driven by economic growth, leading to a decline in water quality in riverine ecosystems (Vörösmarty *et al*., 2010). In this study, we investigated the diversity (richness) and fish community composition along the longitudinal gradient of Vaishav stream across three sampling sites. A total of 630 specimens representing 11 fish species and spanning three orders (*Cypriniformes*, *Siluriformes*, and *Salmoniformes*) and four families (*Cyprinidae*, *Nemachelidae*, *Siluridae*, and *Salmonidae*) were documented from the study sites. Among these, *Cypriniformes* were the most dominant order with nine species, followed by *Siluriformes* and *Salmoniformes* with one species each. Of the eleven fish species recorded, six belong to the family *Cyprinidae*, three to *Nemachelidae*, and one each to *Siluridae* and *Salmonidae*.

In the Vaishav stream, the fish community composition and dominance varied significantly across three study sites. At Site-I (Watoo Reshinagar), *Schizothorax curvifrons* was the most dominant species, followed by *Triplophysa marmorata*, *Schizothorax plagiostomus*, *Glyptosternon reticulatum*, and *Oncorhynchus mykiss*. Moving to Site-II (Kulgam), *Triplophysa marmorata* emerged as the dominant species, followed by *Schizothorax plagiostomus*, *Schizothorax esocinus*, *Triplophysa kashmirensis*, *Schizothorax labiatus, Schizothorax niger*. At Site-III (Arwani), *Schizothorax plagiostomus* exhibited dominance, followed by *Schizothora xesocinus, Schizothorax labiatus, Cyprinus carpio communis, Crossocheilus diplochilus, Schizothorax niger,* and *Triplophysa kashmirensis* (Table 8). The spatial-temporal variation in fish community dominance reflected a pattern where *Schizothorax plagiostomus*, *Triplophysa marmorata, Schizothorax esocinus, Schizothorax labiatus, Schizothorax curvifrons, Triplophysa kashmirensis, Cyprinus carpio communis, Glyptosternon reticulatum, Oncorhynchus mykiss,* and *Crossocheilus diplochilus* were ranked in descending order by population percentage (Table 8). Cypriniformes were overwhelmingly dominant at 92.17%, followed by Siluriformes at 4.44%, and Salmoniformes at 3.33%.The study also revealed seasonal variations in species richness and abundance across the sites. Site-I recorded the minimum richness (5 species) and abundance (197 specimens), while Site-III had the maximum richness (7 species) and abundance (228 specimens), indicating an increase from upstream to downstream. Seasonal variations showed a minimum of 49 species in winter and a maximum of 62 in summer at Site-I, with similar patterns observed at Sites II and III (Table 9). In addition to this the monthly variation in fish catch from three sampling sites is depicted in (Figure 2). Which depicted the monthly abundance of collected fish species at three different sites along the stream gradient and *Schizothrax .plagiostomes* was the most dominated fish species recorded and was collected in every month through out the year due to due to its adaptability to fluctuating environmental conditions and diverse diet of benthic algae and detritus. This flexibility allows it to thrive despite seasonal changes and anthropogenic pressures (Gowhar *et al*., 2023; Bhat *et al*., 2024). Previous studies by Nikoo *et al.,* 2015; Hamid and Singh, 2019 and Arafat *et al.,* 2022 confirmed the similar findings while studying the fish diversity in the Vaishav stream. Additionally, Bhat *et al.*, (2013) reported on fish species from the Lidder stream, including *Schizothorax plagiostomus*, *S. labiatus*, *S. esocines*, *Salmo trutta fario*, *Crosscheilus diplochilus*, *Glyptostern reticulatuma*, and *Triplophysa kashmirensis*.. Hussain and Rashid, (2021) reported nine species from river Jheulum. Nisa *et al.,* 2020 reported sixteen species of fishes Tawi River Rajouri Jammu and Kashmir and comprising of two orders, Cypriniformes with three families, Cyprinidae, Danionidae and Nemacheilidae, and Siluriformes with one family Sisoridae. Similarly, (Awas *et al*., 2023) reported 25 species of fishes from river poonch Jammu and Kashmir and Cyprinidae 64% were reported as most dominant followed by Sisoridae Sisoridae (16%) and Cobitidae (8%). In our study, we reported *S. plagiostomus* as the dominant species, followed by *Triplophysa marmorata* and *S. esocinus* respectively and similar results were obtained by (Bhat *et al.*, 2013) in Lidder stream (Sultan and Kant, 2016) Jhelum river. Thus environmental factors such as water flow, temperature, depth, substrate type, and food availability significantly influence fish species distribution and abundance (Agarwal and Singh, 2014). For instance, *Glyptosternon reticulatum*, adapted to hill streams, thrives in the upper reaches (Site-I) where clean, oxygen-rich water supports its feeding habits among large stones. Conversely, introduced species like Oncorhynchus mykiss are confined to upstream areas due to their preference for cleaner, well-oxygenated environments with abundant benthic insects (Bêche *et al.,* 2006).

In our study, all species were collected throughout the year across four seasons: winter, spring, summer, and autumn. Eight eurythermal species, indicated in Table 8, were present at both sampling sites in all seasons, while three stenothermal species were observed only during the warmer months. Our findings reveal significant variations in fish abundance along the longitudinal gradient (from site-I to site-III) of the Vaishav stream, indicating spatial differences rather than substantial seasonal variations (Figures

24 & 25). Previous research has consistently highlighted spatial and temporal variations in fish abundance in natural streams (Xiang *et al.,* 2022; Naser *et al.,* 2023). Spatial variations along the stream's length often result from changes in habitat characteristics, while seasonal fluctuations in fish abundance are typically linked to factors such as floods, which induce seasonal migrations of fish species (Fernandes *et al.,* 2013; Wolter *et al*., 2016). Our results align with studies by Ostrand and Wilde (2002) and Mullen *et al.,* (2011), which similarly found no significant seasonal variations in fish diversity. This suggests that in the Vaishav stream, fish abundance is influenced more by spatial heterogeneity in environmental conditions than by seasonal changes (Liu *et al*., 2021; Moniruzzaman *et al.,* 2021).

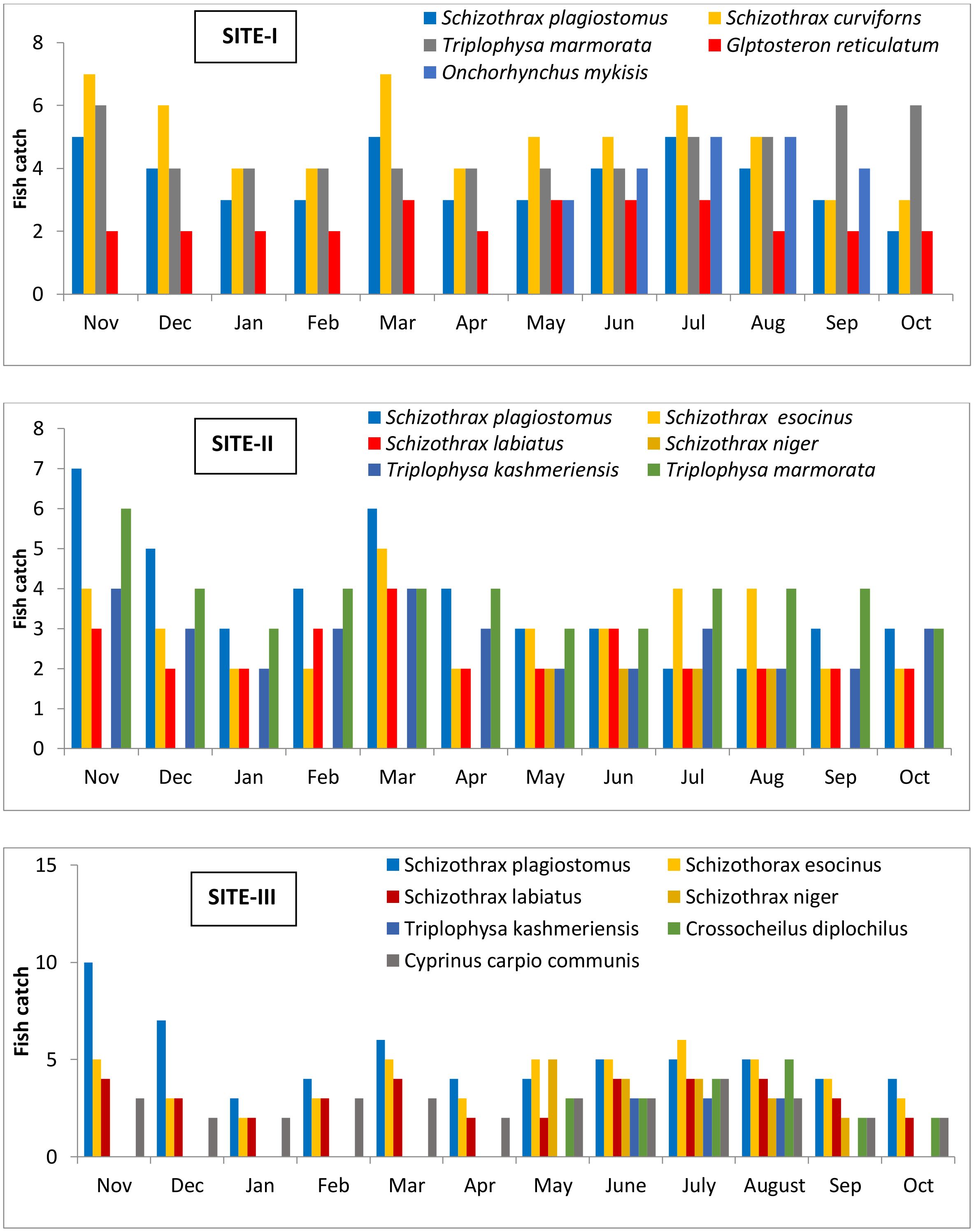


Figure 22: Showing the monthly variation in fish catch from three selected sites (Site-I, Site-II, and Site- III) from November, 2019-Oct, 2020 of Vaishav stream.

Table 8: Monthly occurrence of fish species sampled in three sites of Vaishav Stream (J&K UT) from Nov. 2019 to Oct.2020. Probable seasonal occurrence (S.O. and sites, column) indicated by symbols: Y-Yearlong occurrence, W-present only warmer months, e-entire stream. Sampling with the help of local fishermen.

Fishes	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Total**	**S.O.**	**Site**
Schizothrax plagiostomus	22	16	09	11	17	11	10	12	12	11	10	09	**150**	Y	E
Schizothrax esocinus	09	06	04	05	10	05	08	08	10	09	06	05	**85**	Y	II & III
Schizothrax labiatus	07	05	04	06	08	04	04	07	06	06	05	04	**66**	Y	II & III
Schizothrax curviforns	07	06	04	04	07	04	05	05	06	05	03	03	**59**	Y	I
Schizothrax niger	-	-	-	-	-	00	07	06	06	05	02	-	**26**	W	II & III
Triplophysa kashmeriensis	04	03	02	03	04	03	02	05	06	05	02	03	**42**	Y	II & III
Triplophysa marmorata	12	08	07	08	08	08	07	07	09	09	10	09	**102**	Y	I & II
Glyptosteron reticulatum	02	02	02	02	03	02	03	03	03	02	02	02	**28**	Y	I
Oncorhynchus mykisis	-	-	-	-	-	-	03	04	05	05	04	-	**21**	W	I
Crossocheilus diplochilus	-	-	-	-	-	-	03	03	04	05	02	02	**19**	W	III
Cyprinus carpio communis	03	02	02	03	03	02	03	03	04	03	02	02	**32**	Y	III

Table 9: Percentage composition, abundance and relative abundance of fishes in Vaishav stream at three selected sites from Nov. 2019 - Oct. 2020

Fish species	Site-I			Site-II			Site-III		
	%	**TA**	**RA**	**%**	**TA**	**RA**	**%**	**TA**	**RA**
Schizothorax plagiostomus	21.15	44	26.82	22.16	45	28.48	27.11	61	37.19
Schizothorax esocinus	–	–	–	17.73	36	21.55	21.77	49	33.56
Schizothorax labiatus	–	–	–	14.28	29	16.66	16.44	37	19.68
Schizothorax curviforns	28.36	59	39.59	–	–	–	–	–	–
Schizothorax niger	–	–	–	3.94	08	4.10	8	18	8.69
Triplophysa kashmirensis	–	–	–	16.25	33	19.41	4	9	4.16
Triplophysa marmorata	26.92	56	36.84	22.66	46	29.29	–	–	–
Glyptosteron reticulatum	13.46	28	5.55	–	–	–	–	–	–
Oncorhynchus mykisis	10.09	21	11.22	–	–	–	–	–	–
Crossocheilus diplochilus	–	–	–	–	–	–	8.44	19	9.22
Cyprinus carpio communis	–	–	–	–	–	–	14.22	32	16.58

TA: Abundance, **RA**: Relative abundance

Table 10: Showing seasonal variation in fish catch abundance and distribution in Vaishav stream at three selected sampling sites from Nov. 2019 – Oct. 2020.

Fishes	**Site-I**				**Site-II**				**Site-III**			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Schizothorax plagiostomus	12	11	12	09	15	14	08	08	20	14	14	13
Schizothorax esocinus	-	-	-	-	09	09	10	08	10	11	16	12
Schizothorax labiatus	-	-	-	-	07	09	07	06	09	09	10	09
Schizothorax curviforns	17	15	16	11	-	-	-	-	-	-	-	-
Schizothorax niger	-	-	-	-	-	-	06	02	-	-	13	05
Triplophysa kashmirensis	-	-	-	-	09	10	07	07	-	-	06	03
Triplophysa marmorata	14	12	13	17	13	12	10	11	-	-	-	-
Glyptosteron reticulatum	06	07	09	06	-	-	-	-	-	-	-	-
Oncorhynchus mykisis	-	-	12	09	-	-	-	-	-	-	-	-
Crossocheilus diplochilus	-	-	-	-	-	-	-	-	-	-	10	09
Cyprinus carpio communis	-	-	-	-	-	-	-	-	07	08	10	07
Total	**49**	**45**	**62**	**52**	**53**	**54**	**48**	**42**	**46**	**42**	**79**	**58**

Table 11: Showing seasonal percentage variation in fish catch abundance and distribution in Vaishav stream at three selected sampling sites fromNov. 2019 – Oct. 2020.

Fishes	**Site-I (%)**				**Site-II (%)**				**Site-III (%)**			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Schizothorax plagiostomus	24.48	24.44	19.35	17.30	28.30	25.92	16.66	19.04	43.47	33.33	17.72	22.41
Schizothorax esocinus	-	-	-	-	16.98	16.66	20.83	19.04	21.73	26.19	20.25	20.68
Schizothorax labiatus	-	-	-	-	13.20	16.66	14.58	14.28	19.56	21.42	12.65	15.51
Schizothorax curviforns	34.69	33.33	25.80	21.15	-	-	-	-	-	-	-	-
Schizothorax niger	-	-	-	-	-	-	12.50	4.76	-	-	16.45	8.62
Triplophysa kashmirensis	-	-	-	-	16.98	18.51	14.58	16.66	-	-	7.59	5.17
Triplophysa marmorata	28.57	26.66	20.96	32.69	24.52	22.22	20.83	26.19	-	-	-	-
Glyptosteron reticulatum	12.24	15.55	14.51	11.53	-	-	-	-	-	-	-	-
Oncorhynchus mykisis	-	-	19.35	17.30	-	-	-	-	-	-	-	-
Crossocheilus diplochilus	-	-	-	-	-	-	-	-	-	-	12.65	15.51
Cyprinus carpio communis	-	-	-	-	-	-	-	-	15.21	19.04	12.65	12.06

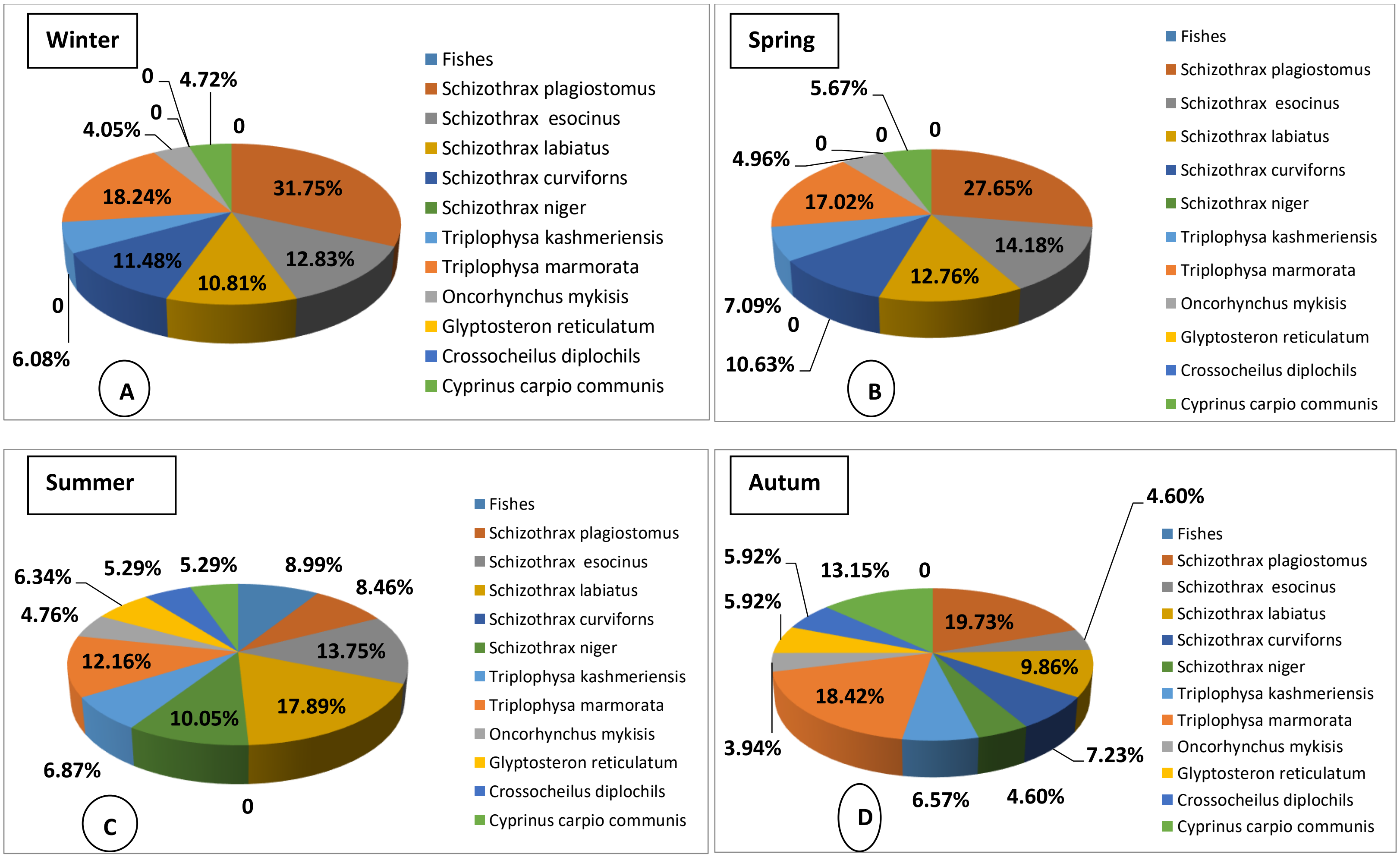


Figure 23: Showing total seasonal percentage (%) of fish catch in Vaishav stream at three selected sites from Nov,2019-Oct,2020

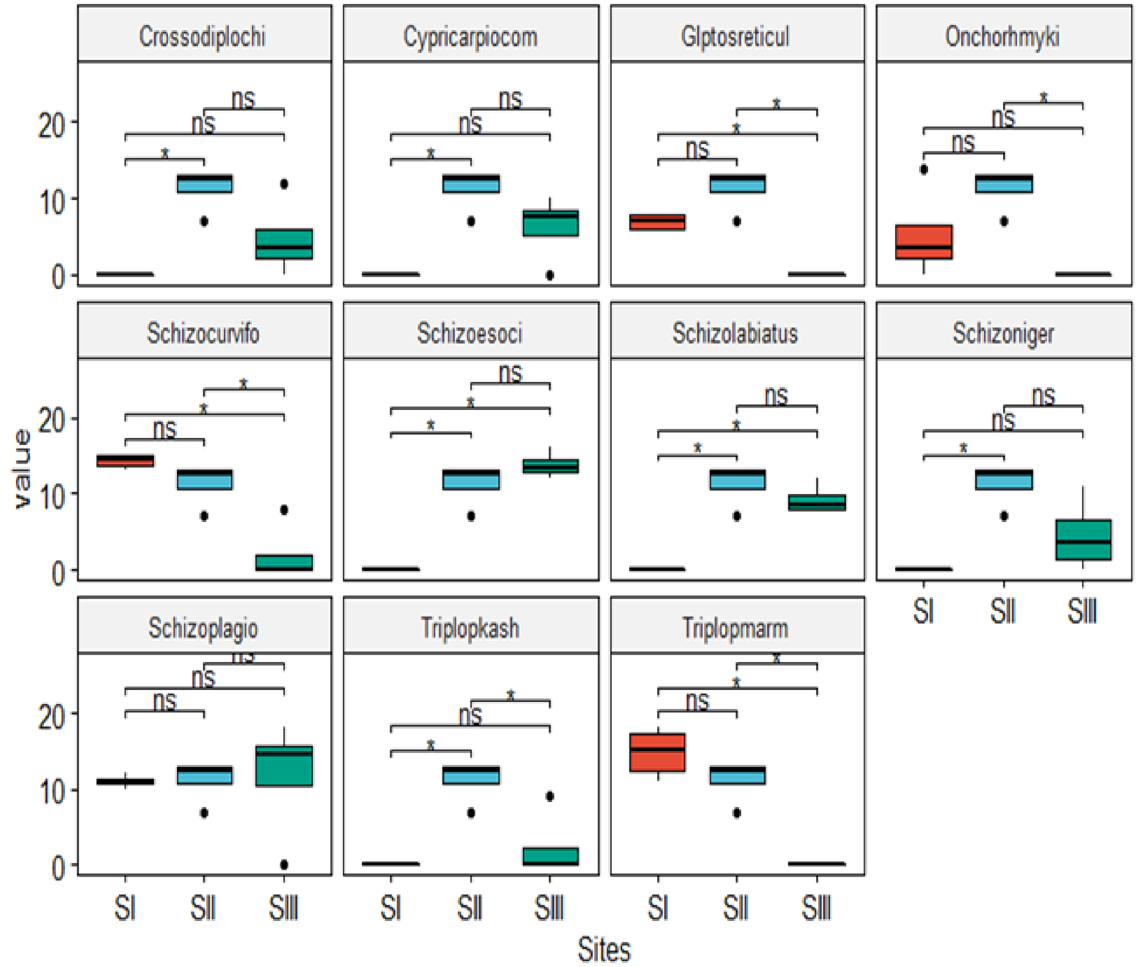


Figure 24 : Illustration of t-test between the sites

("***"=0.001,"**"=0.01,"*"=0.05, ns= not significant)

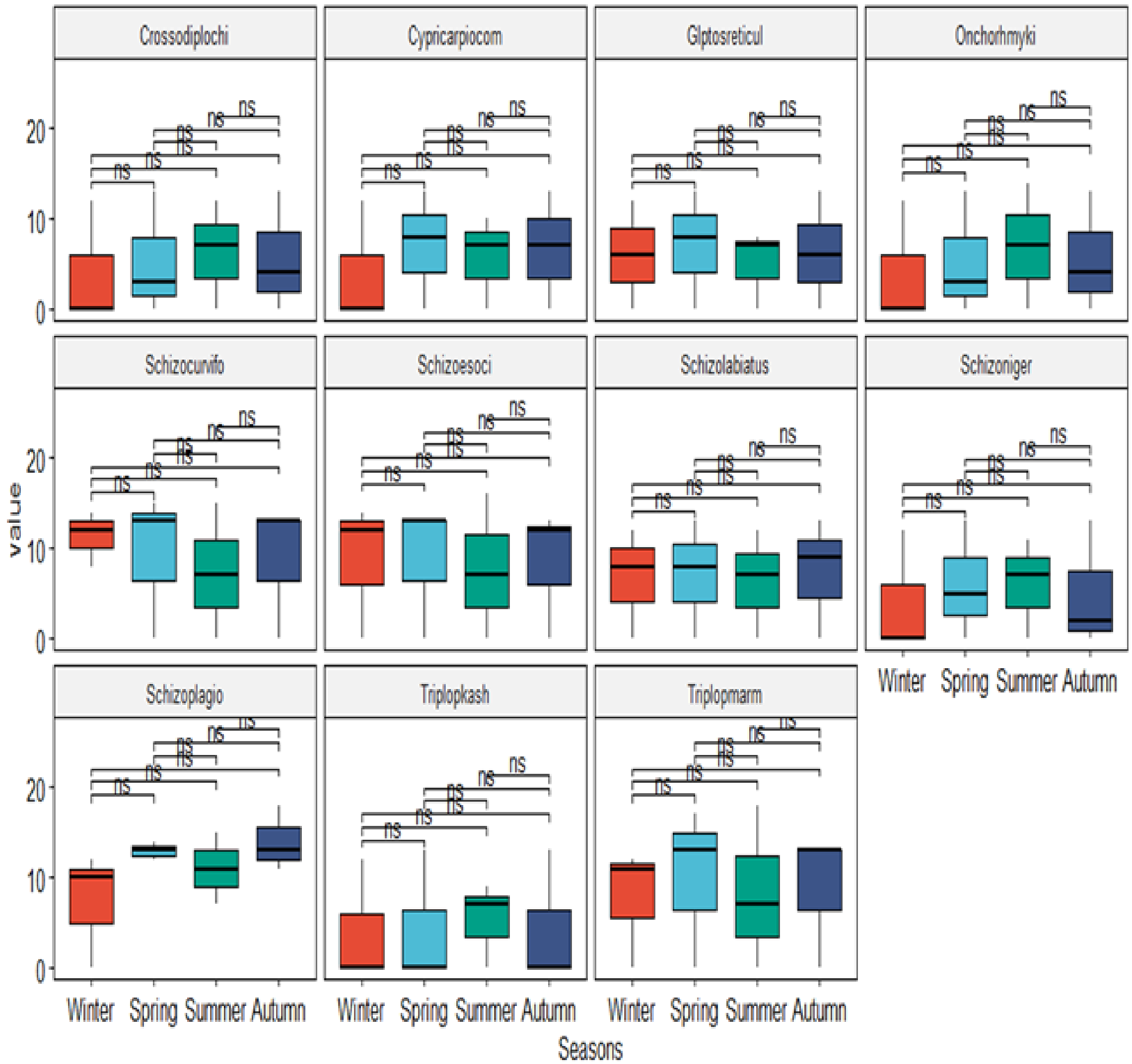


Figure 25: Illustration of t-test between the seasons.

("***"=0.001,"**"=0.01,"*"=0.05, ns= not significant)

•

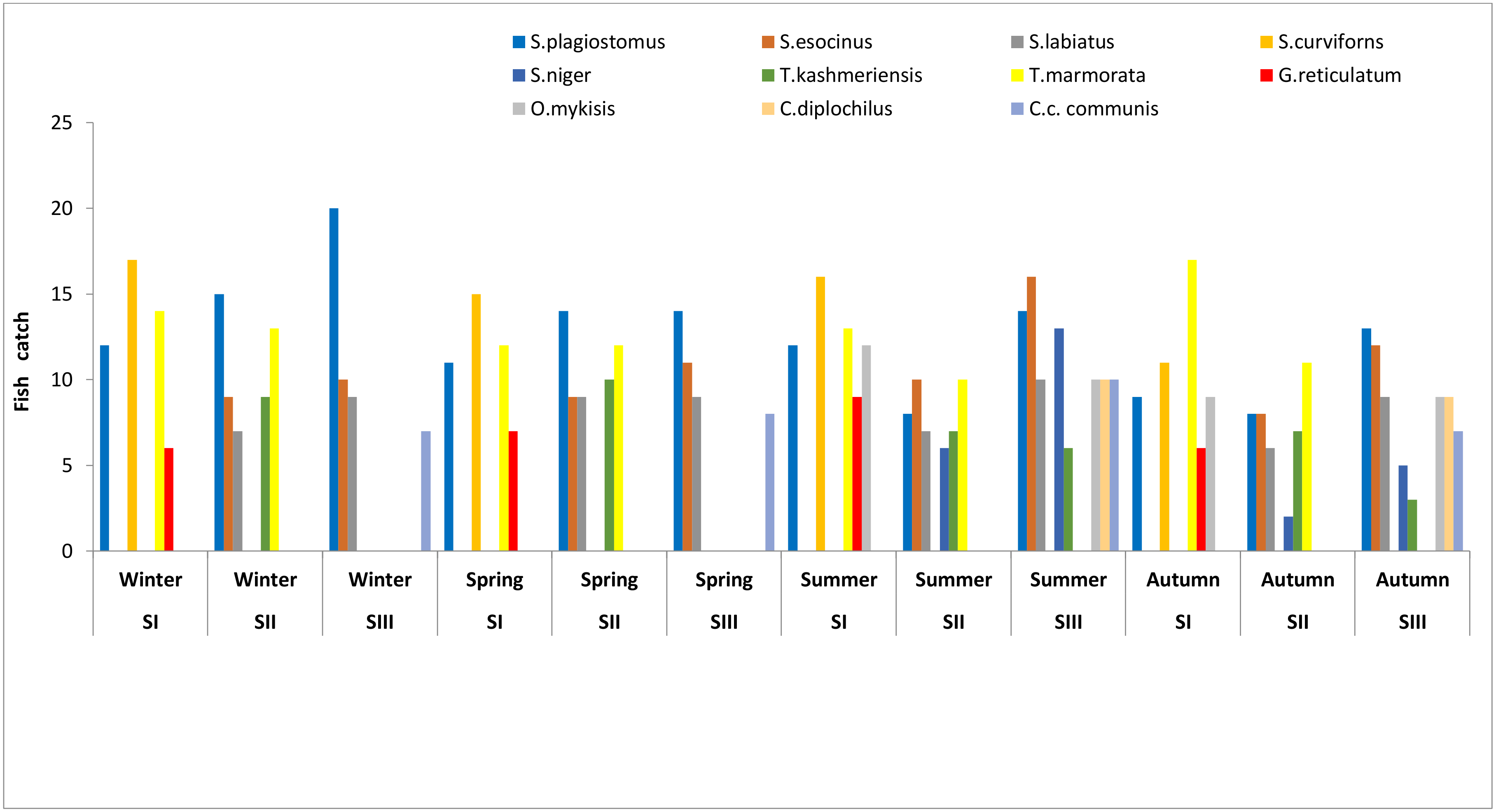


Figure 26: Seasonal fish catch in Vaishav stream at three selected site from Nov. 2019 - Oct. 2020,

6.8 t- test (Between the sites & between the seasons)

t- test was applied to determine the mean significant difference between the three sites and four seasons based on 11 fish species and the finding revealed statistically significant difference between the sites and not between the seasons which may be due to habitat heterogeneity, physical structure includes riffle, pool and substrate that can support diverse fish species (Huang *et al*., 2021). In addition to this, variable physico-chemical parameters can create distinct habitates, flow pattern and water depth can differ which influence the habitate conditions (Rathnayake *et al.*, 2022). Difference in elevation and local climatic conditions can control the water temperature which consequently effects the species distribution (Marin *et al*., 2019). Different stream strectches experience varying anthropogenic effect which can be affecting fish population (Larentis *et al*., 2022). Generally Himalayan streams have stable environmental conditions round the year due input from melting of snow and glaciers and continuous food supply through out the year may diminish seasonal chanfe in fish population (Gebrekiros, 2016). Besides that adaptation of fishes species to local conditions and life cycle matched with these local conditions (Ferreira *et al*., 2021).

6.9 Community Diversity Indices

Diversity indices were calculated to explore the ecological dynamics of the fish community and their interactions (Verberk, 2012). Site-III exhibited the highest alpha diversity compared to Site-I, indicating a distinct community structure at Site-III (Figure 27). The Shannon diversity index is commonly used to assess species diversity across ecosystems (Clarke *et al.*, 2014). The Pielou Evenness Index, which measures how evenly individuals are distributed among species, indicated that Site-I had lower evenness, suggesting a dominance of few species. In terms of diversity indices, Site-III (Arwani) showed the highest fish species richness, followed by Site-II (Kulgam) and Site-I (Watoo Reshinagar). Sites II and III also exhibited higher values of Shannon H' and Pielou Evenness index, whereas Site-I showed lower values of both indices (Watoo Reshinagar). Previous research by Hamid and Singh (2019) reported a Shannon-Weiner index (H) of 1.48 and Pielous Evenness (E) of 0.82 indicating relatively low fish diversity in the Vaishav stream, with dominance by a few species.The lower species richness at Site-I could be attributed to harsher environmental conditions such as lower temperatures, higher flow velocity, and less suitable habitat areas for fish growth and development. These conditions may have led to environmental filtering, favoring certain species over others and affecting the overall composition of the fish community (Carvajal-Quintero *et al.*, 2020). Additionally, the higher altitude of Site-I (2266 masl) compared to Site-II (1882 masl) and Site-III (1534 masl) (Negi and Mamgain, 2013), as well as the influence of stream order, where species diversity typically increases downstream (Bhat *et al.*, 2013) could also contribute to the observed differences in fish diversity. The higher diversity observed at Site-III (lower reaches) may be linked to factors such as lower altitude, moderate water quality, diverse substrate, ambient temperature, riparian vegetation, and suitable flow conditions, which provide refuge and support for a greater variety of fish species (Gebrekiros ,2016; Hamid *et al.*, 2021).

Fish species richness increases from upstream to downstream primarily due to differences in altitude, which significantly influence fish community composition in rivers and streams. Other factors contributing to increased fish diversity include habitat quality, food availability, and stream order (Smith and Wilson, 1996; Jan *et al.*, 2023). The longitudinal distribution pattern of fish is influenced by factors such as site elevation, water temperature, stream size, and width. This pattern is evident in streams where wide, unshaded channels support higher species diversity ((Mostafavi *et al.,* 2021). Among the sampling sites, significant differences in fish diversity, abundance, and distribution were observed. These differences are primarily attributed to varying habitat conditions and secondarily to environmental factors such as anthropogenic pollutants and the relative tolerance of fish species at each site. Downstream areas, characterized by pool habitats, tend to support higher fish diversity (Johal *et al*., 2002). Freshwater fish diversity is typically higher in lowland and intermediate land locations where deepwater bodies provide niche segregation, allowing fish to coexist with reduced intra- and interspecific competition (Lévêque *et al.,* 2008).

During the winter months, when water temperatures drop and food resources become scarce, fish diversity tends to decrease (Liu *et al.*, 2019). Conversely, warmer water temperatures and abundant food resources in wider and deeper habitats favor colonization by multiple fish species (Castillo *et al*., 2023; Whitefield, 2024). Riffle environments generally support fewer species due to their fluctuating water temperatures, strong flow, and limited food availability. During dry seasons with reduced water flow, some fish species may become trapped in small, shallow pools (Temesgen *et al.,* 2021). Geographical barriers such as forests, mining activities, rocks, and bridges can also restrict fish movement within water bodies (Hubbell, 2001). Seasonal changes in water levels influence fish migrations, with fish moving downstream during dry seasons and returning upstream during rainy seasons (Ngor *et al*., 2018). This migratory behavior contributes significantly to fish collections, especially in areas where streams converge with larger rivers (Ngor *et al.,* 2018). Overall, these findings underscore the importance of habitat characteristics, seasonal variations, and environmental factors in shaping fish diversity and distribution patterns in riverine ecosystems.

6.10 Cluster analysis

Cluster analysis was employed to assess the similarity of fish communities among different sampling sites along the Vaishav stream. The datasets obtained from three sites were analyzed using this statistical method, which identifies groups (clusters) of similar objects within a dataset. The results revealed two main clusters within the fish assemblage, indicating similarities between sites 1 and II, likely due to their proximity and similar environmental conditions. In contrast, site III exhibited significant dissimilarity compared to sites I and II, attributed to its distance and varying environmental parameters. Despite these variations, the major species contributing to each site showed comparable patterns, albeit with varying degrees of dominance. Seasonal changes played a crucial role in driving these similarities and dissimilarities, influencing hydrological conditions and consequently impacting the fish communities (Gupta *et al*., 2022) (Figure 27).

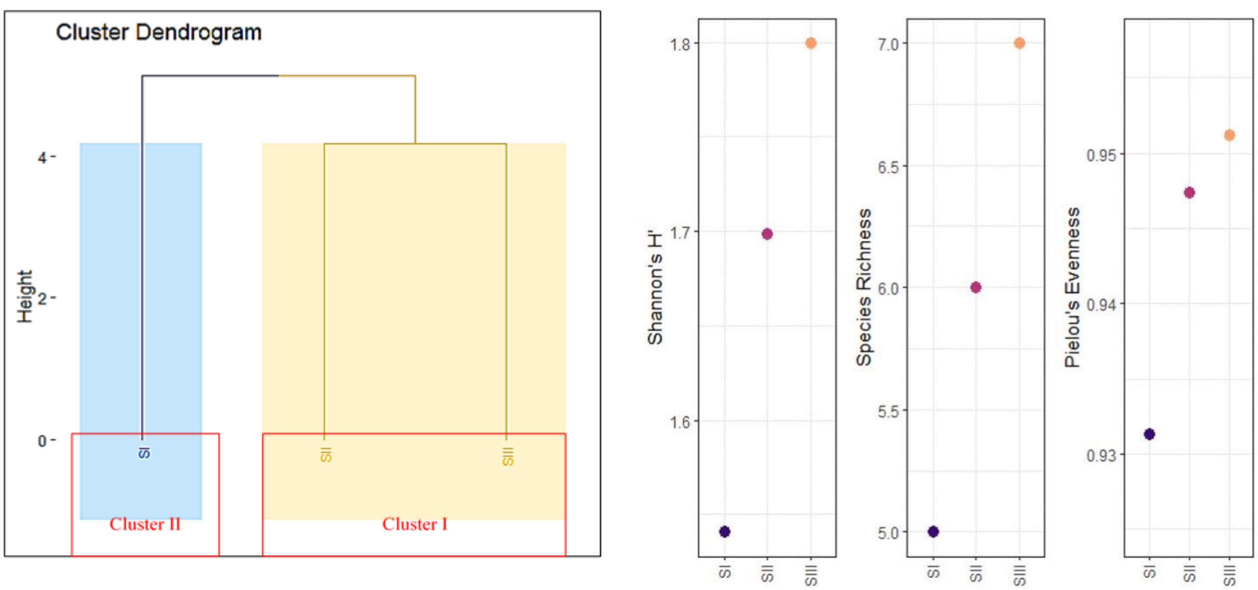


Figure 27: Cluster dendogram and alpha diversity between the sampling sites on the basis of fish community.

6.11 Community Similarity (Jaccard's Index)

In ecology, Jaccard'S index is used to measure the similarity or disimilarity by comparing species composition between different sampling sites of ecological communities. During the present it was observed that Site-I and Site-II have 22% of similarity whereas Site-II & Site-III have 62% of similarity and 9% similarity have been shown by Site-I & Site-II (Table 12). The 22% similarity between Site I and Site II suggests limited species overlap, likely due to differences in habitat structure and water quality. Site I, a cooler, oxygen-rich headwater, predominantly supports rheophilic species, while Site II has altered habitat and physico-chemical conditions. Headwaters typically host unique assemblages due to distinct environments compared to midstream areas (Chen *et al*., 2018). The 62% similarity between Site II and Site III reflects a significant overlap in species composition, likely due to their proximity and similar environmental conditions. Shared flow regimes, substrate types, or human impacts may contribute to a more uniform fish community, especially in mid- to downstream areas where conditions are typically more consistent (Negi and Mamgain, 2013). The 9% similarity between Site I and Site III highlights their distinct ecological conditions, with Site I influenced by headwater characteristics and Site III affected by downstream nutrient input, sediment load, and human activities. Similar studies (Yang *et al*., 2021) show significant fish composition differences between upstream and downstream sites due to varied environmental stresses and habitat fragmentation. More over, streams have experienced significant changes from various human activities, which also impact species migration between river habitats (Liu *et al*., 2021,2024)

Table 12: Jaccard's similarity index of fish species at three selected sites

Site	I			II			III		
	JS	PS	JD	JS	PS	JD	JS	PS	JD
I	-	-	-	0.22	22%	78	0.09	9%	91
II	0.22	22 %	78	-	-	-	0.62	62%	38
III	0.09	9%	91	0.62	62%	38	-	-	-

JS=Jaccards Similarity, **PS**= Jaccards percentage similarity, **JD**= Jaccards dissimilarity.

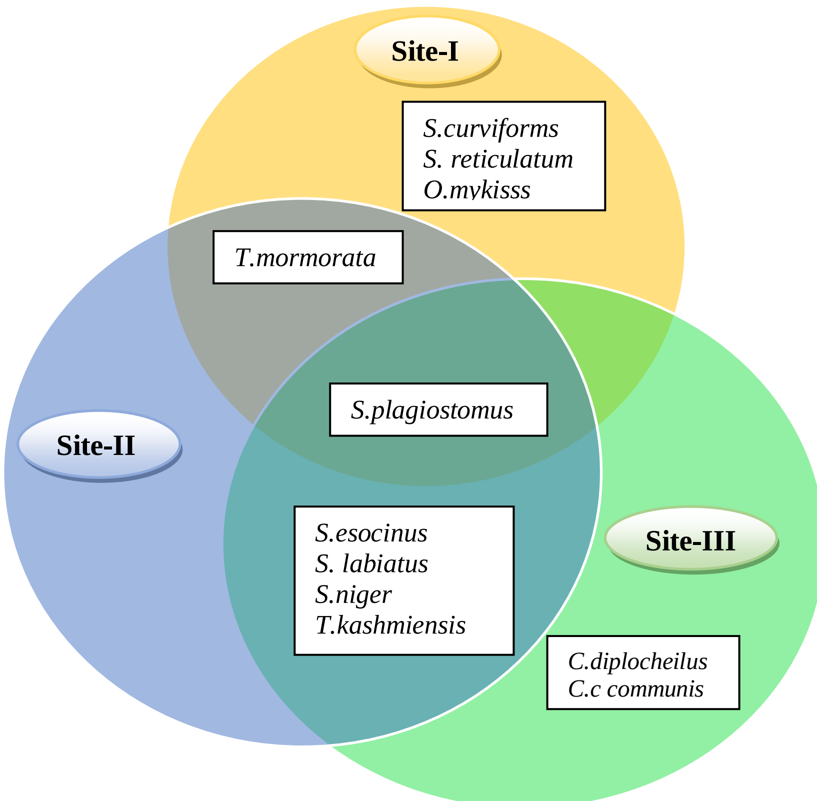


Figure 27: Venn diagram showing overlap of fish species between three different sites

6.12 Fish community pattern

NMDS based on fish abundance data (stress=0.031), followed by ANOSIM ($p<0.05$), indicated a clear distinction among sites ($R = 0.9754$, $p = 0.0001$), while there was no statistically significant difference based on seasons ($R = -0.02748$, $p = 0.6468$), with 9999 permutations (Figure 29). The study revealed that sites did not show distinct separation by seasonality, suggesting that fish taxa preferences for specific locations remained consistent throughout the seasons. Permutational analysis of variance (PERMANOVA) also supported this finding, indicating no significant difference among sites based on count data. Similar conclusions were drawn in a study on fish richness in mountain streams of the Ren River, southwest China, where seasonal variation in fish communities was not discernible (Liu *et al.*, 2021). The NMDS ordination plots showed significant overlap between fish assemblages in wet and dry seasons, corroborated by ANOSIM results indicating no evidence of seasonal variations in fish communities ($R = -0.022$, $p = 0.745 > 0.05$). Regional landscape features were found to exert a stronger influence on fish quantity and composition compared to seasonal differences based on abundance data. Aquatic vertebrates exhibited less seasonal variation despite substantial spatial differences in fish composition and abundance, likely due to factors such as habitat stability, behavioral traits, and life history adaptations (Kreiling *et al.*, 2021). The middle sites (SII) had moderate anthropogenic impacts in the nearby watershed, whereas upstream sites (SI) were largely within forested areas with minimal human disturbance. Downstream reaches (SIII) were characterized by high levels of agricultural activities, human settlements, and alterations to the streambed. While SII and SIII overlapped in terms of fish species composition, SI was distinguished by the presence of species sensitive to pollution and typically found in hill streams. Changes in land use and human activities significantly affected the structure and composition of aquatic communities by deteriorating water quality (Allan, 2004). Studies by Ostrand and Wilde (2002), Fernandes *et al.,* (2014), Mullen *et al.,* (2011) also indicated that spatial variation among watersheds or along stream gradients was more pronounced than seasonal changes in fish assemblages. These findings collectively suggest that persistent spatial heterogeneity in environmental conditions plays a more crucial role in shaping fish communities than seasonal fluctuations in habitat features.

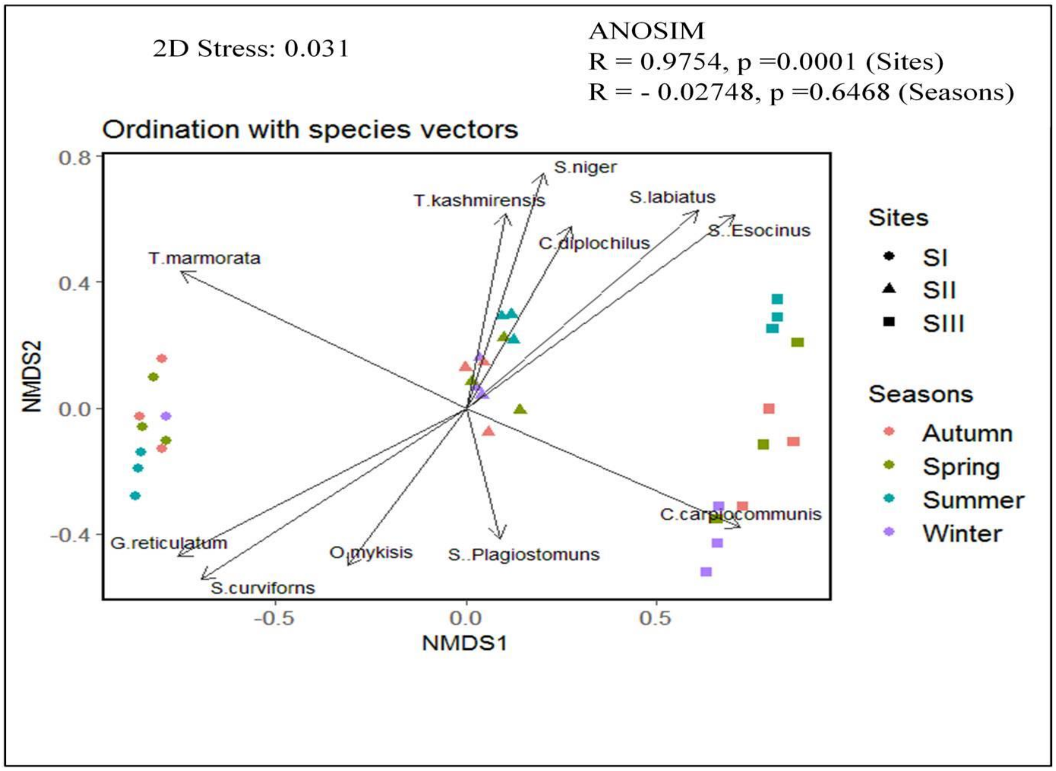


Figure 29: NMDS showing spatiotemporal patterns and relationships between various environmental factors and fish community

6.13 Principal Component Analysis (PCA)

The suitability of the dataset for factor analysis (FA) prior to principal component analysis (PCA) was evaluated using Kaiser-Meyer-Olkin (KMO) measure (0.76) and Bartlett's sphericity test ($p<0.05$, chi-square = 1345), indicating adequacy for PCA (Lo *et al*., 2012). PCA reduces the dimensionality of datasets with numerous interrelated variables by transforming them into orthogonal principal components (PCs), arranged by decreasing relevance (Shrestha and Kazama, 2007). To mitigate classification errors due to data dimensionality, water quality data underwent Z-scale normalization, promoting normality required for statistical analyses and minimizing the influence of varying measurement units and parameter variances (Mainali *et al*., 2024). PCA was conducted using the "prcomp" function and visualized with the "ggbiplot" package in the R Programming Language. The analysis encompassed both water quality and fish datasets to uncover fundamental environmental factors influencing the distribution of fish communities. Factor loadings above 0.75, between 0.75–0.50, and 0.50–0.30 were considered strong, moderate, and weak, respectively, indicating their significance in explaining variance.

The PCA of the spatial clusters dataset yielded two principal components with eigenvalues of 17.5 and 3.80 (PCs), collectively explaining 76.11% of the total variance (Figure 24). PC1 accounted for 62.15% of the total variance, characterized by strong and moderate positive loadings from species such as *S. esocinus*, *C. diplochilus, S. niger, S. labiatus, C. carpio communis,* and environmental variables including water temperature (WT), turbidity (Turb), conductivity (Cond), total dissolved solids (TDS), pH, free carbon dioxide (FCO_2), total alkalinity (TA), total hardness (TH), calcium hardness (CH), magnesium hardness (MH), nitrate nitrogen (NO_3N), total phosphorus (TP), and sulfate (SO4). Strong negative loadings were observed from dissolved oxygen (DO), *T. marmorata*, *G. reticulatum*, *and S. curviforns.*

PC2 explained 13.6% of the total variance, with strong loadings from air temperature (AT), water temperature (WT), *O. mykiss, T. kashmirensis,* and *S. curviforns,* and strong to moderate negative loadings *from S. esocinus, S. labiatus,* and *T. kashmirensis.* PC3 accounted for 9.8% of the total variance, characterized by strong positive loadings from ammonia nitrogen (NH_3N) and nitrate nitrogen (NO_3N), and negative loadings from DO. PC4 explained 7.9% of the total variance, with strong positive loadings from WT and nitrite nitrogen (NO_2N) (Figure 30).

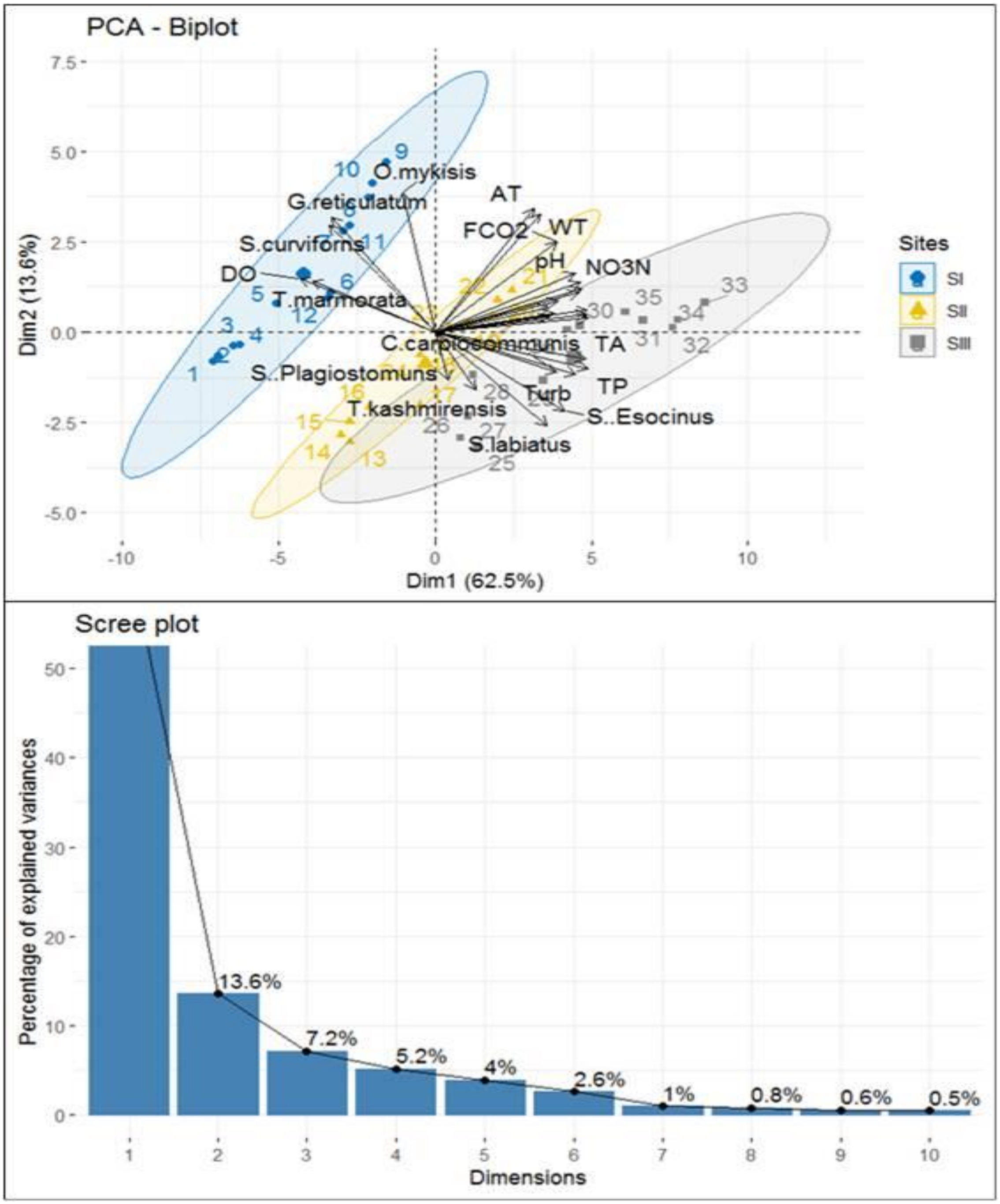
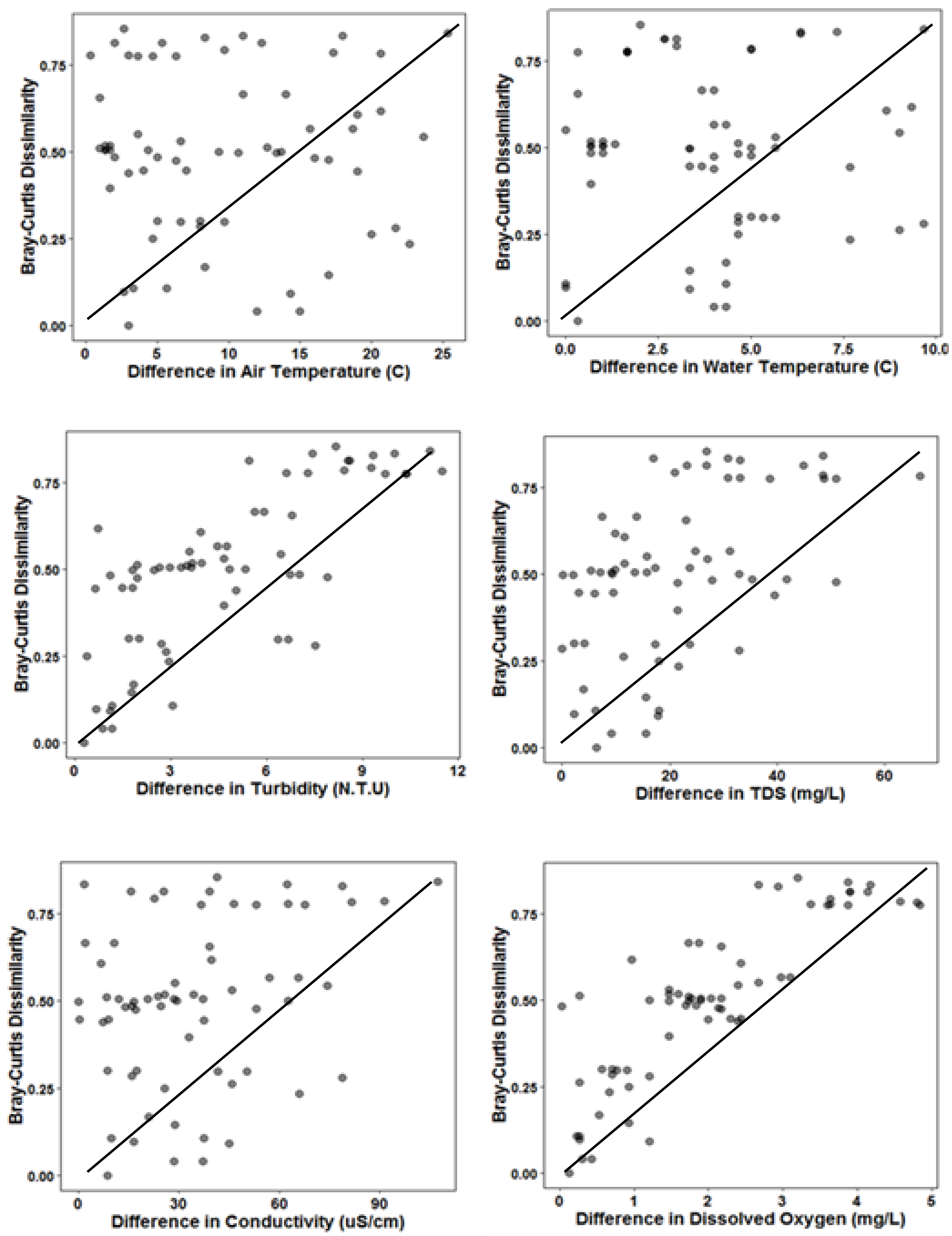


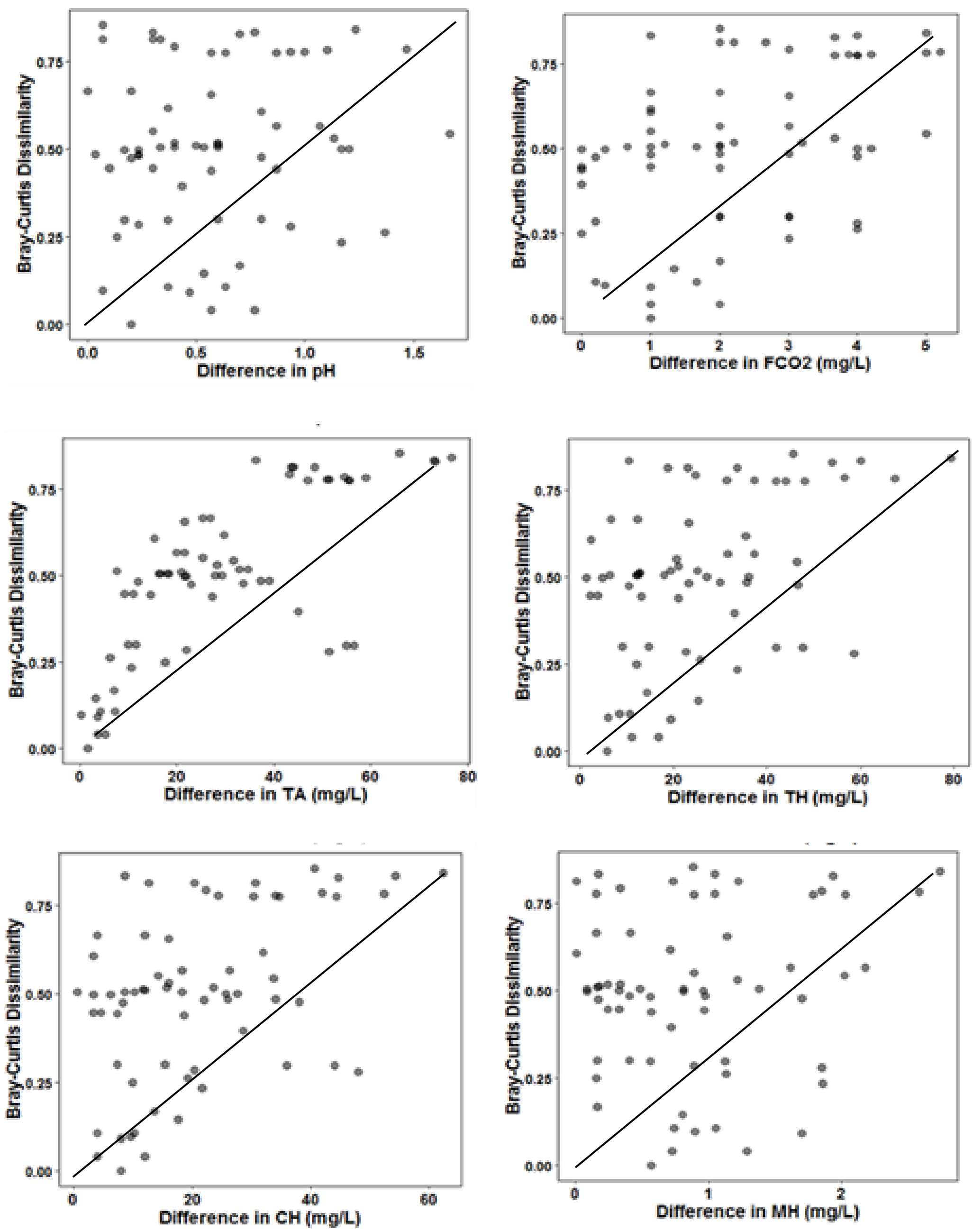
Figure 30: Principal Component Analysis and Scree Plot between fish components and environmental variables

6.14 Relationship between fish species abundance and environmental factors

The result showed that air temperature (AT) distance matrix has no relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic R: 0.008688, p value = 0.4277). Water temperature distance matrix bears no relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.01131, p value = 0.4269). Conductivity distance matrix bears no relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.2866, p value = 0.0256). pH distance matrix bears no relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.1055, p value = 0.2005). MH distance matrix bearsno relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.1403, p value = 0.1607). Mg^{2+} distance matrix bearsno relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.1337, p value = 0.172). NO_3N distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.2213, p value = 0.0674). In other words, as sites become more similar in terms of air temperature, water temperature, conductivity, pH, MH, Mg^{2+} and $NO_{3-}N$, doesn't become more dissimilar in terms of fish community composition (Figure 31).

Turbidity distance matrix has a strong relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.7513, p value = 0.0001). TDS distance matrix has a strong relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.5231, p value = 0.001). DO distance matrix have a strong relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.8544, p value = 0.0001). FCO_2 distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.4337, p value = 0.0074). TA distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.735, p value = 0.0001). TH distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.4328, p value = 0.0029). CH distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.4515, p value = 0.0023). Ca^{2+} distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.4515, p value = 0.0027). TP distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.7313, p value = 0.0001). SO_4 distance matrix bears relationship with the species Bray-Curtis dissimilarity matrix (Mantel statistic r: 0.4468 p value = 0.0034). In other words, as sites become more dissimilar in terms of turbidity, TDS, DO, FCO_2, TA, TH, CH, Ca^{2+}, TP, and SO_4 they also become more dissimilar in terms of fish community composition. Therefore, the results for cumulative environmental factors are strongly correlated with the fish community (Mantel statistic r: 0.5237, p value = 0.0007). Because the fish community is more strongly correlated with the environmental parameters (Figure 31).


Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0
5
10
15
20
25
Difference in Air Temperature (C)
Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0.0
2.5
5.0
7.5
10.0
Difference in Water Temperature (C)
Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0
3
6
9
12
Difference in Turbidity (N.T.U)
Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0
20
40
60
Difference in TDS (mg/L)
Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0
30
60
90
Difference in Conductivity (uS/cm)
Bray-Curtis Dissimilarity
0.00
0.25
0.50
0.75
0
1
2
3
4
5
Difference in Dissolved Oxygen (mg/L)


Bray-Curtis Dissimilarity
Difference in pH
Difference in FCO2 (mg/L)
Difference in TA (mg/L)
Difference in TH (mg/L)
Difference in CH (mg/L)
Difference in MH (mg/L)

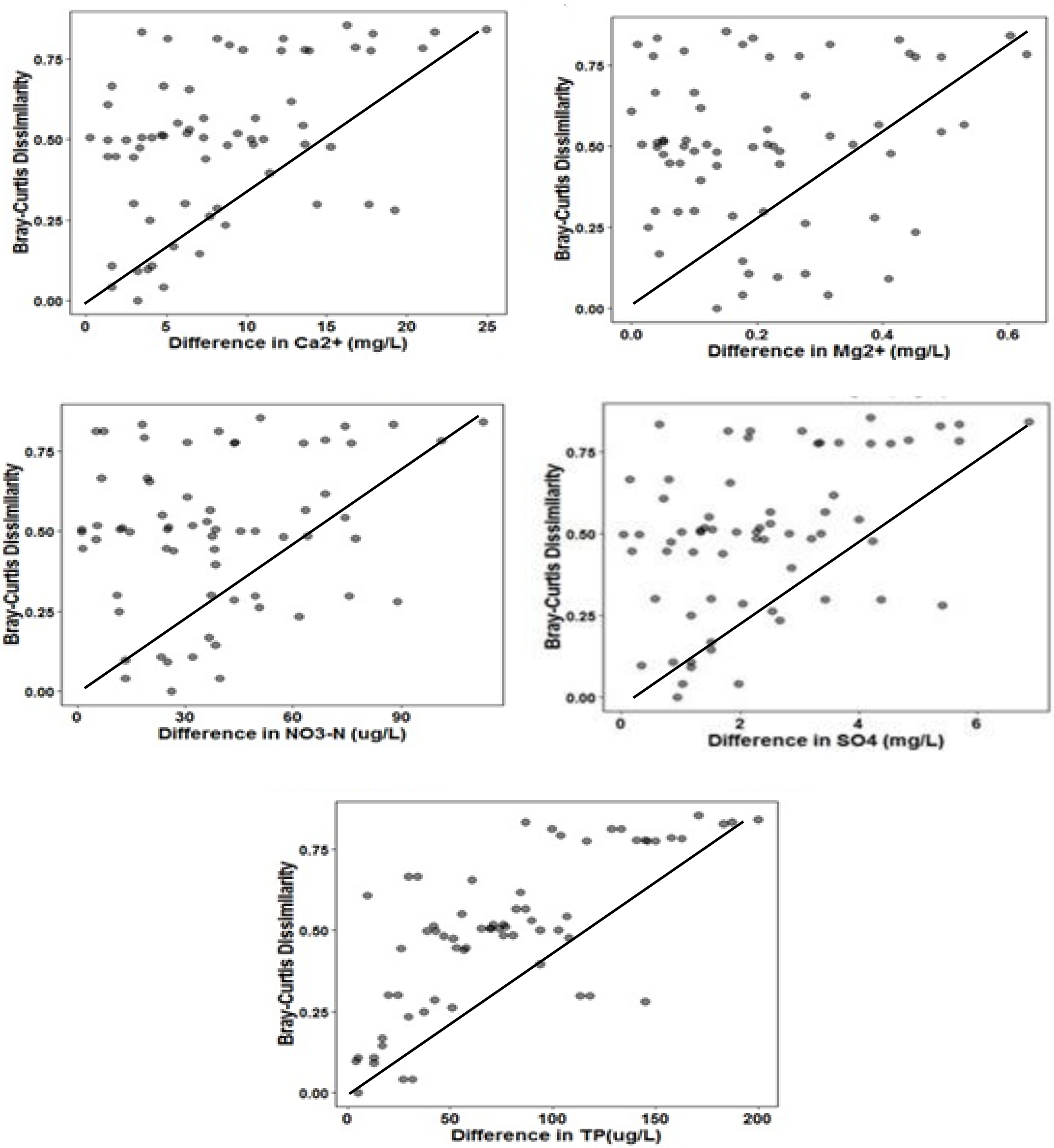


Figure 31: Scatterplot showing relationship between fish species metrices and environmental variables at three sites across four seasons in Vishav stream.

Previous research on riverine ecosystems has identified key environmental factors influencing macro-vertebrate distribution and abundance (Tsisiche, 2018). These factors include habitat diversity, substrate characteristics, flow dynamics, temperature, elevation, stream size, and riparian vegetation, along with various chemical parameters across different spatio-temporal scales (Ouellet *et al.,* 2020; Musonge *et al.,* 2020). Elevated anthropogenic activities often lead to increased turbidity, conductivity, total dissolved solids, and decreased dissolved oxygen levels, resulting in reduced fish species richness. Fish abundance and diversity are closely associated with environmental variables such as dissolved oxygen, pH, and conductivity in riverine environments (Vieira and Tejerina-Garro, 2020). Recent global studies have highlighted that certain freshwater fish species can adjust their distribution patterns in response to climate change, underscoring the direct impact of water quality on fish diversity, distribution, and production (Ogunbanwo, 2022). Changes in river hydrology and connectivity have disrupted the longitudinal migration of fishes worldwide (Xingyuan *et al.*, 2023). Freshwater fish are particularly sensitive to environmental fluctuations, requiring specific ranges of environmental variables for optimal growth and survival (Adam *et al.*, 2022).

Seasonal variations in factors like temperature and dissolved oxygen significantly influence the composition and relative abundance of fish communities (Castillo-Rivera *et al.,* 2002). The presence and distribution of fish species in freshwater ecosystems are also influenced by physicochemical parameters such as pH and dissolved oxygen, crucial for the health and sustainability of fish populations (Gupta *et al.,* 2022). Studies have consistently shown that water temperature, pH, conductivity, dissolved oxygen, and turbidity play pivotal roles in shaping fish diversity and distribution across various river basins (Shrestha *et al.,* 2023; Suwal *et al.,* 2020; Mondal and Bhat, 2020). Furthermore, investigations into water quality parameters in different river systems, including the Kamala River in Nepal and the Bhini stream, a tributary of the River Ravi in Jammu and Kashmir, India, have highlighted significant correlations between parameters such as temperature, electrical conductivity, total dissolved solids (TDS), and nitrates with fish diversity and abundance (Ghimire and Koju, 2021; Gupta *et al.,* 2022). Similarly, studies on tropical savanna headwater streams have emphasized the role of water temperature, conductivity, and dissolved oxygen in shaping fish community structure and composition (Vieira and Tejerina-Garro, 2020). Similarly studies conducted by (Dubey *et al.*, 2012) Kali Gandaki River basin in Nepal, River Singhiya Nephal by (Limbu *et al.*, 2023). Ganjiang river China by (Guo *et al.*, 2018). Soranam, 2022 also reported that enviramental parameters like that dissolved oxygen, total alkalinity, total hardness and TDS are strongly correlated with fish abundance. Our findings align with previous research indicating that environmental variables, particularly those related to water quality, exert significant influences on fish abundance, diversity, and distribution in diverse riverine ecosystems globally.

Objective 3: To assess the anthropogenic threats and challenges of Vaishav stream

6.15 Anthropogenic threat

Anthropogenic threats have emerged as significant disruptors of the ecological equilibrium within aquatic ecosystems, profoundly affecting the natural habitats, breeding sites, and feeding grounds crucial for fish populations. Illicit fishing practices, siltation, rapid urbanization, encroachment by human settlements, and the influx of sewage, domestic effluents, agricultural runoff, as well as pesticides and fertilizers, have collectively imposed considerable stress on water quality, rendering it unsuitable for potable consumption. Moreover, these anthropogenic influences have exerted profound impacts on the ecological dynamics and piscine biodiversity of water bodies, resulting in a gradual decline in the abundance of fish species

6.16 Demographic data of respondents

In this study, respondents were both males and females. The inclusion criterion for the questionnaire survey was on any male or female above 20 years who was available in sampled village/sites during the visit.

6.16.1 Gender wise distribution of respondents

For data analysis (Table 12) 307 males and 93 females were selected.The samplesize for the questionnaire was 400. Out of 400 respondents, 76.75% were males and 23.25% were females. During the survey more males were willing and interested in taking part in the research because anthropogenic activities are male dominated. Very less women are involved in anthropogenic activities and are also less aware about such activities. Earlier (Madyise, 2013) also reported more male willingness while observing impacts of sand mining and gravel extraction for urban development in Gaborone reflecting the fact that sand mining is a male dominated activity.

Table 13: Distribution of respondents by gender

Gender	Frequency	Percentage
Male	307	76.75
Female	93	23.25
Total	**400**	**100**

6.16.2 Distribution of respondents by age

Individuals aged 21-25 years exhibited a notably high frequency (15.75%), primarily comprising educated young adults capable of comprehending the survey questions and discerning the direct or indirect impacts of anthropogenic activities on the Vaishav stream. Conversely, respondents within the age bracket of 26-45 years were relatively evenly distributed, reflecting their ubiquitous presence in the study villages and involvement in various anthropogenic endeavors. Conversely, respondents aged 46-56 years and above were underrepresented, predominantly comprising individuals with limited literacy and awareness regarding the ramifications of anthropogenic activities on the Vaishav stream (Figure 32).

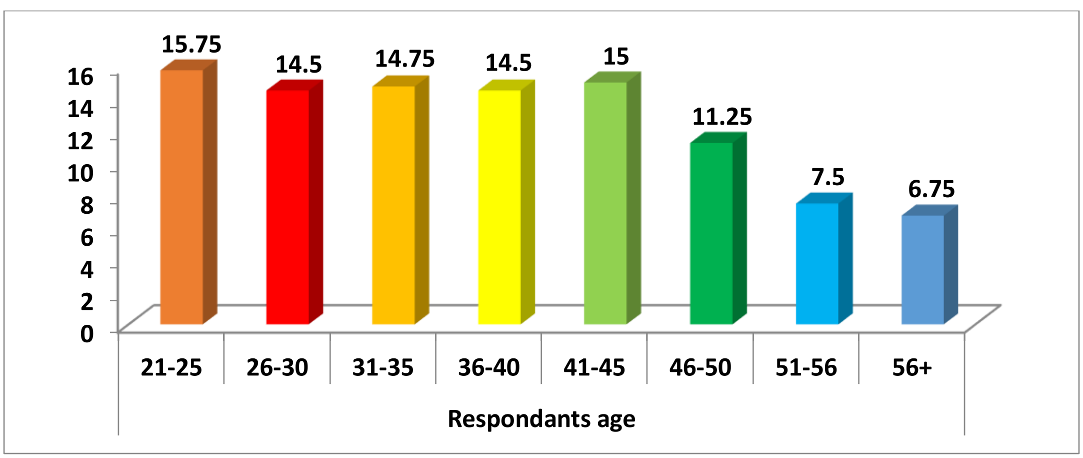


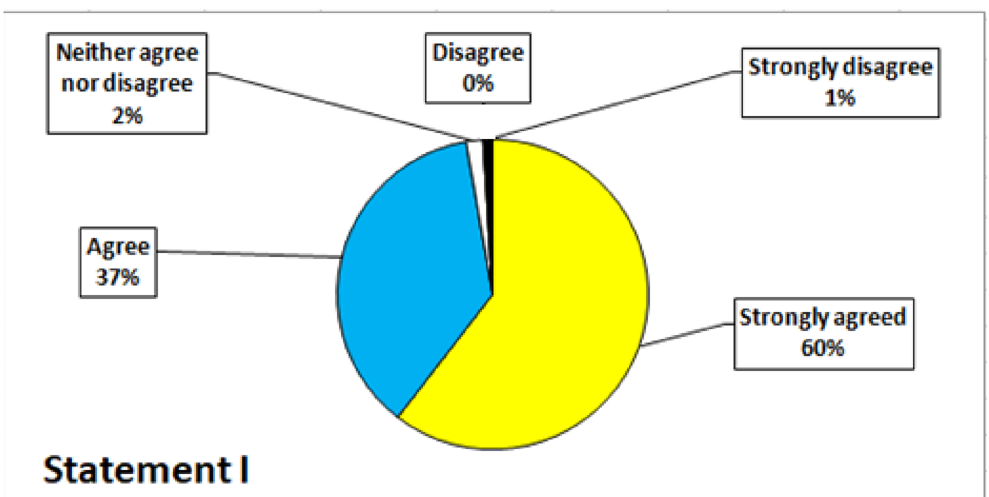
Figure 32: Distribution of respondents by age

6.17 Questionnaire survey/study through respondents

[1] The execution of mining, channelization and slit clearance in stream changes its morphology and makes the stream bed uneven which affects the water flow and subsequently hampers the fish abundance, movement and assemblage.

Statement I

In this study parameter, a survey was conducted among a selected sample, revealing varied responses among the respondents. Among the received responses, a substantial majority of 216 respondents, constituting approximately 60% of the response rate, strongly concurred with the notion that mining, channelization, and silt clearance render the streambed rough in texture, consequently impeding fish mobility, availability, and diversity. Conversely, only 1% of respondents vehemently opposed this argument. However, a considerable proportion of respondents, approximately 37%, expressed agreement with this statement, while none disagreed with the proposition of adverse effects of mining, channelization, and silt clearance on fish availability, diversity, and movement. Moreover, the survey indicated that approximately 2% of respondents remained neutral regarding the anthropogenic impact on fish survival mechanisms (Figure 33).



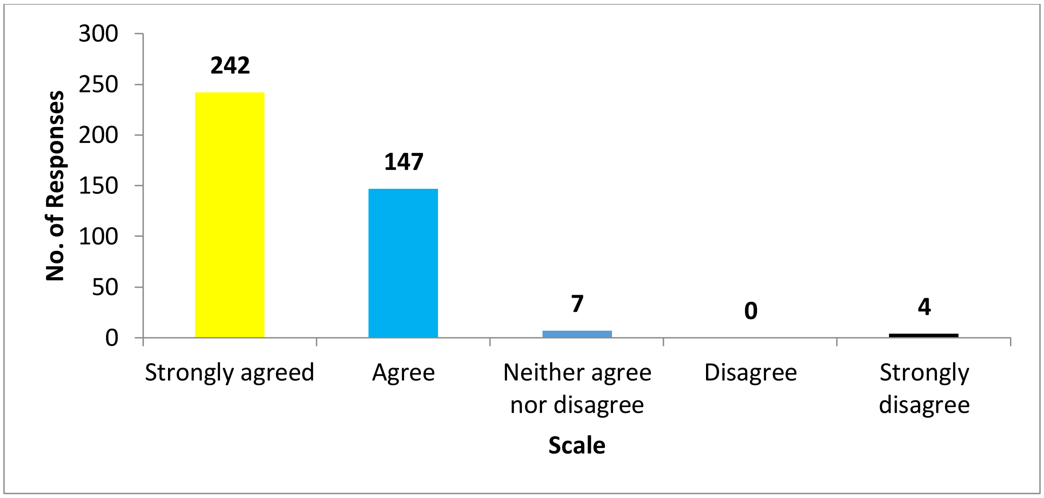


Figure 33: Presenting percentage of responses for Statement I.

[2] Mining is the main threat to fish biodiversity in the stream?

Statement II

There was a diverse set of responses as to the mining being viewed as a critical reason for fish diversity. On this account, around 54% respondents have strongly conceded to the statement unanimously whereas none of the respondents have disagreed. However, in the same vein, 39% i.e. 156 out of 400 responses have slightly agreed and on the contrary, there were only 9 respondents, who have expressed their slight disagreement on viewing mining activity as the main threat to the fish biodiversity. Moreover, it was also noticed that 19 of the total respondents neither agreed nor disagreed on this account (Figure 34).

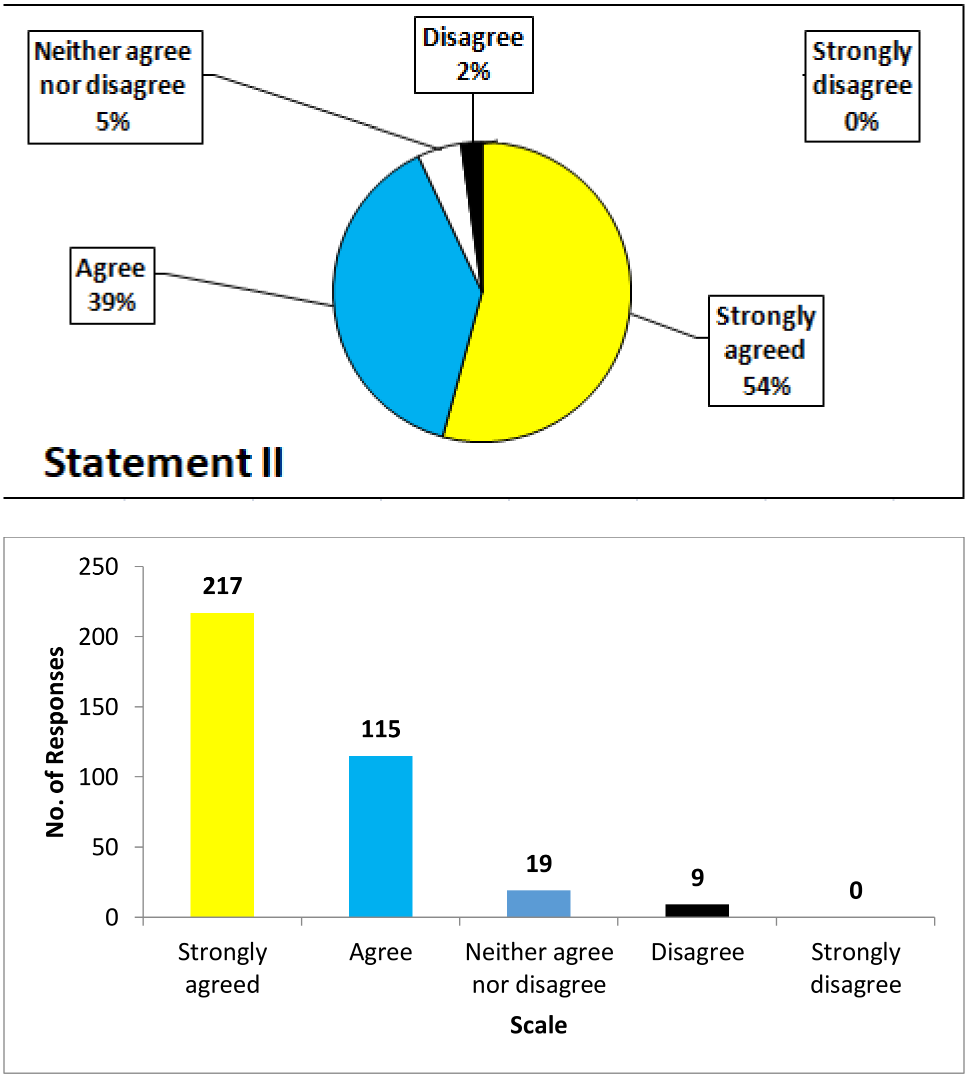


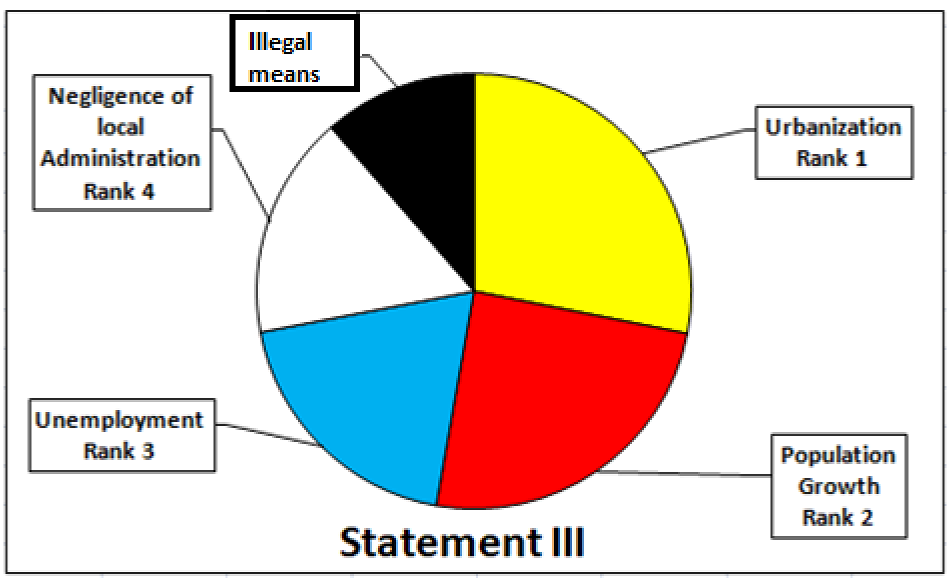
Figure 34: Presenting percentage of responses for Statement II.

[3] How would you rank the following problems which are more responsible for executing of heavy mining in the stream?

Statement III

As analyzed from the findings of statement III, where a substantial majority of respondents concurred that mining has significantly degraded the aquatic environment in riverbeds, posing a significant threat to fish survival, movement, assemblage, and ultimately availability, it became imperative to investigate the underlying causes and associated problems. Consequently, a range of primary reasons and problems were categorized based on demographic, socio-economic, and governance factors. These factors included, among others, urbanization, population growth, unemployment, negligence of local administration, and involvement of illicit entities. Respondents were then tasked with prioritizing these factors by ranking them according to their perceived significance as drivers of mining activities. The survey revealed that urbanization and population growth were identified as the foremost reasons for mining activities, followed by unemployment as the third major factor contributing to the disruption of aquatic habitats. Similarly, negligence on the part of local administration and the influence of illicit entities were also recognized as significant contributors to the deleterious effects of mining activities, thus serving as obstacles to maintaining anthropogenic and aquatic equilibrium. The study's observations are summarized in Figure 3

.



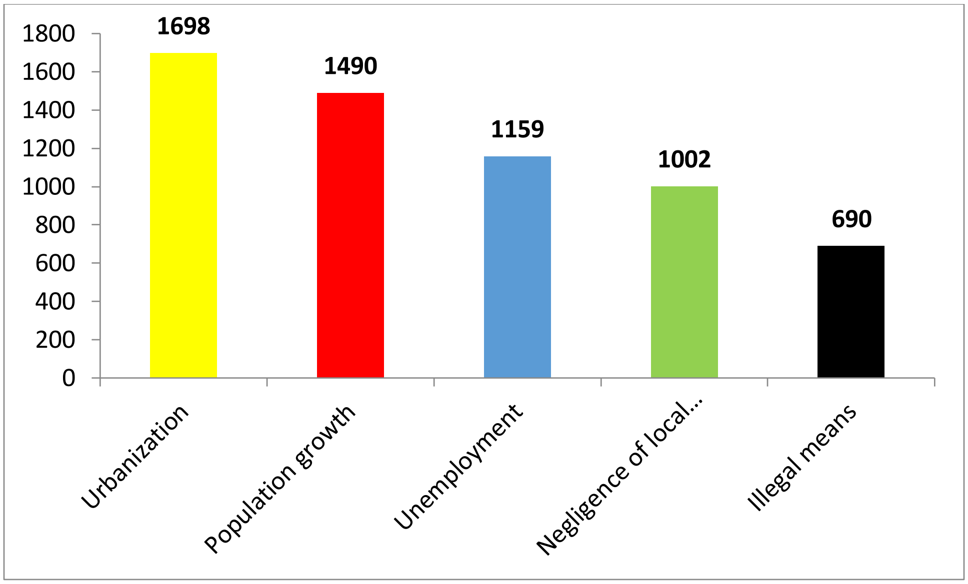


Figure 35: Presenting percentage of responses for Statement III.

[4] The inhabitants along the catchment area of the said stream are not aware about the consequences of heavy mining in the stream like soil erosion, damaging of residential houses, washing of agricultural and horticulture land, roads bridges and so on?

Statement IV

With regard to the heavy mining in the Vaishav stream, respondents were enquired about its adverse consequences in order to gauge the level of its awareness. On this parameter, around 49% respondents were found to be well versed with the impact of heavy mining on the ecosystem. On the contrary, approximately 4% respondents completely disagreed with the direct anthropogenic threat to the surroundings. In the same way, a total of 30% respondents were observed to have considerable knowledge about the negative impact of heavy mining on the persistence of the soil, threat to the residential houses, obsolesce of agricultural and horticultural land and other damage to the natural as well as human made structures. On the opposite side, a share of around 11% respondents slightly disagreed as to the direct interaction of mining with the environment. Moreover, a part of the respondents with a share of 6% were completely oblivion about the impact of mining on soil, residential structures and productive land within the proximity Figure 36 demonstrates the respondent observations with their share.

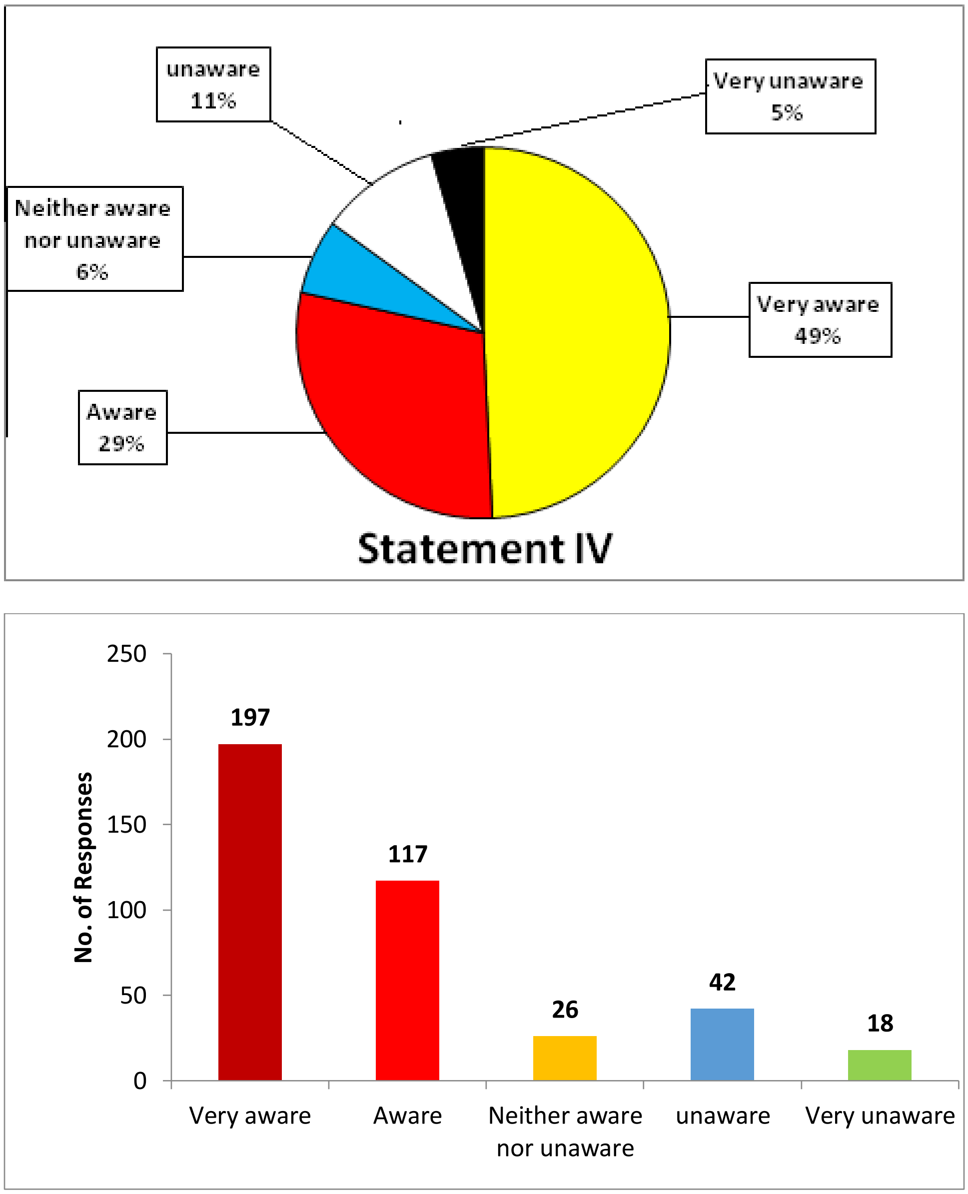
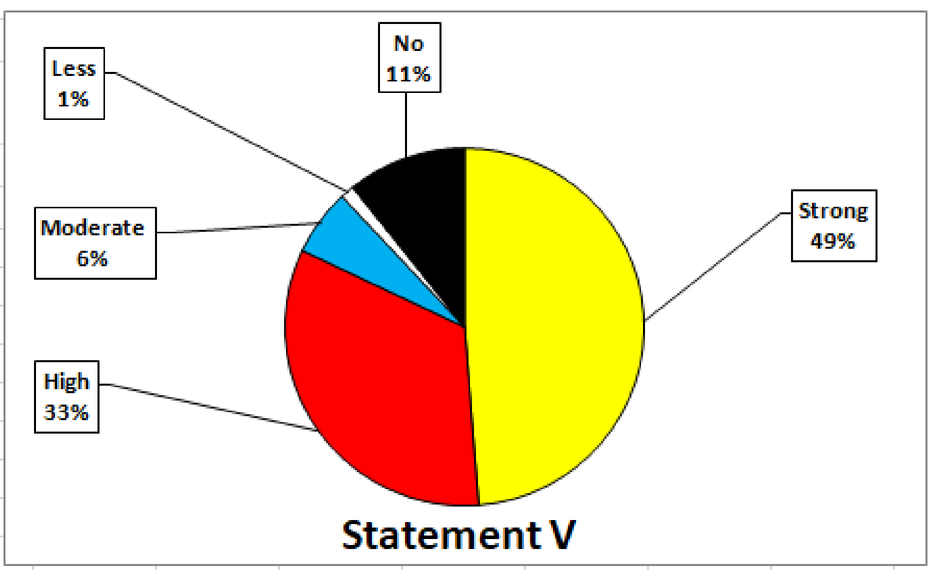


Figure 36: Presenting percentage of responses for Statement IV.

[5] Which according to you is the Impact of mining on fish catch of Vaishav stream?

Statement V

As already observed in the foregoing statements, it was substantially observed that heavy mining disrupts the fish movement, fish assemblage and hence, their availability in the stream. Taking specifically fish catch under consideration in the Vaishav stream, a survey as to the impact of mining on the fish catch was carried out to enquire its intensity from less to strong. On this scale, astonishingly around 11% respondents were witnessed to find no relationship between mining and fish catch, whereas, 1% respondents, approximately, found very less impact of mining on the fish availability. However, 49% respondents revealed a strong association of mining with the fish cath. Furthermore, it was also divulged during the survey that around 6% and 33% respondents found the relationship between mining and fish availability in the Vaishav stream as moderate and high, respectively. Figure 37 exhibits the responses of respondents recorded during the survey.



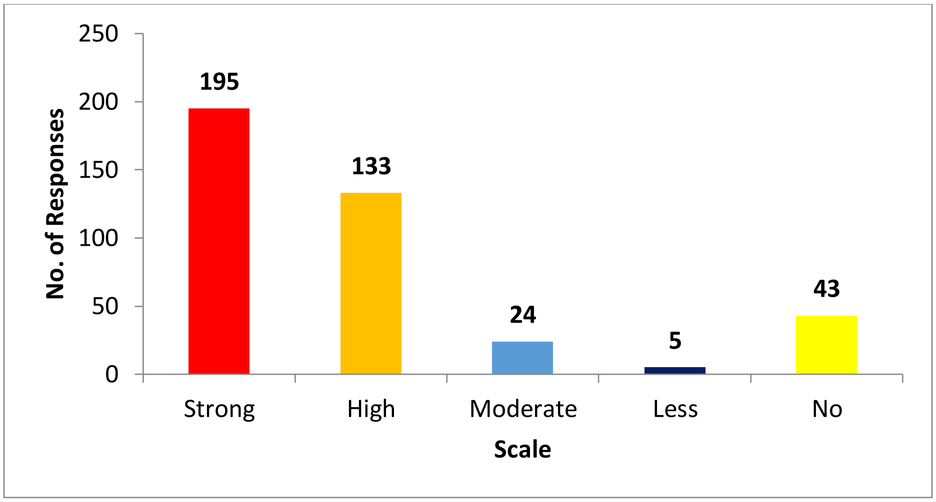
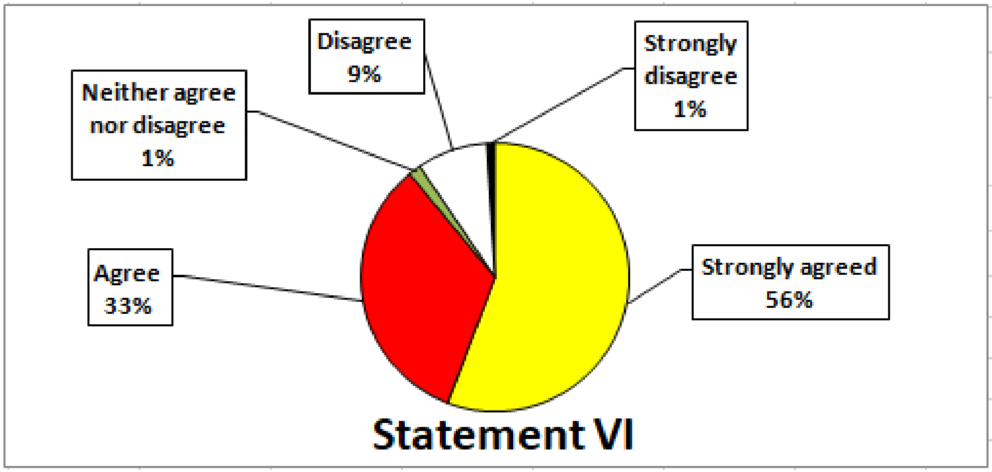


Figure 37: Presenting percentage of responses for Statement V.

[6] Mining is the most important cause for habitat and breeding ground loss of fishes.

Statement VI

Similarly to the preceding parameter, the impact of mining on ground loss for fish habitat and breeding was scrutinized among respondents residing specifically along the stream banks. During the survey, 56% of sampled respondents strongly asserted that mining significantly disrupts fish habitat and breeding processes, while only 1% expressed strong disagreement with this notion. Moreover, approximately 33% of respondents moderately agreed with the direct association between mining and fish survival, whereas an equal proportion of around 32% perceived this relationship as inconsequential. Additionally, 1% of respondents remained neutral on this parameter. The responses, captured on a five-point Likert scale, are summarized in Figure 38.



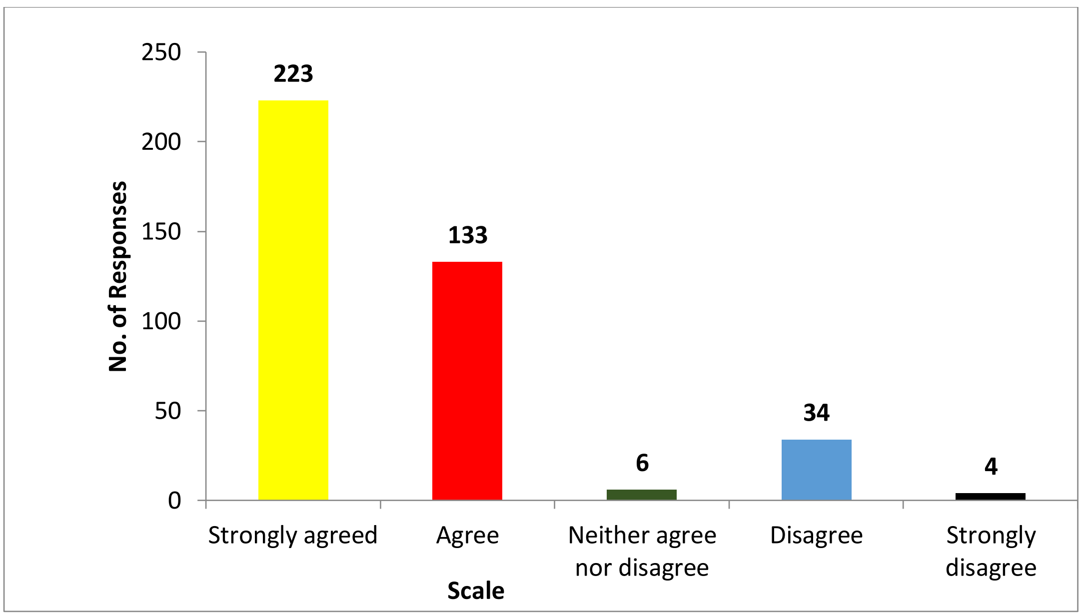


Figure 38: Presenting percentage of responses for Statement VI.

[7] The stream water is still potable for drinking purpose.

Statement VII

Following anthropogenic activities such as mining, the suitability of Vaishav stream water for drinking purposes was assessed among respondents using a five-point Likert scale. At the highest end, approximately 14% of respondents strongly agreed on the water's drinkability, whereas about 25% strongly disagreed with its suitability for drinking. However, nearly 17% of respondents believed the water to be acceptable for drinking, while 37% strongly disagreed with this notion. Additionally, 6% of respondents remained neutral regarding the potability of Vaishav stream water. The responses observed during the study are summarized in Figure 39.

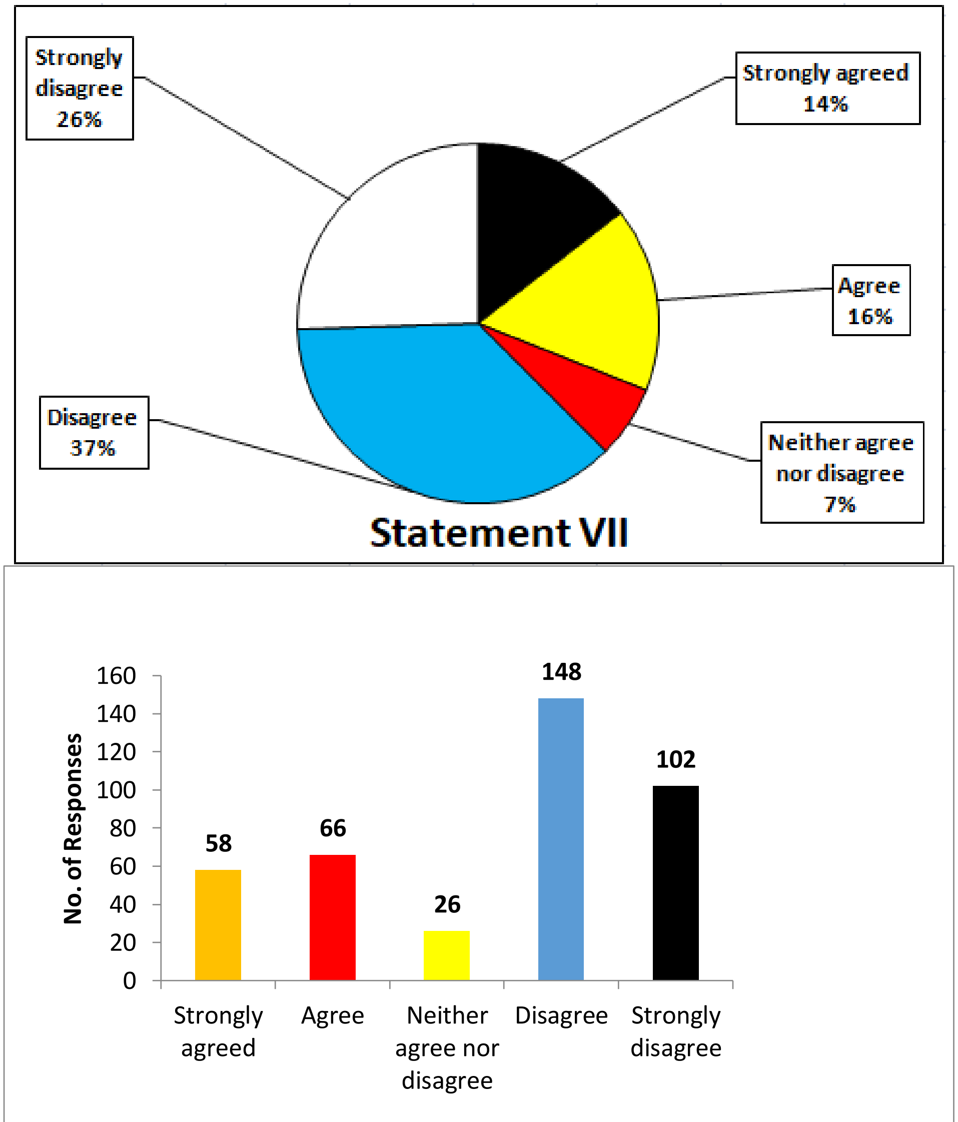
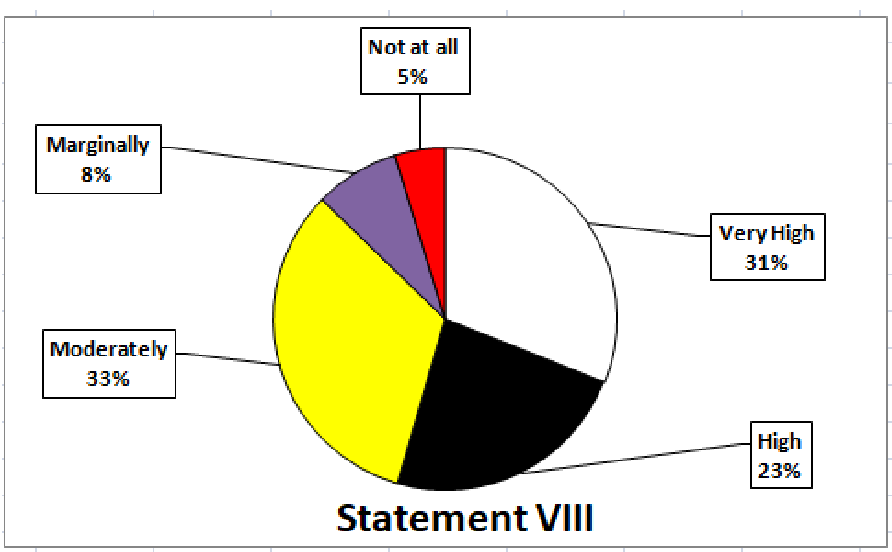


Figure 39: Presenting percentage of responses for Statement VII.

[8] To what extent the Vaishav stream is polluted.

Statement VIII

In consideration of the aforementioned statement, the degree of pollution in the Vaishav stream was assessed among the selected sample. Pollution levels were categorized into five severity levels: from "not at all" to "very high." Approximately 31% of respondents indicated a perception of very high pollution in the sampled stream, while 5% asserted no pollution at all. Conversely, 23% of respondents acknowledged a high level of pollution in the Vaishav stream. Moreover, 33% and 8% of respondents perceived the pollution intensity as marginally moderate and marginal, respectively. The rankings of pollutants reported by respondents during the study are detailed in Figure 40.



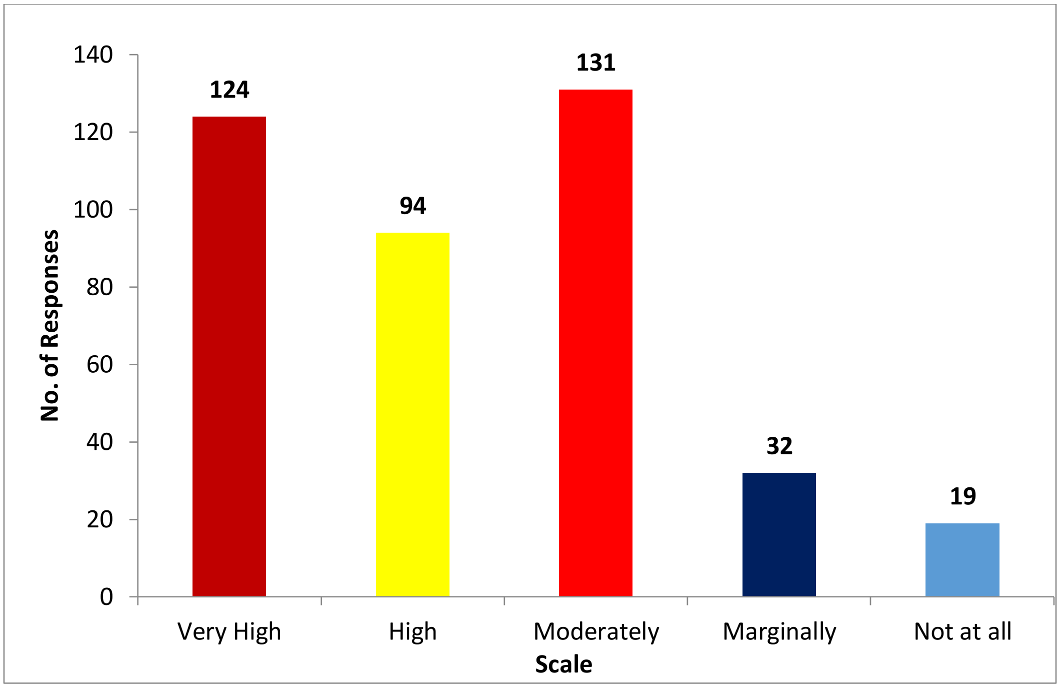
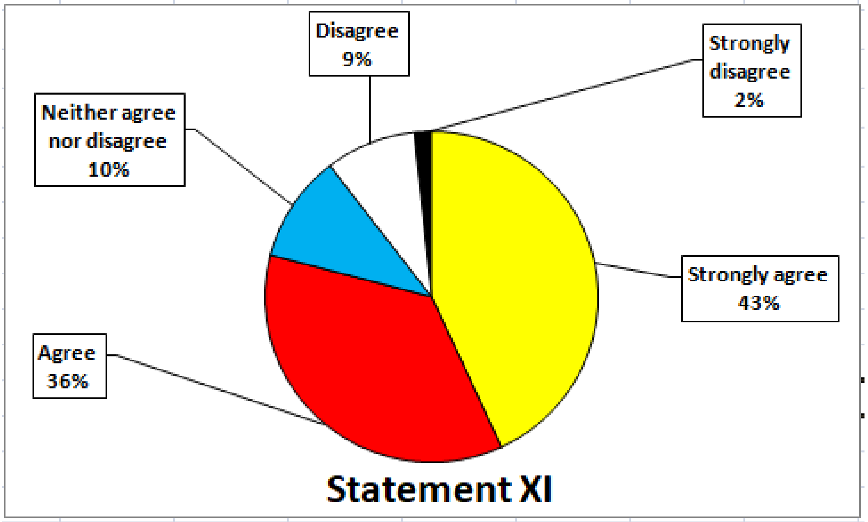


Figure 40: Presenting percentage responses of the survey for Statement VIII.

[9]The illegal fishing like (chemicals and electric currents etc) are used for fish capturing in the said stream.

Statement IX

With regard to catching of fish in the sample stream, the illegal ways of capturing fish were also enquired by the researchers on a five-point likert scale. The prevalent and widely practiced illegal ways include in particular the use of chemicals and electric currents. During the survey, the maximum respondents i.e. 45% strongly agreed on the argument, while as, a minimum of 2% sample respondents strongly disagreed on this statement. In the same manner, 38% respondents substantially believed the use of illegal ways while as 9% respondents notably disagreed on the unlawful practices to be employed for capturing fishes in the Vaishav stream. In addition to this, 11% respondents were observed to have responded in a neutral fashion Figure 41 is a consolidation of responses given by sample respondents on a five-point likert scale during the survey.



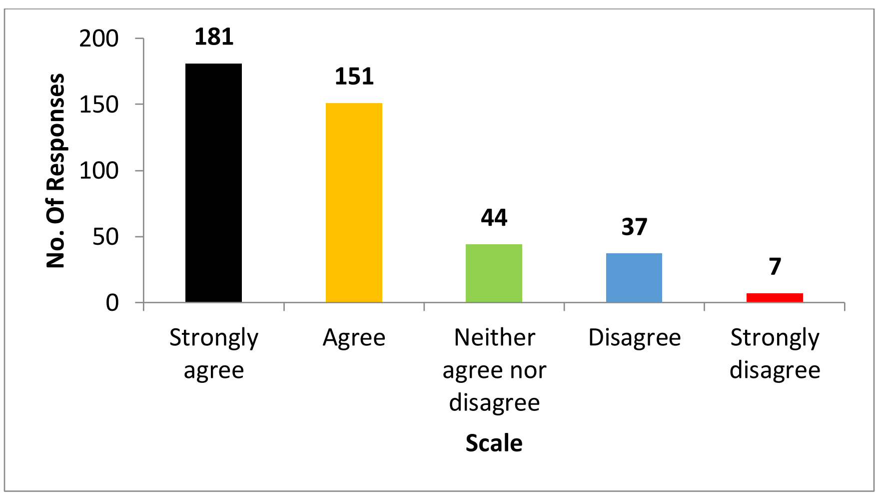
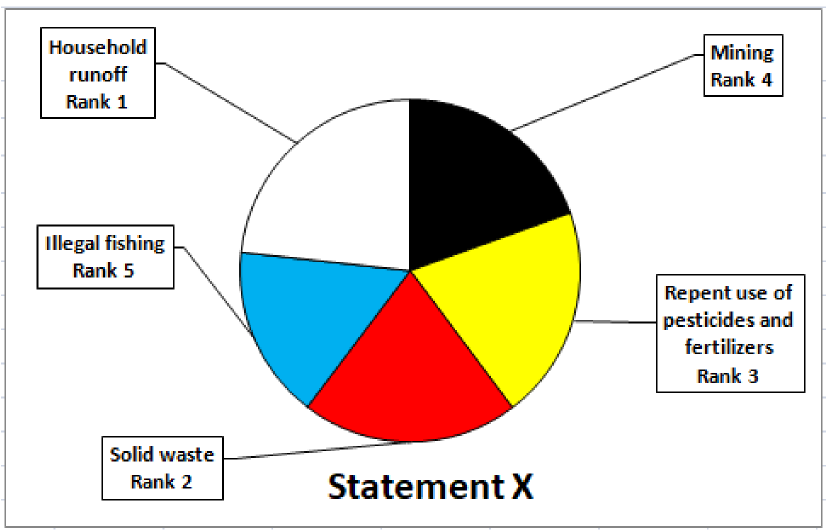


Figure 41: Presenting percentage responses of the survey for Statement IX.

[10] How would you rank the following pollutants in terms of threat that the stream is facing according to their order of importance.

Statement X

The survey also included ranking of different pollutants in order of their importance as one of the important parameters. The possible pollutants included in the scale were selected depending on the factors responsible for degradation of the stream especially for fish survival and livelihood of the nearby inhabitants and henceforth, include mining, use of pesticides and fertilizers, solid wastes, illegal fishing and household runoff. During the survey, respondents were asked to rank these pollutants in order of their perceived impact on the stream. It was advocated that household runoff was categorized as the top most pollutant followed by solid wastes disposed off into the stream. Subsequently, abundant use of pesticides and fertilizers flushed into the stream ranked as third most factor attributed for stream contamination followed by mining activities. In addition to this, illegal use of chemicals and electric currents were credited as the pollutant on the lowest side. Figure 42 represents the responses given by sample respondents on a five point likert scale during the survey for Statement X.



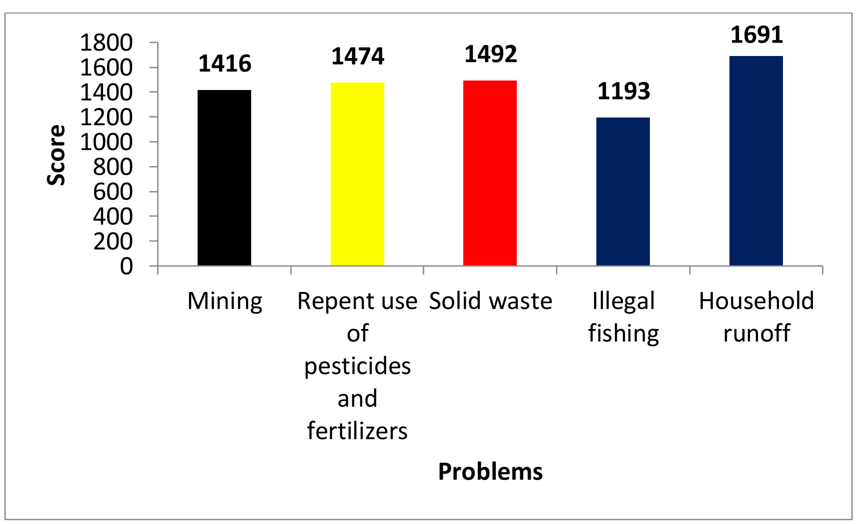


Figure 42: Presenting percentage responses of the survey for Statement X.

[11] How would you rank the following problems in terms of importance which is more responsible for deteriorating the water quality of the said stream?

Statement XI

Likewise the above statement, respondents were also questioned about the ranking of multiple factors responsible for deteriorating the quality of water in the sample stream. The different water pollutants included in the scale are deforestation, solid wastes, mining, encroachment, sewage, illegal fishing, pesticides, insecticides and fertilizers, washing and bathing, stone crushers, solid waste dumping and built latrines and open defecation on banks. Among all these factors, sewage was viewed as a major water pollutant followed by latrines and open defecation on the banks. Moreover, mining and solid waste dumping were ranked as third and fourth pollutant responsible for water quality deterioration while as pesticides, insecticides and fertilizers were rated as fifth water pollutant. Furthermore, solid waste pollution like polythene was graded as sixth such pollutant whereas, illegal fishing instruments were positioned as seventh water pollutant. In the same vein, deforestation and encroachment were perceived as eighth and ninth such pollutant respectively; while as washing and bathing was levelled at tenth position by the sample respondents. In addition to this, stone crushers were ranked at the last point on the scale by the respondents. Figure 43 represents the responses given by sample respondents on a five point likert scale during the survey for Statement XI.

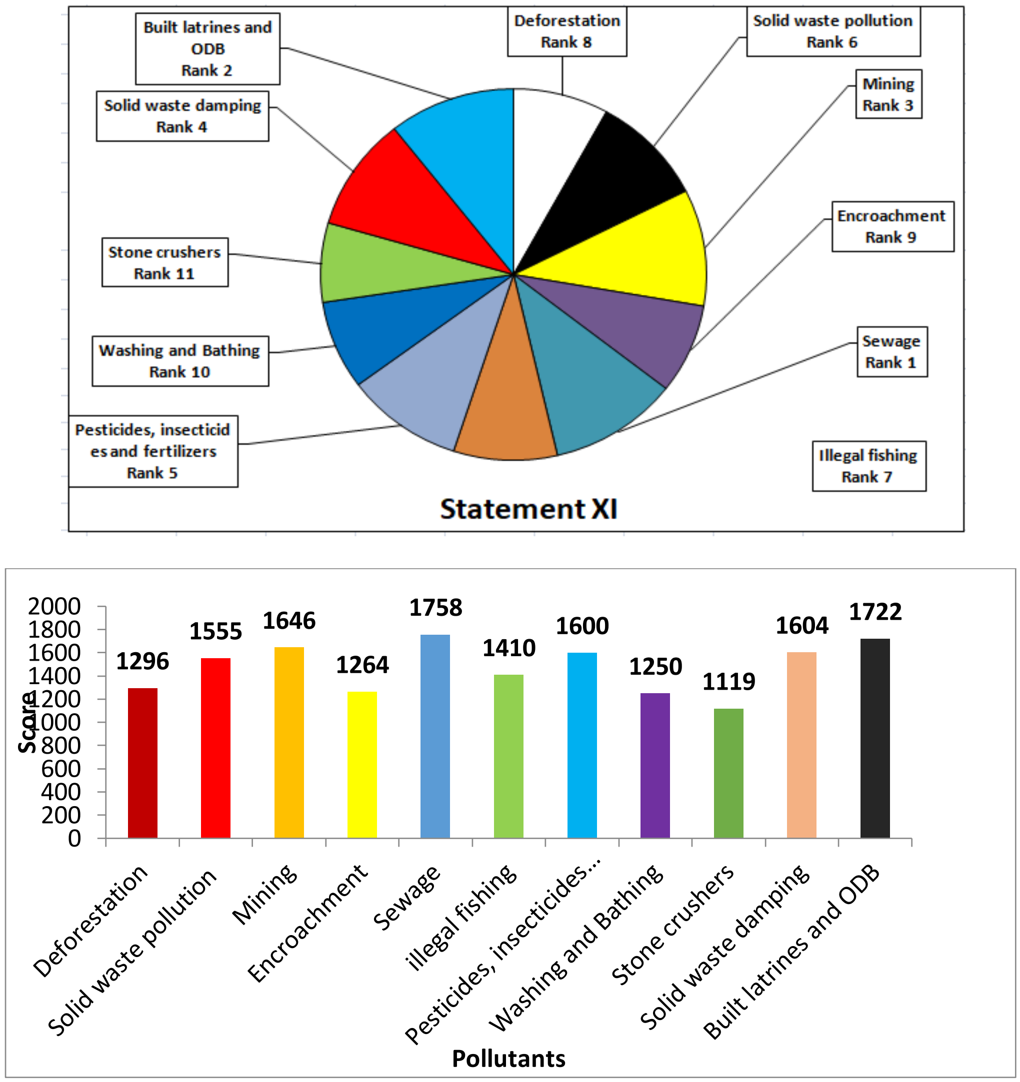
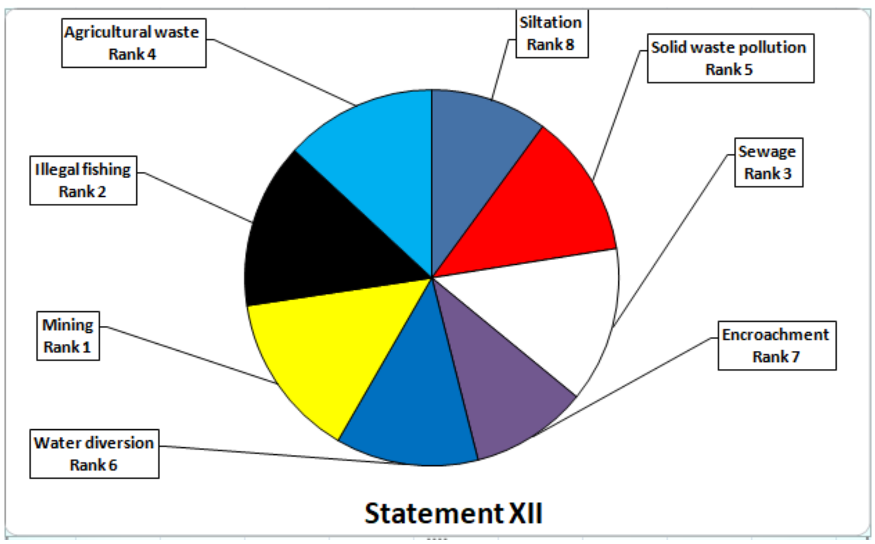


Figure 43: Presenting percentage responses of the survey for Statement XI.

[12] Which of the following anthropogenic threats is the main cause of decline in fish diversity of the Vaishav stream in order of importance?

Statement XII

Given the anthropogenic threats, there is a subsequent decline in the fish breeds and diversity in the streams. The various human threats detrimental for the survival of fish included in the scale were siltation, solid waste pollution, sewage, encroachment, water diversion, mining, illegal fishing and agricultural wastes. The survey was attempted to enquire such threats in order of their seriousness and their adverse consequences on the fish diversity. During the survey it was asserted that mining proves to be major threat for fish assemblage while as siltation was ranked as the last human threat posed to fish environment. In the parallel way, illegal fishing, sewage and agricultural waste occupied the second, third and fourth position as human threats in order of their importance, respectively. Furthermore, solid waste, water diversion and human encroachment were graded as fifth, sixth and seventh anthropogenic intimidation to the ideal fish survival and hence, their breeds and diversity.The study's observations are summarized in Figure 44 below.



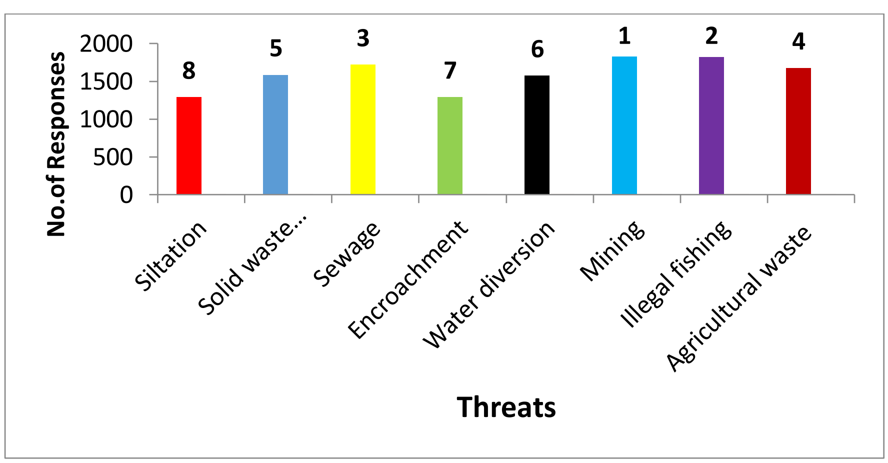
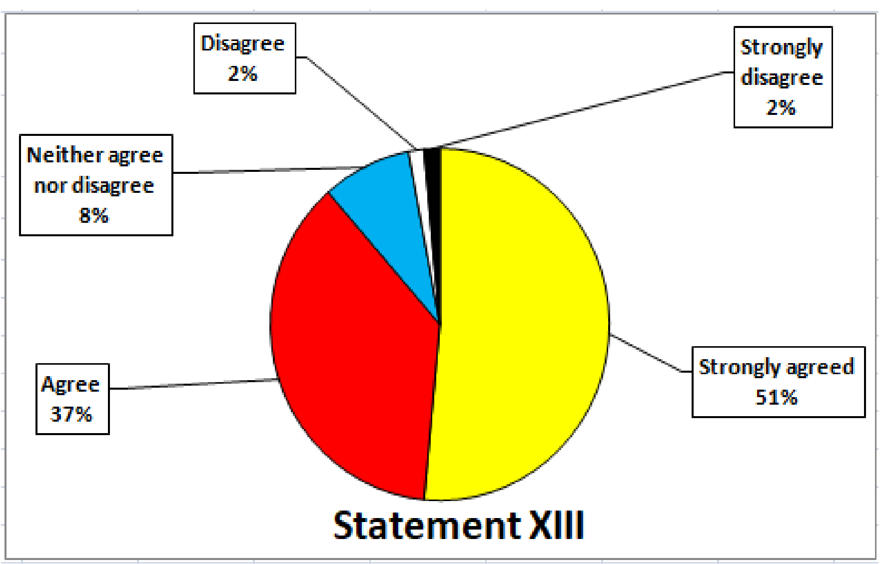


Figure 44: Presenting percentage responses of the survey for Statement XII.

[13] The continuous increase in population growth along the catchment area of the said stream has also increased the anthropogenic disturbances which subsequently deteriorating the water quality and declines in fish diversity.

Statement XIII

The anthropogenic threats irrefutably disrupt the aquatic environment through a number of ways. With regard to the survey, these threats deteriorate the quality of water and interrupt the fish diversity in the streams. In the survey, it was also aimed to investigate such awareness among the respondents and to possibly derive some logical conclusions, respondents were asked about deterioration of quality of water and interruption in the fish diversity caused due to human intervention. It was elucidated that 51% respondents strongly agreed and approximately 1% respondents strongly denied the statement. Similarly, 37% of respondents moderately believed the statement to be true while as 1% respondents denied in a considerable fashion. Moreover, there was also a chunk of respondents of around 9%, who were neutral regarding the statement.The study's observations are summarized in Figure 45 below



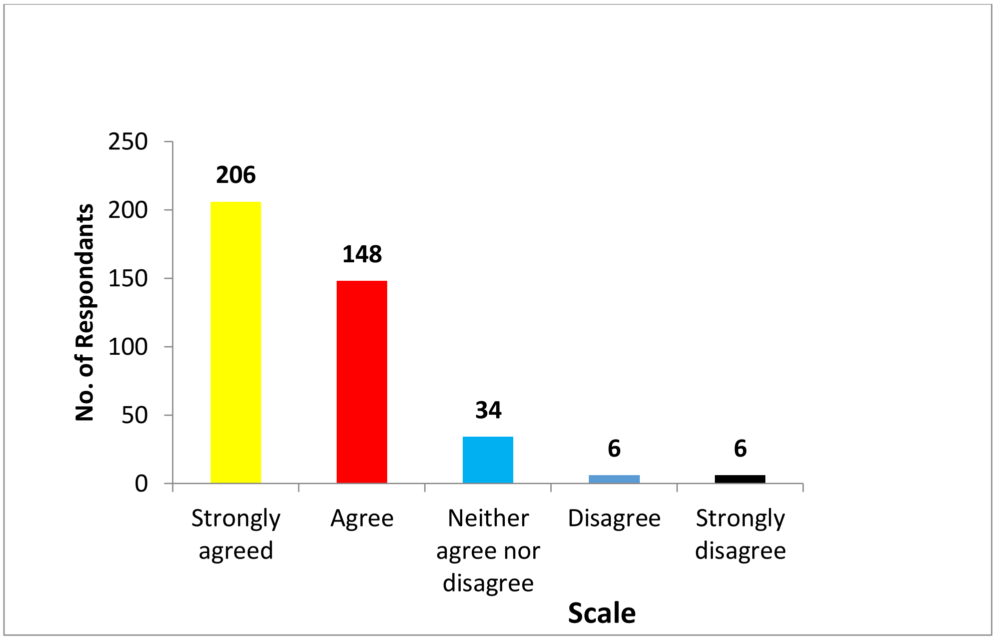


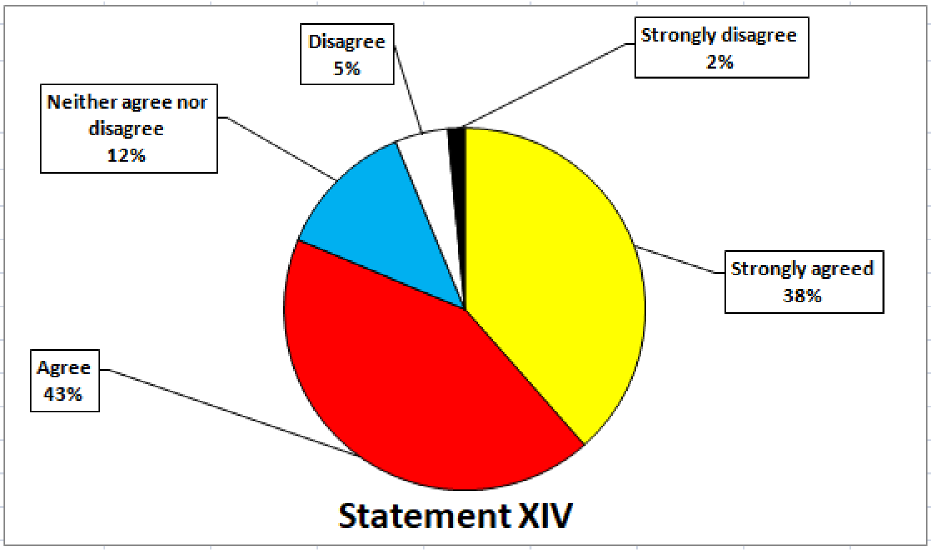
Figure 45: Presenting percentage responses of the survey for Statement XIII.

[14] The threats mentioned in the said questionnaire are challenges for the public in general and government in particular

Statement XIV

The anthropogenic threats so far discussed and enquired from the sample respondents apparently played a great role in disrupting the balance between human and aquatic environment. More specifically, mining, illegal fishing, sewage, household runoffs and agricultural wastes including use of fertilizers and pesticides flushed into the stream, have significantly deteriorated the quality of water for potable use and substantially interrupted the fish culture in the stream. Resultantly, these prove to be challenges for the conscious habitation and administration in particular. The same was attempted to be enquired from the sample respondents. During the survey, it was reflected that 39% respondents significantly agreed on the statement while as 1% respondents do not acknowledge these anthropogenic threats as challenges neither for the pubic nor for the administration. Similarly, there was a share of 43% respondents who moderately accepted these threats as challenges whereas nearly about 5% respondents relatively disagreed on the statement. In addition to this, roughly 12% respondents were found to be neutral on the statement.

Figure 46 represents the responses given by sample respondents on a five point likert scale during the survey for Statement XIV



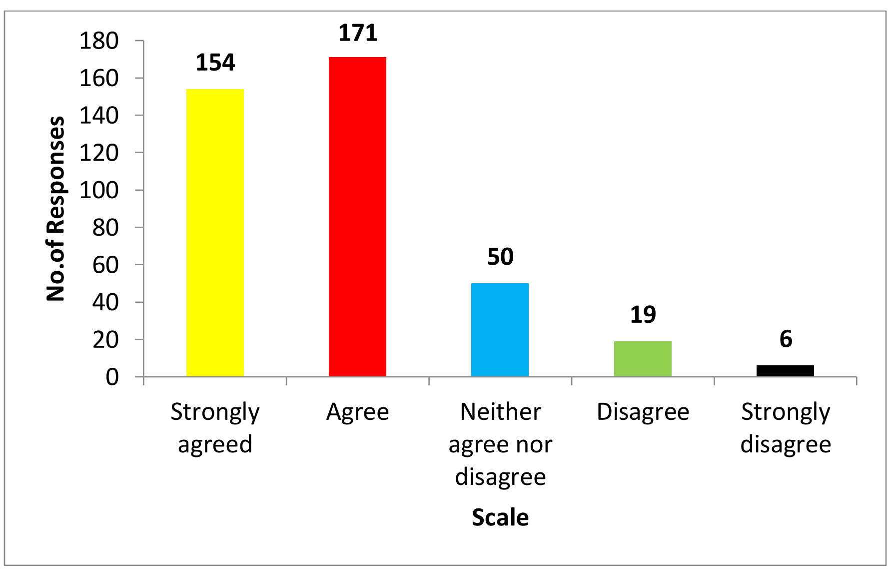


Figure 46: Presenting percentage responses of the survey for Statement X

6.18 Impact of Anthropogenic threats on Water and fish diversity

6.18.1 Anthropogenic Threats

Anthropogenic activities exert multifaceted impacts on stream ecology due to rapid human population growth, agricultural practices, sediment accumulation, nutrient enrichment, and industrial development (Bhat *et al.*, 2021). These disturbances pose severe threats to both humans and 99.8% of riverine environments worldwide. Particularly sensitive regions such as the Himalayas, which serve as vital water sources, are experiencing accelerated glacier melting due to anthropogenic pressures, endangering water resources, biodiversity, and associated ecosystem services (Chandra *et al*., 2024;Romshoo *et al*., 2020). The effects of climatic change require minimizing other anthropogenic disturbances, such as water pollution and habitat fragmentation (Vaughan and Gotelli, 2019). Changes in landscape patterns globally, driven by contemporary agricultural techniques, lead to deforestation, soil erosion, and water pollution from pesticides and nutrients. These alterations profoundly impact the integrity and health of stream ecosystems with time, space, and scale (Giri, 2021).

Human population density and associated land use developments, including urbanization and road construction, alter stream hydrology and channel morphology, significantly impacting aquatic organisms (Green *et al.*, 2022). Agriculture and urbanization are among the most influential land use types that contribute to increased hydrological alterations and channelization (Puerto *et al.*, 2022). Urbanization introduces direct runoff pollutants such as sewage into streams, while agriculture and urbanization alter hydrology, partly mitigated by measures like riparian forest buffers and vegetative strips (Schurings *et al.*, 2023).Anthropogenic pollutants, released into aquatic ecosystems from various sources including industrialization and urbanization, contaminate water resources, adversely affecting aquatic fauna, including fishes (Mushtaq *et al.*, 2020).

The consequences of pollution are particularly evident in regions like Jammu and Kashmir, where untreated effluents and agricultural chemicals degrade water quality and threaten aquatic organisms (Qayoom *et al.,* 2022; Islam *et al.,* 2023). Moreover, physical alterations to landscapes, such as channelization and mining (Figure 47, 48), exacerbate habitat destruction, sedimentation, and pollution, further compromising aquatic ecosystems (Khatri and Tyagi, 2015). These activities lead to channel widening, altered water flow, increased nutrient accumulation, eliminate riparian vegetation, and elevated pollution levels, negatively impacting water quality, biodiversity, and ecosystem health (Bashir *et al.,* 2020; Hamid *et al.,* 2020). In addition to this, mining cause damages to stream banks and genral ecosystem due to formation of accesses ramps to riverbed which generate extra load of vechiles that negatively effects the aquatic enviroment (Yen and Rohasliney, 2013).The increase in sedimation at mining sites due to stockpiling as well as damping of excess mining material also effect the faunal population and makes aquatic ecosystem instable.Besides that the continous removel of stream bed material erodes the stream banks and increase the sedmintation load in water body during high flow (Pacetti *et al*., 2020). Mining activities have significant environmental ramifications at various scales, including point, large, regional, and global levels, both directly and indirectly (Bhat *et al.,* 2021). These effects encompass sinkhole formation, erosion, biodiversity loss, and the release of chemicals from mining processes.In streams, mining directly damages ecosystems, causing habitat loss, altering channel morphology, and deteriorating water quality, thus affecting fish movement and biodiversity. A survey conducted during this study revealed widespread acknowledgment of mining's impact on fish biodiversity, with a majority of respondents strongly agreeing or agreeing with this notion. The alteration of stream morphology due to mining results in the loss of habitat, food sources, and breeding sites, ultimately affecting fish populations and community composition (Deinet *et al*., 2020). Hydraulic changes resulting from mining activities lead to stream channel incision and widening, favoring invasive species over native ones and altering physicochemical water parameters (Koehnken *et al.,* 2020) (Figure 49). Fish, being sensitive to environmental changes, increased turbidity, temperature fluctuations and reducetion in dissolved oxygen level in aquatic ecosystem (Hamel and Chapman, 2024). Moreover, increase in turbidity can also impede the photosynthetic activity and cause depletion of dissolved oxygen as the light plays an important role in the growth, diversity and density of aquatic flora and fauna (Sheek *et al*.,2017) Besides these mining operations also have a huge negative impact, altering the hydrology as well as damaging the habitats of fish and benthic organisms as well as destroying spawning grounds, thereby disrupting the food chain and causing a decrease in fish resources. Sand mining activities should therefore be strictly controlled according to river conditions, and simultaneously, fish habitats and breeding grounds should be protected (Hu *et al.*, 2014). Change in water flow and increases the accumulation of nutrients in streams that leads to eutrophication of water bodies, which could affect the human health & fishes. Channelized streams carries huge volume of water loaded with pollutants, sediments and heavy metals which degrade the water quality and increases the cost of drinking water treatment (Bashir *et al.*, 2020). Mining have significantly reduced the abundance of planktons, periphytons, in the water bodies which are the primary source of food for fishes as reported by along the Ganga River (Jaiswal *et al*.,2021). The invertebrates form the bulk of primary consumers in riverine and lake food webs, such impacts can affect higher order organisms and animals in the food chain, all the way to human beings due to loss of fish (Wang *et al*., 2021).Removal of boulders and benthic sediment aggregates of different sizes that are used by fishes for spawning, breeding and also provides shelter to the growing embryos within them are lost by mining (Gray, 2023).

Decreased habitat complexity through the replacement of substrates containing fine-grained aggregates threatens reproductive guild requiring coarse substrates for nesting, which directly impacted silt sensitive fish species. Decline in the fish population such as mahseer, common carb, rohuwas reported in Madhya Pradesh due to increasing turbidity caused by mining activities.

Mining activities effects the feeding and food web as the sight feeders are more harmed than non-sight feeders at higher level of turbidity, and fish from non-mining sites have been shown to obtain nutrients from the benthos, whereas fish in mining areas relied on phytoplankton and terrestrial detritus (Scharnweber *et al*.,2024). Overall, anthropogenic activities pose significant threats to stream ecosystems worldwide, necessitating comprehensive conservation and management strategies to mitigate their adverse impacts and safeguard freshwater resources and biodiversity (Ahmad *et al*., 2022)

During the present study, respondents were asked to rank the factor which is more responsible for heavy mining in Vaishav stream among the factors, urbanization was ranked 1 and is likely the primary driver, as it creates a consistent and growing demand for construction materials, leading to sustained and heavy mining. However, it is essential to consider how these factors interact. For example, urbanization, coupled with population growth and unemployment, can intensify mining activities, particularly if local administration fails to regulate the process effectively.Urbanization leads to increased gatherings of people, market activities that forces migration of people for labour directly or indirectly influences the environment (Nuissal and Siedentop, 2021) Expanding urban areas increase demand for resources like sand and gravel for construction, driving mining activities. Urbanization also leads to the development of infrastructure, which requires significant amounts of these materials (Bryceson and Mackinnon, 2012). Urbanization leads to the expansion of infrastructure and development, which frequently encroaches on natural habitats, including streams. The development associated with urbanization can increase sedimentation and pollution in streams, further stressing aquatic ecosystems and complicating mining activities. Urbanization leads to change in land-use and land cover that is increasing rapidly across the globe and modifies the croplands, wetlands, forests, pastures, grasslands, and other land cover forms to commercial, industrial residential, and transportation purposes. Besides construction works such as river embankments, irrigation and drainage, bridges, water wells, dams, and reservoirs (Muller *et al.,* 2020). Further, land cover modifications are typically the first sign of urbanization of a region. It changes the vegetation cover, porosity of soil, topography, and surface water properties that influences the recycling groundwater movements (Burri *et al.,* 2019).Urbanization introduces direct runoff pollutants such as sewage into streams, while agriculture and urbanization alter hydrology, partly mitigated by measures like riparian forest buffers and vegetative strips

(Turunen *et al*., 2019). Anthropogenic pollutants, released into aquatic ecosystems from various sources including industrialization and urbanization, contaminate water resources, adversely affecting aquatic fauna, including fishes (Bagchi, 2010). Growing populations need more housing, roads, and other facilities, leading to higher demand for construction materials. This often results in increased mining to meet the needs of a larger population.To meet growing demands resources are exploited to such an extent that they may not be replenished. The growing population is associated with severe environmental consequences such as deforestation, soil degradation, pollution and a loss of biodiversity (Pimm, 2001). Increased population leads to unemployment people mostly residing on the stream and rivers banks prefer to get their livelihood from the water resources which include mining and fisheries due to easy accesses.Besides that rapid population growth can lead to increased demand for natural resources, including minerals extracted from streams. This often results in increased mining activities to meet the needs of the expanding population, which can exacerbate environmental degradation and strain on local water bodies. High unemployment rates can drive local populations to engage in illegal or unregulated mining activities as a source of livelihood even if it is in illegal. These activities are often carried out with minimal environmental safeguards, leading to significant ecological damage and reduced water quality. High unemployment rates can push people toward mining as a source of income,. This can lead to unregulated and excessive mining practices (Anwar, *et al* 2024**).**similarly, negligence of the local administration and mafia also play a vital role in the destructive mining activities thereby deteriorating aquatic equilibrium. Weak enforcement of regulations or lack of monitoring by local authorities can allow illegal mining to flourish. Negligence can also lead to corruption, where illegal activities go unchecked due to bribes or lack of interest from officials. In regions where organized crime groups are involved in illegal mining, there is often an increase in illegal and unregulated mining operations due to their influence and financial power. . These operations tend to disregard environmental regulations and can lead to severe ecological damage, including the destruction of stream habitats and contamination of water sources (Hoffmann, 2021.

Figure 47: Showing the mining activities in four different sites A, B, C and D in Vaishav Stream.

Figure 48: Showing Channalisation in four different locations A, B, C and D in Vaishav Stream**.**

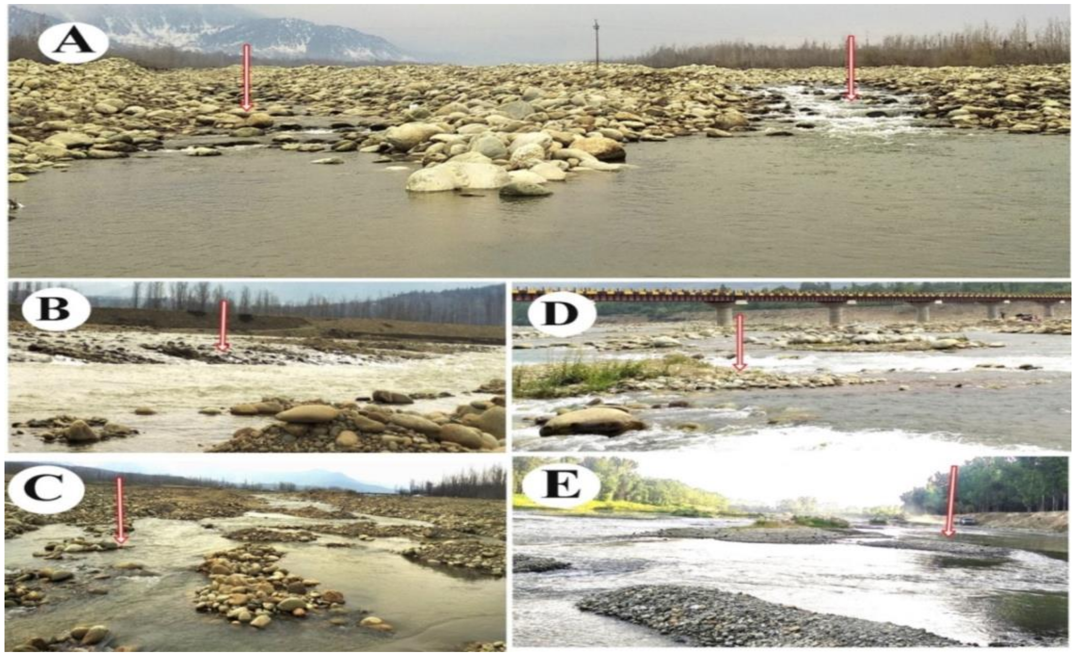


Figure 49: Showing the change in stream morphology and hydraluics in Vaishav stream.

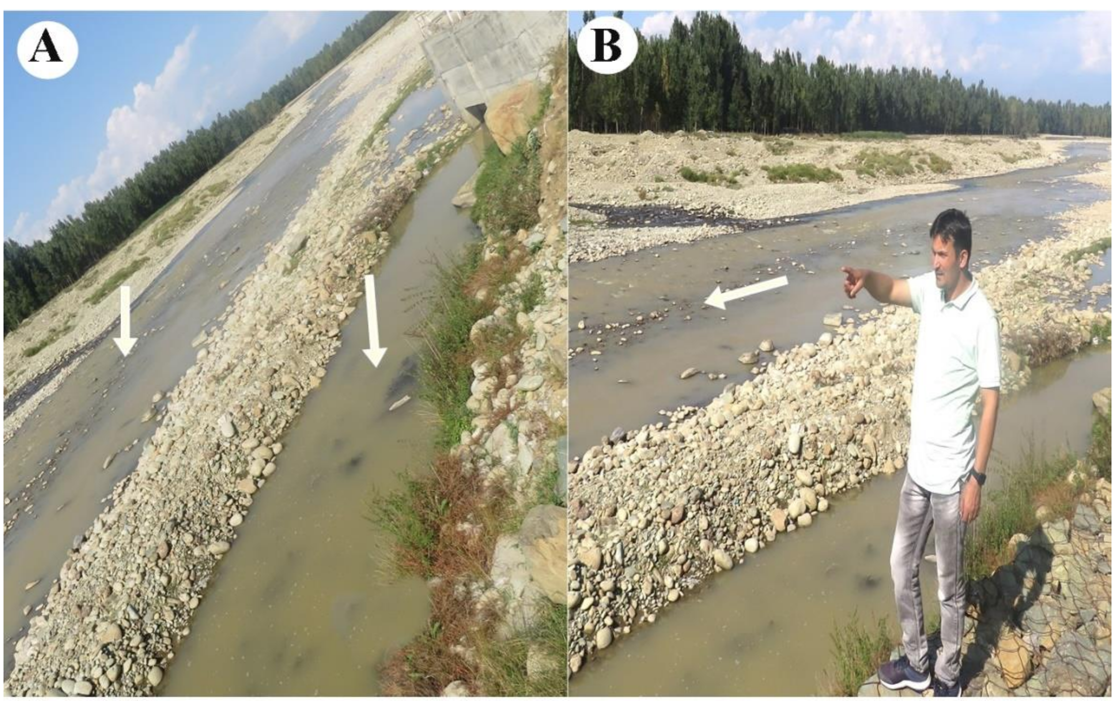


Figure 50: Showing the turbidity of water during mining in Vaishav Stream.

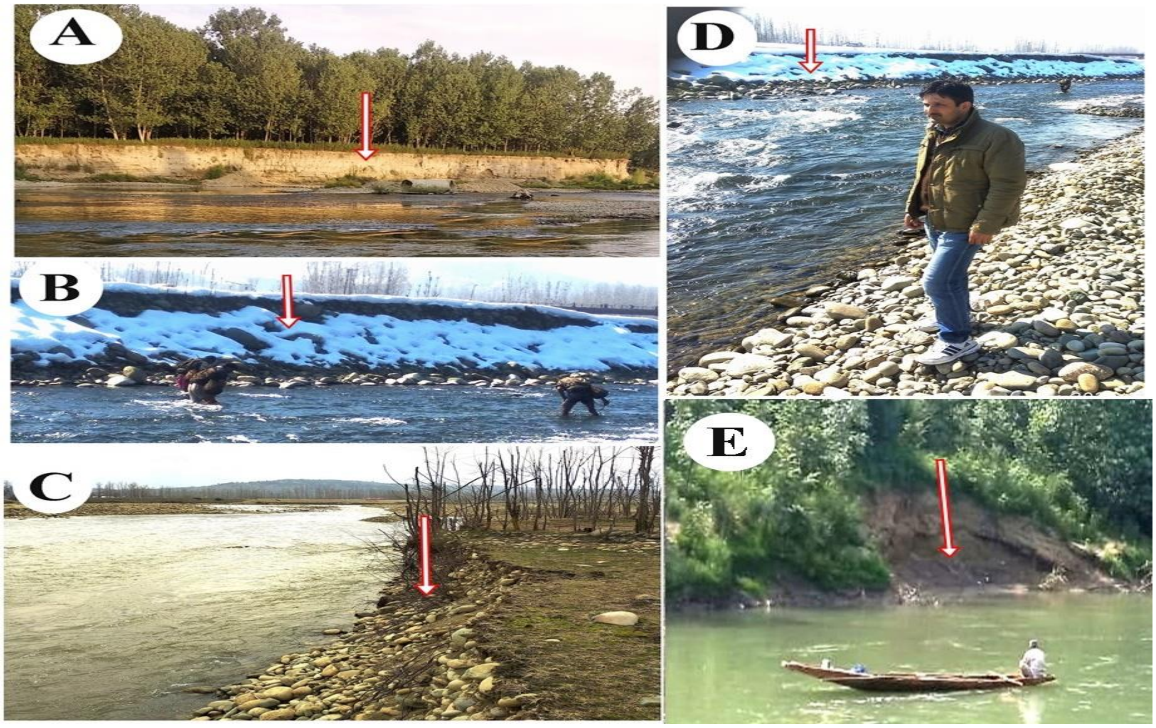


Figure 51: Showing the soil erosion in Vaishav stream.

Figure 52: Showing siltation in the Vaishav stream.

The illegal fish practices is prevalent and widely practiced activity through out the country by different ways such as water diversion, electric fishing, and chemical poisoning, pose additional threats to fish biodiversity and ecosystem health (Mazzariol *et al.,* 2021). These activities result in fish mortality, decline in species diversity, and contamination of water resources, leading to adverse effects on human health through the consumption of poisoned fish and contaminated water (Effah, 2019). Overfishing exacerbates the decline in fish populations globally, especially high-value food fishes, further impacting aquatic ecosystems and human protein sources (Sumaila *et al.,* 2016). The electic fied generated due to electric fishing effects all the fishes present in the area leads to immoblization and muscular atropy and eventually leads to death of fishes and that could be the cause for decline of fishes species ((Fodor *et al.* 2011). In addition to this, chemicals like cyhalothrin,Cyclomethrine,coppar sulphate,chlorpyrifos and bleaching powder is used for illegal fishing which cause chemical poisoning of fishes and its persistence massively contributed to the depletion of fish diversity (Kumar *et al.*, 2020).The serious impact of chemical toxicity mainly effects the juvenile fauna and get whiped out immediately after its exposure and pople consume the poisoned fish as wll as the contiminated water for drinking purposes which cause serious issues through bio megnification (Alinnor, 2005). In this study, the impact of water diversion was ranked as the 7th most significant factor contributing to water quality deterioration and fish diversity decline, according to survey respondents. Water diversion another illegal activity practiced for fish capturing during the present study (Figure 56), which significantly affects the ecological integrity of streams, particularly impacting fish populations and diversity by reducing flow volume and altering habitat availability. In Himalayan streams, reduced water levels disrupt fish migration, especially for species like *Schizothorax* species leading to population declines. Changes in flow regimes raise water temperature and increase sedimentation, degrading spawning grounds and essential habitats. These disruptions also alter food web dynamics, leading to reduced fish abundance and diversity. Water diversion further fragments habitats, isolating populations and reducing genetic connectivity, threatening the long-term survival of fish communities (Guzman *et al.*,

2022) .Alterations in flow regimes affect the stream's physical properties, including temperature, depth, and sediment movement. Lower water levels, especially in summer, raise temperatures, negatively impacting cold-water fish that prefer cooler environments. Reduced flow also increases sediment deposition, which can bury spawning grounds and diminish critical habitats like riffles and pools, essential for various fish life stages. This reduction in flow further disrupts the food web by decreasing macroinvertebrate populations, a key food source for fish, leading to declines in sensitive species and a shift towards more tolerant species, ultimately reducing biodiversity and disturbing predator-prey dynamics (Shah *et al.*,2020).Water diversion from the main streams causes habitat alteration by lowering of water depth, with the result that fish in such habitats is badly affected as they do not find the required water depth and flow for their movement and other activities required for survival (Ekka *et al.*, 2020; Gurí *et al.*, 2024). Moreover, it causes low-flow conditions that involve a reduction of aquatic physical habitat, habitat heterogeneity, food availability, and changes on water velocity that can lead to less opportunity to large sized fishes (Rolls *et al.*, 2012; Walters, 2016). When water levels are decreases, fish are easier to catch, Moreover, spawning grounds are also destroyed when water levels decrease (Yang *et al.*, 2021).Overall, illegal fishing activities compounded by overfishing and nutrient loading, pose severe threats to fish biodiversity and ecosystem integrity. Addressing these challenges requires comprehensive conservation measures, including improved regulatory frameworks, public awareness campaigns, and sustainable resource management practices, to safeguard aquatic ecosystems and ensure the well-being of both humans and aquatic fauna.

Figure 53: Showing the fishing by local fishermen in four different locations A, B, C and D in Vaishav Stream.

Figure 54: Showing illegal fishing (electrical) in Vaishav Stream.

Figure 55: Showing the extensive fishing by local fishermens in Vaishav Stream.

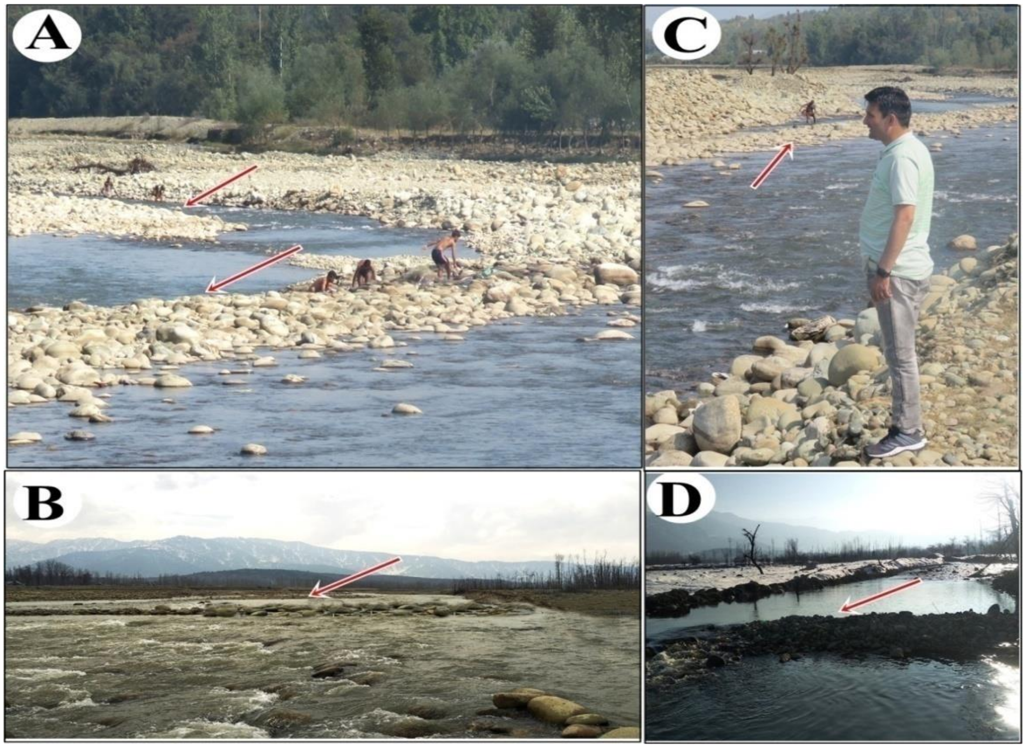


Figure 56: Showing the water diversion followed by fish catch in the Vishav stream.

In the present study, the respondants rank pesticides and fertilizers 5th most significant anthropogenic threat to Vishav stream which are extensively utilized to eliminate unwanted organisms in orchards and agricultural areas, contributing significantly to global agricultural productivity. These fertilizers, particularly nitrogen and phosphorus applied in agricultural fields across catchment areas, enter water bodies through surface runoff (Mateo-Sagasta *et al.,* 2017). Phosphorus fertilizers are particularly notable for their ability to leach into water bodies along with soil, leading to water quality deterioration in rivers and streams and contributing to eutrophication, which can be detrimental to fish populations (Akhtar *et al.*, 2021).

Nitrogen fertilizers undergo conversion into nitrate, a highly soluble compound in water that poses risks such as methemoglobinemia (blue baby syndrome) in infants by reducing the blood's oxygen-carrying capacity. Nitrate also poses significant health hazards to livestock and aquatic organisms (Liu *et al*., 2024). During our study, livestock grazing along the stream banks of Vaishav Stream was identified as a significant source of phosphorus and nitrogen, thereby exacerbating eutrophication of surface water resources (Figure 44). Agricultural nitrate is recognized as a prevalent chemical pollutant responsible for deteriorating water quality in both surface water and groundwater. Continuous use of fertilizers and septic leachate are primary contributors to increased nitrate concentrations in surface water, often exceeding safe thresholds set for drinking water supplies (Craswell *et al.*,2021).Similarly Pesticides are chemicals extensively employed to eliminate unwanted organisms in agricultural fields, posing a persistent threat to groundwater through surface runoff from nearby fields or direct application. Their presence in water sources is a significant concern, posing potential risks to human health and aquatic life; including fish (Ahmad *et al.*, 2024). Inadequately managed agricultural practices (Figure 57) can result in surface water and groundwater contamination by pesticides and nutrients. Pesticides, which encompass fungicides, herbicides, nematicides, insecticides, and rodenticides, are utilized in agriculture to combat pests (Pandya, 2018). Soluble pesticides are more prone to leaching, while residual pesticides, being less soluble, have a lower likelihood of leaching into the environment through drift, runoff, and drainage. The toxicity ofpesticides in agricultural fields was found toxic tonon-target organisms like fishes by affecting fish health through impairment of metabolism and leads to mortality.Besides this pesticide toxicity can cause diverse effects including inhibition of acetylcholinesterase activity, histopathological changes as well as developmental changes, mutagenesis and carcinogenicity (Rohani, 2023). The killing of fishes through the rampant use of pesticide in agricultural fields results in decline of fishes and other aquatic species worldwide. The indirect effects of pesticides are interfering food supply of fishes, altering the aquatic habit, reduces the growth and survival of fishes. Moreover, chronic toxicity of pesticides may cause death which results in elimination of certain fish species through induced sterility, interference in defense mechanisms, and loss of appetite, hyper exitability and reduction in fertility (Yang *et al.*, 2021). Fish and shellfish diseases are muchprevalent due to pesticitcide toxicity, especially liver tumors occurring in demersal fish inhabiting polluted waters which results in devoid of fish species in some major rivers. Besides, that contimnation of stream water through influx of pesticides and fertilizers applied to agricultural uses also threatns the suevival and reproduction of fish species as well as killing of huge number of juvenile fish species (Mustafa *et al*., 2024).

Figure 57: Showing the agricultural and horticultural land on banks of Vaishav stream.

In the present study,it was recorded that Vaishav stream is used for damping site by locals inhabiting in the catchment of the stream and was ranked as 4th most important anthroprogenic threat. Solid waste damping on the stream and river banks causes pollution which has harmful impact on aquatic biota, besides cause's ecological imbalance (Kumar and Mishra, 2024). Solid waste or garbage is a major concern as the amount of garbage is increasing daily in dumping areas that it can cover our safe zone and leads to severe impact on environment (Figure 58). Damping of solid waste near to aquatic bodies may result inobstruction of water runoff that acts as site for breeding ground of diseases such as Diarrhea, Malaria and Cholera and direct dumping of untreated waste in water bodies can lead into accumulation of toxic substances through food chain (Ogidi and Izah, 2024). It was also observed during the study thatunplanned dumping of solid wastes in open areasis major threat to theaquatic bodies due to lackof dumpingsites and local population prefer to dump their wastes near the banks of Vaishav stream.During rainfall, hazardous substances leach from landfill sites into adjacent water bodies, leading to contamination of water resources. Decomposing waste at these sites releases toxic chemicals that permeate into the underlying soil and subsequently flow into streams, causing water contamination. Open dumping of waste creates large piles that become breeding grounds for disease-carrying vectors, posing health risks to humans. Pollution originating in upstream river basin areas can exacerbate downstream water pollution by introducing additional pollutants. Contaminated water adversely affects human health, animal well-being, and soil productivity, particularly in densely populated regions where numerous septic tanks contribute to groundwater pollution. Domestic wastewater, including urine, human excreta, and wastewater from washing, is often discharged into pits to prevent surface contamination, but high liquid volumes can reach the water table and nearby water systems, contributing to pollution (Randall and Naidoo, 2018). Aside from waterborne diseases, accumulated human waste attracts flies that can spread disease-causing microbes to surrounding human settlements, acting as direct disease vectors such as cholera (Null *et al.,* 2018). Decision-makers in developing countries face significant challenges in managing solid and liquid waste. In recent years, many communities have intensified efforts to develop sustainable, long-term solutions for waste management. Liquid waste, including industrial effluents (chemical compounds and wastewater) and municipal waste (sanitary sewers), has increased, posing ongoing challenges in urban waste treatment and wastewater management. With more than half of the global population living in urban areas, a figure projected to reach around 70% by 2050 according to the UN World Urbanization Prospects 2018, poorly managed waste poses acute risks to urban residents and threatens urban water sources.

Figure 58: Showing the damping of garbage on the banks of Vaishav stream

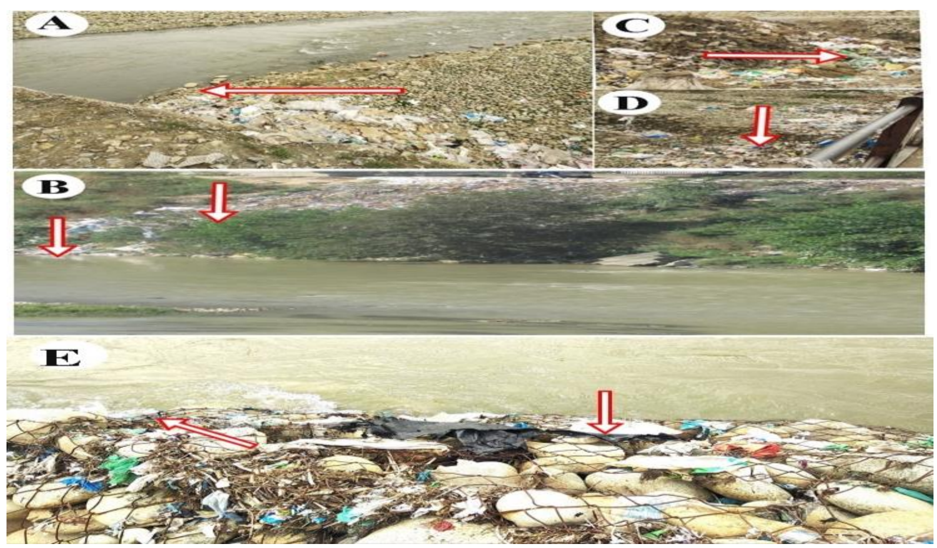


Figure 59: Showing the presence of solid waste in Vaishav stream.

During the present study deforestation was ranked as 8th important anthropogenic threat by respondants and maximum deforestation was observed occurs along the stream catchment which has posed serious threat to the stream ecology (Figure 60).Deforestation emerges as a major global environmental concern, primarily driven by changes in land use that lead to biodiversity loss, landslides, and elevated CO2 levels in the atmosphere. Deforestation also alters annual precipitation patterns, impacting the hydrological cycles of streams and rivers and potentially intensifying flood occurrences (Filoso *et al.*, 2017). Conversely, forested catchment areas exhibit higher rates of water infiltration, which can lower overall runoff from catchments. However, deforestation increases soil erosion, alters stream flow dynamics, and ultimately diminishes both water quality and soil fertility (Potic *et al* .,2022,Danacova *et al.*, 2020).

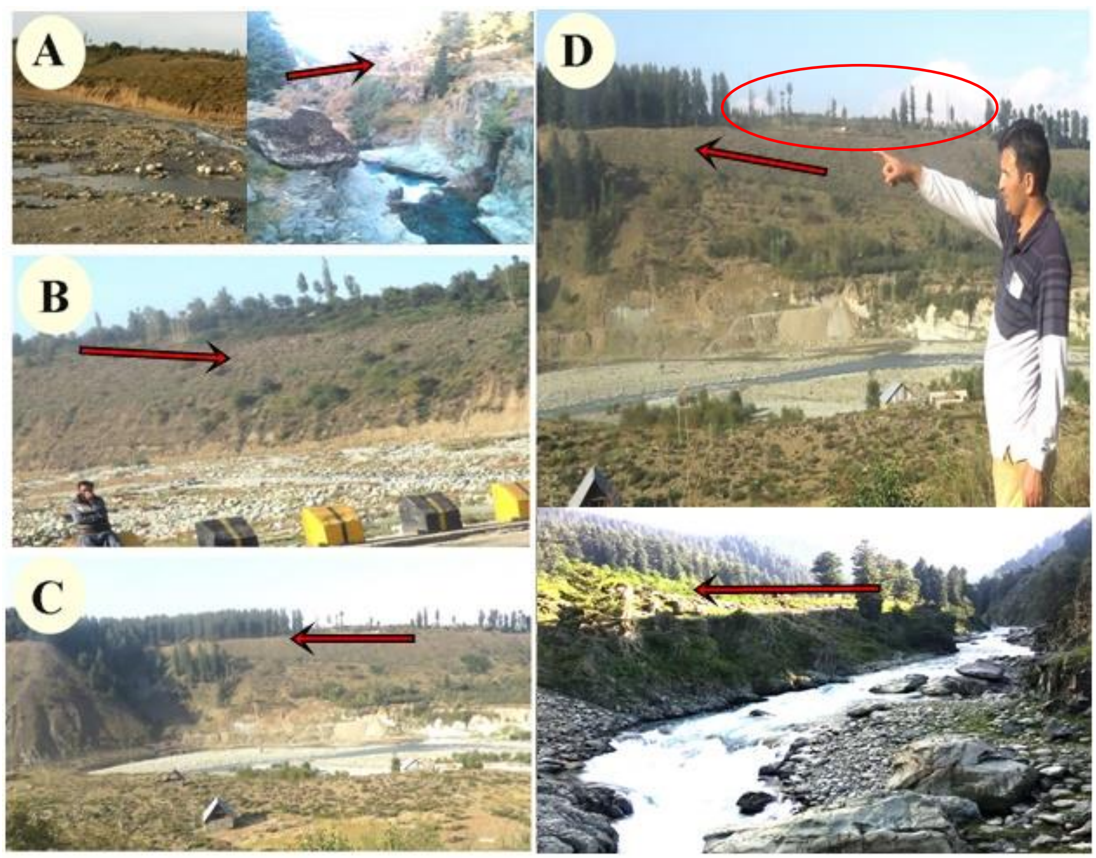


Figure 60: Showing the deforestation in riparian area of Vaishav stream.

In the present study, respondents rank 9 washing and bathing as anthropogenic threat in the Vaishavstream (Figure 61). The washing effluent is responsible for surface water pollution in the waterbodies. Utilization of stream water for washing and bathing of cloths, vehicles, and livestock involvesthe use of various chemicals like detergents, soaps, shampoos influx into the streams and can deteriorate the water quality.Some phosphate-based detergents causes eutrophication and leads to depletion of oxygen in the water and cause severe damage to aquatic animals including fishand alsoinfluences Limnological characteristics by turning the water murky (Borah, 2022).These detergents also contain some heavy metals like zinc, lead which makes the water unfit for human consumption and also detrimental to aquatic life (Azizullah *et al.*, 2021).

During the survey period, females were seen using synthetic detergents for washing clothes at many sites and these detergents are responsible for acute toxicity to fishes and other organisms. The continuous usage of detergents can lead to accumulation of phosphates in aquatic environment that can cause eutrophication. Since most synthetic detergents contain water-softening agent's viz., washing soda and sodium carbonate, which may increase the bicarbonates henceincrease alkalinity. The use ofSodium silicate detergents may also contribute to enhance the toxicity and decreasing the surface tension of the water which affects the aquatic life (Azizullah *et al*., 2021). The concentration of detergents in aquatic system effects the aquatic fauna when detergent concentrations approach 15 parts per million, fish survival becomes low and at 5 ppm, eggs will die. Thus a detergent concentration up to 2 ppm cans leadto endocrine disruptors affecting directly health of piscine fauna.

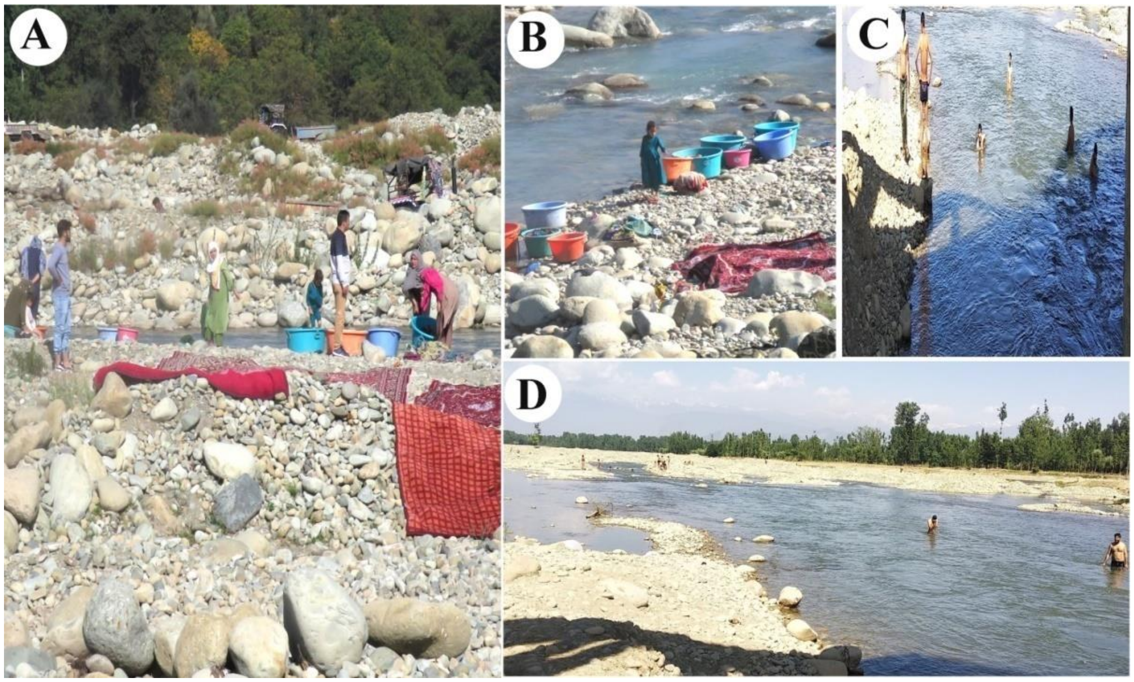


Figure 61: Showing bathing and washing in the Vaishav stream by locals.

In this study, respondents ranked sewage as the foremost water quality deteriorating factor (Figure 65) highlighting its global threat to aquatic biodiversity. Sewage, predominantly comprising water (99.9%) and solids (0.1%), contains a plethora of organic and inorganic components, including heavy metals and diverse microbial pathogens such as Escherichia coli, Salmonella, and parasites(Pandith and kumar, 2019). In addition to this it cantaines human urine, rich in nitrogen and phosphorus, exacerbates nutrient loading in aquatic ecosystems, leading to eutrophication and harmful algal blooms mainly those of cyanophytes which liberate cyanotoxins which have harmful effects on aquatic life, livestock, and humans (Bhat & Qayoom, 2021). Thus increase in nitrogen concentration damages aquatic life by damaging certain tissues and organs and cause symptoms such as hypoxia, reduced immunity, and even mortality of aquatic fauna (Bashir *et al.*, 2019). Escherichia coli serve as a reliable indicator of fecal pollution, correlating strongly with swimming-associated illnesses. Untreated sewage introduces a host of contaminants into natural ecosystems, posing risks to human health, cognitive development, and biodiversity (Mateo-Sagasta *et al.*, 2017). Toxins released from sewage can accumulate in aquatic organisms, posing risks to the food chain due to their non-degradable nature and inorganic nitrogen compounds, like ammonia, discharged from various sources, impair aquatic life and ecosystem function, exacerbating freshwater crises worldwide (Bhat *et al*., 2022).

In this study, built of Latrines and open defecation on banks of streams depicted was ranked as the 2nd most imortant factor contributing to water quality deterioration, according to survey respondents. During the present study water samples collected from three sampling sites alsoconfirm deterioration of water quality by the presence *Coliform* bacteria (Figure 66) at the site III reflecting the fact that this water is highly polluted and unfit for drinking. The prevalence of *Coliform* bacteria at site-III indicates the presence of fecal sources may be due to growing urbanization and lack of adequate sewage treatment facilities which results in increase in the levels of *Coliform* bacteria along downstream reaches. Similar observation was found in lower Jhelum, Dara watershed and Rambiarrah Stream (Qayoom *et al*., 2022; Islam *et al*., 2023) which could jeopardize water quality and public health. Aside from waterborne diseases, accumulated human waste attracts flies that can spread disease-causing microbes to surrounding human settlements, acting as direct disease vectors such as cholera (Alumu, 2023). During the present study it was found that various input sites of anthropogenic wastes that influx into the stream alter its physico-chemical parameters which subsequently affects water quality and make it unfit for human consumption. Similar observation was reported by (Uqab *et al.*, 2017) in Tawi River Jammu.

Similarly, respondents identified sedimentation as a significant water quality deteriorating factor, primarily driven by soil erosion from agricultural fields and mining activities.Sediment loaded runoff increases suspended materials in water bodies, triggering algal blooms and oxygen depletion, endangering aquatic life. Encroachment, ranked ninth by respondents, involves human development encroaching on natural areas such as floodplains and river corridors, leading to reduced river dimensions and altered flow dynamics (Figure 52). These anthropogenic activities collectively exacerbate water pollution and degrade aquatic habitats, necessitating concerted efforts for effective conservation and management strategies (Muruganandam *et al*., 2023).

In the present study, encroachment was ranked 9 by respondents as a water quality deteriorating factor (Figure 62). Encroachment includes building of houses, roads, improved paths and other development into natural areas including floodplains, river corridors, lakes and pond .The encroachment of water bodies reduces its width and depth which in turn impacts the normal discharge, volume and thus permanently shrinks the river in terms of size and flow volume (Wang *et al.*, 2010). Globally, in all countries the continuous construction of bridge piers and culverts through the rivers to enhance the transportation network between different urban nodes or growth centers has in great demand and their impact on overall ecology of water bodies.The construction of bridge piers and culverts on the stream and rivers may cause change in water velocity which results in increase in the rate of siltation and changes the stream ecology (Biswas and Banerjee, 2018). In the present study it was observed that constructions of bridge piers (Fig. 64) on the Vaishav stream at several places had changed water velocity, increased rate of siltation, obstruction of boulders and woody debris and formation of pool habitats which consequently impacts the fish migration other mobile aquatic species by longitudinal disconnect from downstream to upstream channel (Bundhoo *et al.*,2020) Similar observation was reported from the Haora River Tripura, India (Bandyopadhyay and De 2018).

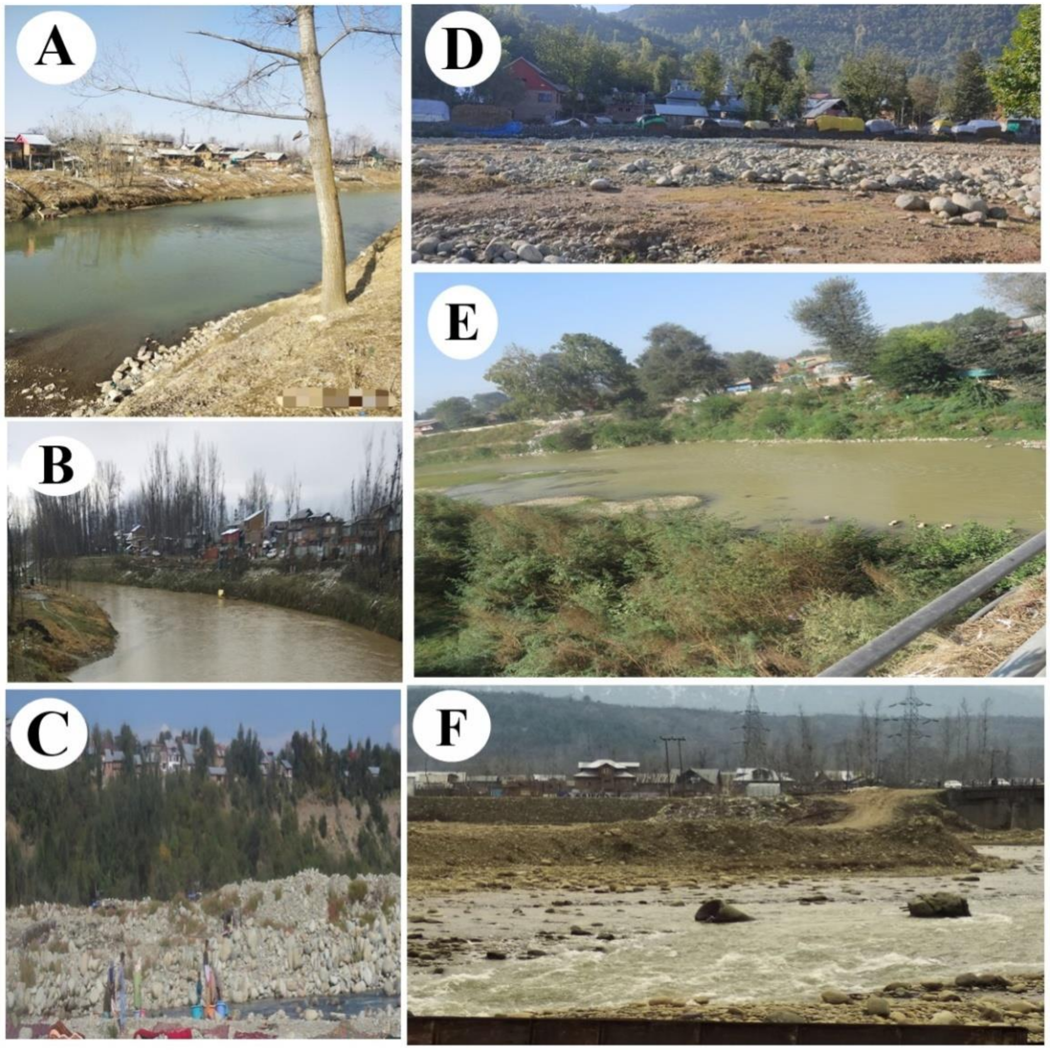


Figure 62: Showing the encroachment (houses) on the banks of Vaishav stream.

In this study, the impact of stone crushing (depicted in Figure 63) was ranked as the 11th most significant factor contributing to water quality deterioration, according to survey respondents. Previous research has largely overlooked the assessment of stone crushers, particularly in the Kashmir region, despite the industry's rapid growth. Occupational and environmental health issues associated with this industry require immediate attention .Earlier studies primarily focused on the effects of stone crushing dust on vegetationsocioeconomic conflict, water quality, land degredation, and severe human health hazards (Manzoor and Khan, 2020). Vulnerable areas near stone crushing units were identified in the study area, highlighting concerns such as impacts on human health, agricultural productivity, water quality, and stream morphology in dust-affected zones (Pal and Mandal *et al.,* 2021).In the stone crushing industry, stones of various sizes are crushed as per requirement for diverse applications such as road construction, bridges, buildings, and canals (Pal and Mandal, 2017). Dust emitted from these activities settles on land, vegetation, trees, and surface waters used for consumption, leading to alterations in natural ecosystems and degradation of aquatic habitat (Marmon and Plumlee, 2013). Along the banks of the Vaishav stream, a large number of stone crusher units were identified, posing severe threats to aquatic flora and fauna (Mishra and Kumari, 2008). The raw materials for stone crushers are obtained through mining, which further endangers aquatic biodiversity by reducing forest cover and contributing to air and water pollution as well as land degradation (Prakash and Budhwan, 2024). Additionally, increased dust concentrations from stone crushing activities may elevate temperatures, thereby altering local ecological conditions (Paul and Mandal, 2021). Previous studies have indicated that the slope of drainage regulates the dispersal of dust and sediment from its source to other areas within the stream channel (Sipos *et al.,* 2014; Nagy and Kiss, 2016).The elevated levels of dust contamination in water bodies increase water turbidity, affecting aquatic species, including fish, by reducing dissolved oxygen levels and hindering their ability to locate food sources (Breitburg, 2000). Consequently, particulate emissions released during stone crushing activities directly contribute to environmental degradation (Karbasi *et al.,* 2007).

Figure 63: Showing the installation of stone crusher on the bank of Vaishav stream.

During the present study, respondents were asked to rank the following threats which are most important cause for decline in fish diversity. There is a subsequent decline in the fish breeding and diversity in the streams by various anthropogenic threats which are detrimental for the survival of fish where siltation, solid waste pollution, sewage, encroachment, water diversion, mining, illegal fishing and agricultural wastes significantly declined the fish diversity. The survey was attempted to enquire such threats in order of their seriousness and their adverse consequences on the fish diversity. During the survey it was asserted that mining proves to be major threat for fish decline and prevent them to assemblage and impede their mobalization, while as siltation was ranked as the last human threat posed to fish environment. In the parallel way, illegal fishing, sewage and agricultural waste occupied the second, third and fourth position as human threats in order of their importance, respectively. Furthermore, solid waste, water diversion and human encroachment were graded as fifth, sixth and seventh anthropogenic intimidation to the ideal fish survival and hence, their breeds and diversity.

In the primary survey, the respondents were asked about increase in population growth and its impact on water quality as well as fish diversity. It was elucidated that 51% respondents strongly agreed and approximately 1% respondents strongly denied the statement. Similarly, 37% of respondents moderately believed the statement to be true while as 1% respondents denied in a considerable fashion. Moreover, there was also a chunk of respondents of around 9%, who were neutral regarding the statement. The anthropogenic threats irrefutably disrupt the aquatic environment through a number of ways. With regard to thepresent survey, these threatsaffectthe water quality as well as fish diversity in the rivers and streams.The continuous increase in population growth along the catchment area of the streams is one of the anthropogenic disturbances which has increased changes in land use/land cover, agricultural activities, generation of household runoff, solid waste, constructions, mining activities, stream bifurcation, sedimentation and over fishing which subsequently deteriorates impacts the water quality and overall production including fish diversity (Hamid *et al*., 2020).

Globally, in all countries the continuous construction of bridge piers and culverts through the rivers to enhance the transportation network between different urban nodes or growth centers has in great demand and their impact on overall ecology of water bodies. The construction of bridge piers and culverts on the stream and rivers may cause change in water velocity which results in increase in the rate of siltation and changes the stream ecology (Biswas and Banerjee, 2018) In this study, it was observed that the construction of bridge piers (depicted in Figure 64) along the Vaishav stream at various locations has altered water velocity, increased siltation rates, blocked boulders and woody debris, and created pool habitats. These changes have subsequently affected the migration of fish and other mobile aquatic species, causing longitudinal disconnection from downstream to upstream channels (O' Mara *et al.*, 2021).Similar impacts were documented in the Haora River, Tripura, India (Bandyopadhyay and De, 2018).

Figure 64: Showing Bridge Piers on Vaishav Stream

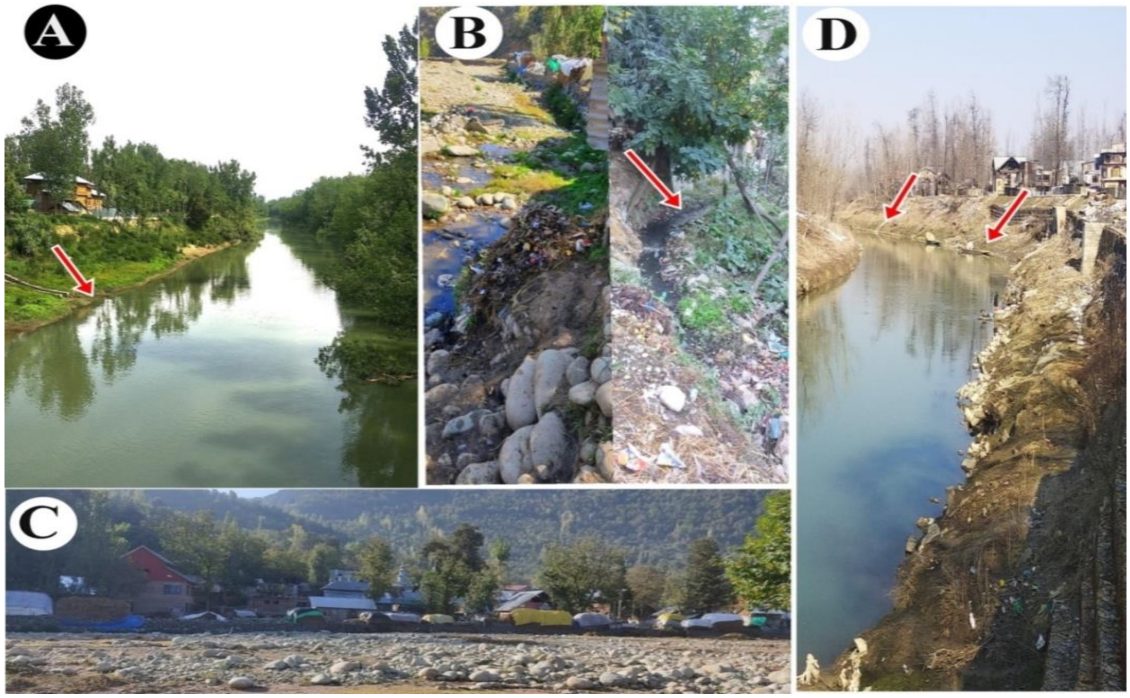


Figure 65: Showing the influx of domestic sewage into Vaishav Stream.

Figure 66: Showing built of latrines on the bank of Vaishav Steram.

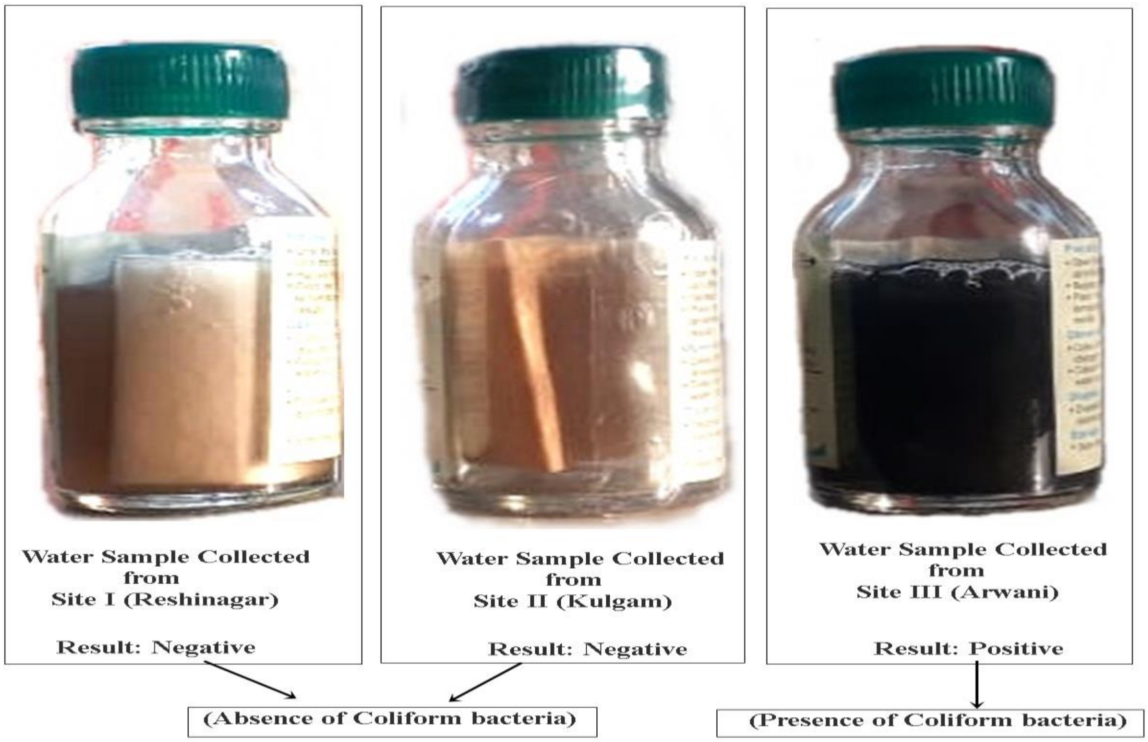


Figure 67: Showing presence of *Coliform* Bacteria in water sample collected from Vaishav Stream at site-III

Many countries host numerous livestock and poultry farms, engaging in activities that enhance beef and dairy cattle, hogs, and swine production. Additionally, animal manure serves as fertilizer for agricultural farms to bolster production and soil nutrient levels. However, the leaching of nutrients from these agricultural fields flows into streams, elevating nutrient loads that lead to eutrophication and consequently impact water quality (Khan and Mohammad 2014) In the present study grazing of livestock in the riparian areas of Vaishav stream discharges animal wastes mostly during the precipitation.Animal waste contains nutrients like phosphorus, nitrogen and pathogens which causes pollutes the aquatic bodies that consequently affects the fishes (Polat and Olgun, 2018).Moreover, overgrazing by livestock leads to increased erosion which may alsodeteriorate the aquatic ecosystem, encouraging invasion of unwanted species, stream bank destruction, water quality deteriorationthat subsequently affects the aquatic fauna including fishes (Dufour and Bartram, 2012). The animal excreta including urine and fecal matter of domestic animals are widespread across the globe and frequently contaminate water used for bathing, recreation, human consumption, and for irrigation purposes (Sewak and Saxena 2016). In the present study, it was observed that many herds of livestock were found grazing on the banks of Vaishav stream (Figure 68) thus indirectly polluting this fresh water stream by their excrete. The contamination of fresh water streams with animal excreta needs a special concern as there are reports of many waterborne diseases transmitted from animal to humans (Dufour and Bartram, 2012). Further, 96.6% human infections caused by *Campylobacter jejuni* in Lancashire, UK could be attributed to farm livestock (Wilson *et al*., 2008). Another study conducted in Swaziland, confirms that more than 40, 000 cases of waterborne infection was linked with cattle manure (Schoeman, 2013).

Figure 68: Showing grazing of animals in and on the banks of vaishav stream

The major problem worldwide in the twenty-first century is facing unavailability of potable water and adequate sanitation (Nagaraju *et al* 2014).The degradation of water resources is a much-studied phenomenon which can be caused by natural processes and human activities (Nagaraju *et al*., 2016).Aquatic environment have a natural tendency to dilute pollution to some extent, but severe contamination of aquatic ecosystems results in alteration of flora and fauna community (Akpor *et al.,* 2014).During the present study water samples collected from three sampling sites also confirm deterioration of water quality by the presence *Coliform* bacteria at the site III reflecting the fact that this water is highly polluted and unfit for drinking purposes. The prevalence of *Coliform* bacteria at site-III indicates the presence of fecal sources may be due to growing urbanization and lack of adequate sewage treatment facilities which results in increase in the levels of *Coliform* bacteria along downstream reaches (Figure 67). Water quality index also reveled that the concentration of physico chemical parameters of site III exceeds the WHO/BIS standards. Smilar observation was found in lower Jhelum, Dara watershed and Rambiarrah Stream (Qayoom *et al.,* 2022; Islam *et al*., 2023) which could jeopardize water quality and public health. Anthropogenic activities viz, land use practices, solid waste pollution, sand mining, sewage, pesticides, solid waste damping and latrines and open defecation on banks of streams are responsible for deteriorating the water quality (Mukate *et al*., 2018). During the present study it was found that various input sites of anthropogenic wastes that influx into the stream alter its physico-chemical parameters which subsequently affects water quality and make it unfit for human consumption. Similar observation was reported by (Uqab *et al.,* 2017) in Tawi River Jammu.

The anthropogenic threats discussed so far have apparently played a great role in disrupting the balance in the aquatic environment. Moreover, anthropogenic threats specifically, mining, illegal fishing, sewage, household runoffs and agricultural wastes including use of fertilizers and pesticides flushed into the stream, have significantly deteriorated the quality of water for potable use and substantially interrupted the fish diversity in the stream. During the survey, it was reflected that 39% respondents significantly agreed on the statement while as 1% respondents do not acknowledge these anthropogenic threats as challenges neither for the pubic nor for the administration. Similarly, there was a share of 43% respondents who moderately accepted these threats as challenges whereas nearly about 5% respondents relatively disagreed on the statement. In addition to this, roughly 12% respondents were found to be neutral on the statement.

Prior studies have shown that the uptake of heavy metals from leachate, influenced by factors such as pH, soil composition, and leachate volume, can significantly affect both shallow and deep aquifers. Increased levels of aluminum and copper have been detected in groundwater, adversely affecting the quality of surface water and groundwater, as well as the ecosystems they support. Water resources, crucial for domestic, agricultural, industrial, and other purposes, are intricately interconnected in terms of both quality and quantity, although they are often assessed separately. Hydrological monitoring stations provide data on water quantity, including water level, discharge, and velocity, while water quality is assessed through periodic analysis of samples collected at these stations. Evaluations of water quality monitoring data at local, regional, and global levels help in understanding the impacts positive and negative of human activities on aquatic environments. Prolonged sand mining activities can permanently disrupt fish spawning habitats and alter the structure of fish populations and communities.

In surveys aimed at ranking pollutants according to their perceived importance, household runoff emerged as the primary pollutant, followed by solid waste disposal into streams, excessive use of pesticides and fertilizers, and mining activities. Similarly, respondents ranked various factors contributing to water quality deterioration, with sewage identified as the foremost pollutant, followed by open defecation, mining, and pesticide use. Overexploitation, deforestation, and encroachment were also recognized as significant threats to fish and aquatic biodiversity. To address pollution, it is essential to employ treatment methods aimed at eliminating detrimental metal ions from water systems. Progress in technologies for monitoring heavy metals, including wireless sensors and automated detectors, improves the accessibility and management of data, highlighting the critical role of robust monitoring networks. Adopting adaptive management approaches and promoting interdisciplinary research are vital for ensuring sustainable management of natural resources, especially in response to evolving environmental conditions. Future research should focus on understanding the impacts of emerging technologies and developing comprehensive warning systems for inorganic substances. Effective removal of harmful heavy metals from water resources is essential to safeguarding human health and environmental integrity.

Figure 69: Showing the protest and government action on illegal miners.

6.19 Recommendations

Regular water monitoring is essential to understand ecological impacts, develop sustainable management strategies, and support ecologists, policymakers, and stakeholders in creating long-term conservation plans for water resources and to sustain this freshwater ecosystem from further detoriation. Separate authority should be constituted to monitor the ecological aspects of the stream. Environmental impact assessment should be taken periodically to ensure stream conservation and sustainable utilize of stream resources. Since the stream is owned by different government departments such as forestry, engineering, geology mining and fisheries if any project is executed by the concerned departments, they should have common consensus and synergy, so that ecology of the stream should not be disturbed.

Sustainable fishery practices must be established to document and protect freshwater fish diversity. Regulate fishing practices to maintain sustainable fish populations by implementing limits, closed seasons, and gear restrictions for overexploited and endangered species. Conduct awareness campaigns to educate local communities on sustainable fishing methods. Long-term ecological monitoring program should be established to regularly assess fish diversity, species richness, and water quality. This will allow policymakers to make informed decisions and implement adaptive management strategies to maintain the health of the Vishav stream ecosystem. In order to conserve the fish diversity in the Vaishav stream, it is imperative that monitoring should be carried out on regular basis and immediate steps should be undertaken. All the stakeholders must devise a policy for conservation of fish biodiversity in this vital ecosystem. Promote eco-friendly tourism that supports the local economy while preserving the environment. Implement incentive-based conservation programs to reward communities and stakeholders for their involvement in ecosystem protection.

Water bodies should be effectively managed to fulfill domestic water needs and support irrigation. Banning the construction of settlements near water bodies is a proactive approach that promotes environmental well-being, improves community safety, and strengthens resilience to climate change effects, helping to safeguard these vital resources for future generations

Recommending the further research to fill gaps in knowledge about the stream's biodiversity and the long-term effects of anthropogenic activities and to explore more sustainable method of water resource management in the area. There is an urgent need for stricter enforcement of existing environmental regulations regarding waste management, mining activities, and water resource usage in the Vaishav stream area.

Mining activities have significant environmental ramifications as continuous removal of bed material is responsible for the decline in water quality and biodiversity within the stream. Remedial measures through systemic monitoring should be initiated to comprehensively evaluate the impacts of mining on Vaishav stream morphology. Excavation of sand, pebbles, boulders and channelization during pre-spawning or breeding seasons should be controlled. The monitoring protocol will elucidate phenomena such as bar replenishment and morphological alterations within the stream, encompassing channelization, mining activities, siltation, bank erosion, and gravel extraction.

The entry of sewage, agricultural and solid wastes into the stream needs to be controlled and properly managed. Solid waste dumping sites should be located away from water bodies and incinerated rather than disposed of in open areas. Install effective sewage treatment plants to prevent untreated wastewater from residential, industrial, and agricultural sources from entering streams. Promoting decentralized wastewater treatment in rural areas can significantly reduce pollution from human activities. Master plan should be framed for the treatment of all point source pollution entering into the Vaishav stream especially for sewage released from the residential areas.

Maintaining a buffer zone between latrines and water bodies is essential for protecting biodiversity. Healthy riparian zones filter pollutants, provide habitats, and support the ecological balance of streams.To address these issues, communities should be educated on proper sanitation practices and the importance of situating latrines away from water sources. Regulations establishing safe distances between latrines and streams can help protect freshwater ecosystems and public health. Promoting eco-friendly sanitation options, like composting toilets or constructed wetlands, can also reduce the negative impacts of human waste on aquatic environments. Reduce fertilizers and pesticides, to prevent water pollution. Promote organic farming, precision agriculture, and eco-friendly alternatives to limit runoff, and establish buffer zones along riverbanks to filter pollutants before they enter water bodies.

Encouraging afforestation in riparian will prevent soil erosion, minimize nutrient leaching, and improve the overall health of freshwater ecosystems. By actively restoring and maintaining these essential areas, we can safeguard the sustainability of our water resources and support the biodiversity that depends on them. Reforesting stream banks, creating fish passages, and restoring wetlands can improve habitat quality and maintain ecological balance. The government-led and local people-led deforestation should be stopped immediately. Forest cutting and overgrazing should be banned by law. Only the wilted stock of forest should be taken out and sold to the people at reasonable rates.

By taking these steps, we can mitigate the adverse impacts of anthropogenic activities on streams like the Vaishav, ensuring the protection of water quality, fish diversity, and overall aquatic ecosystems for future generations.

-

CHAPTER 7

SUMMARY AND CONCLUSION

CHAPTER 7 – SUMMARY AND CONCLUSION

Water sources often face pollution and contamination due to a combination of natural factors and human activities.The study investigated through ANOVA & Fischer's LSD test showed seasonal & site variations in physico-chemical parameters along the Vaishav stream, revealing fluctuations due to various anthropogenic factors. The values of some parameters such as temperature, turbidity, pH, total alkalinity, total hardness, free CO_2, electrical conductivity, TDS, and nutrients like nitrate-nitrogen, total phosphorus, and sulphate showed an increasing trend except dissolved oxygen from upstream site-I to downstream site-III. The lower value of DO and high concentration of other investigated parameters due to human disturbances like sewage, agricultural runoff, mining activities, washing, solid waste, and human settlement are responsible for causing polution to the stream water. Cluster analysis highlighted spatial differences in water quality, particularly between upstream and downstream areas, underlining the impact of human habitation, and the most important physicochemical factors responsible for site clustering were determined by Wilks' lambda test.Total dissolved solids, turbidity, and total phosphorus were factors that were highlighted during the clustering process. The research divided the sites into two clusters, with Cluster-I (Sites I and II) indicating upstream areas with superior water quality and less human activity. The downstream locations in Cluster II (Site III) had relatively lower water quality as a result of habitation, and agricultural and urban land use.This research demonstrates that Cluster analysis is a valuable tool for policymakers to assess pollution levels through practical indicators. It also emphasizes the importance of the water quality index in classifying stream water for different uses, such as drinking and irrigation.

Moreover, PCA was executed on the whole WQ dataset to recognize the main factors responsible for causing significant variation in the water quality of the Vaishav stream. Two principal components (PC1 and PC2) accounted for 85.78% of the total variation, according to the research. The parameters air temperature, water temperature, turbidity, conductivity, pH, total dissolved solids, total alkalinity, calcium hardness, total hardness, calcium, magnesium, free CO_2, sulphate, nitrate nitrogen, and total phosphorus showed strong positive loadings in PC1 (explaining 73.9% of the variance). It showed a significant negative loading for dissolved oxygen, though. According to this, dissolved oxygen levels are negatively impacted by environmental factors like urbanization, the influx of household waste, and agriculture runoff as well as, climate factors like flashfoods, heavy rainfall,erosion, and inorganic nutrients. Positive loading of water temperature and negative loading of dissolved oxygen can be explained by the fact that as the temperature increases organic matter rapidly decomposes by consuming more and more dissolved oxygen. The substantial positive loadings for air temperature, water temperature, free CO_2, and dissolved oxygen were seen in PC1 (explaining 11.9% of the variation), while the significant negative loadings for turbidity, total dissolved solids, total alkalinity, and total phosphorus were seen. By showing increases in turbidity, conductivity, and TDS as a result of home sewage, agricultural runoff, and geological characteristics, this demonstrates the influence of watersheds and climate conditions on water quality. The results also showed that dissolved oxygen concentrations and water temperature are inversely correlated, with warm water having lower concentrations of dissolved oxygen than cold water. The PCA analysis overall indicated the major determinants of water quality in the Vaishav stream, including human activities, inorganic nutrients, climatic variables, and geological characteristics.These findings highlight the significance of these characteristics in assessing and understanding the overall water quality of the Vaishav stream, Nevertheless, the physico-chemical parameters associated with PC2 exhibited less importance than those associated with PC1.WQI values ranged from a minimum of 41.50 at Site-I to a maximum of 177.70 at Site-III. Based on these calculations, Site-I and Site-II fall under Category-I, indicating water suitable for drinking, while Site-III falls under Category-II, indicating water unsuitable for drinking due to increased pollution from non-point sources.

In addition to this correlation and linear regression analysis were conducted to reveal the association and relationship between different physic0-chemical parameters. Pearson's test showed that a significant positive correlation exists between pH with total hardness ($r= 0.833$, $p<0.05$) WT and NO3-N ($r=.835$, $p<0.05$) WT and TDS ($r=.490^*$, $p<0.05$)WT and EC ($r=.490^*$, $p<0.05$). The electrical conductivity showed a significant positive correlation with TDS ($r=1.00$, $p<0.05$), total hardness ($r=.897$, $p<0.05$), and sulphate ($r=.917$, $p<0.05$). The nitrate shows a significant positive correlation with sulphate ($r=0.947$, $p<0.05$). The DO shows a negative correlation with water temperature ($r=-0.396$, $p<0.05$), total alkalinity ($r=-0.843$, $p<0.05$), and sulphate ($r=-0.902$, $p<0.05$)

respectively.The various water parameters interplay led to a positive-negative correlation reflecting complex dynamics within an aquatic environment. The findings of the regression analysis for various Vaishav stream water quality metrics show that WT and pH, TH, TDS, EC, TP, NO_3-N, and free CO_2 had strong positive associations.

A total of 630 individuals including 11 fish species, 3 orders, and 4 families were collected. In the Vaishav stream, the fish community composition and dominance varied significantly across three study sites. At Site-I (Watoo Reshinagar), *Schizothorax curvifrons* was the most dominant species, followed by *Triplophysa marmorata*, *Schizothorax plagiostomus*, *Glyptosternon reticulatum*, and *Oncorhynchus mykiss*. Moving to Site-II (Kulgam), *Triplophysa marmorata* emerged as the dominant species, followed by *Schizothorax plagiostomus*, *Schizothorax esocinus, Triplophysa kashmirensis, Schizothorax labiatus, Schizothorax niger*. At Site-III (Arwani), *Schizothorax plagiostomus* exhibited dominance, followed by *Schizothorax esocinus, Schizothorax labiatus, Cyprinus carpio communis, Crossocheilus diplochilus, Schizothorax niger,* and *Triplophysa kashmirensis*.The spatial-temporal variation in fish community dominance reflected a pattern where *Schizothorax plagiostomus, Triplophysa marmorata*, *Schizothorax esocinus, Schizothorax labiatus*, *Schizothorax curvifrons, Triplophysa kashmirensis, Cyprinus carpio communis, Glyptosternon reticulatum, Oncorhynchus mykiss,* and *Crossocheilus diplochilus* were ranked in descending order by population percentage.Cypriniformes were overwhelmingly dominant at 92.17%, followed by Siluriformes at 4.44%, and Salmoniformes at 3.33%.The study also revealed seasonal variations in species richness and abundance across the sites. Site-I recorded the minimum richness (5 species) and abundance (197 specimens), while Site-III had the maximum richness (7 species) and abundance (228 specimens), indicating an increase from upstream to downstream. Seasonal variations showed a minimum of 49 species in winter and a maximum of 62 in summer at Site-I, with similar patterns observed at Sites II and III. Thus environmental factors such as water flow, temperature, depth, substrate type, and food availability significantly influence fish species distribution and abundance. To better understand the community characteristics of fish species, diversity metrics were used in the data set, which confirmed that the highest diversity index values were observed downstream at site-III in comparison to the upstream site-I due to the high altitude, low temperature, high water flow, less availability of food resources at site-I. t-test was applied to determine the mean significant difference between the three sites and four seasons based on 11 fish species and the finding revealed, statistically significant difference between the sites and not between the seasons which may be due to habitat heterogeneity, the physical structure including riffle, pool, and substrate that can support diverse fish species. In addition to this, variable physico-chemical parameters can create distinct habitats, flow pattern, and water depth which influence the habitat conditions. Differences in altitude and local climatic conditions can influence the water temperature which subsequently affects the species distribution. Most Himalayan streams have stable environmental conditions around the year due to input from the melting of snow and glaciers and continuous food supply throughout the year which may reduce seasonal population change. Besides that adaptation of fish species to local conditions and life cycles synchronized with these local conditions.Cluster analysis was employed to assess the similarity of fish communities among different sampling sites along the Vaishav stream which identifies two main clusters within the fish assemblage, indicating similarities between 1 and II, likely due to their proximity and similar environmental conditions. In contrast, site-III exhibited significant dissimilarity compared to sites I and II, attributed to its distance and varying environmental parameters. Despite these variations, the major species contributing to each site showed comparable patterns, albeit with varying degrees of dominance. Seasonal changes played a crucial role in driving these similarities and dissimilarities, influencing hydrological conditions and consequently impacting the fish communities. Jaccard'sindex is used to measure the similarity or compare species composition between different sampling sites of ecological communities. During the present sudy, it was observed that Site-I and Site-II have 22% of similarity whereas Site-II & Site-III have 62% of similarity and 9% similarity shown by Site-I & Site-II in terms of fish composition. The similarity and dissimilarity between sites are potentially due to differences in habitat structure, physio-chemical parameters, environmental conditions, flow regimes, substrate type, the proximity of the sites, andthe level of human impact allowing for a more homogenous fish community. NMDS based on fish abundance data (stress=0.031), followed by ANOSIM ($p<0.05$), indicated a clear distinction among sites ($R = 0.9754$, $p = 0.0001$), while there was no statistically significant difference based on seasons ($R = -0.02748$, $p = 0.6468$), with 9999 permutations.The study revealed that sites did not show distinct separation by seasonality, suggesting that fish taxa preferences for specific locations remained consistent throughout the seasons. Permutational analysis of variance (PERMANOVA) also supported this finding, indicating no significant difference among sites based on count data. Regional landscape features were found to exert a stronger influence on fish quantity and composition compared to seasonal differences based on abundance data. Aquatic vertebrates exhibited less seasonal variation despite substantial spatial differences in fish composition and abundance, likely due to factors such as habitat stability, behavioral traits, and life history adaptations. The present study suggests that in the Vaishav stream, fish abundance is influenced more by spatial heterogeneity in environmental conditions than by seasonal changes.

Examining a range of physicochemical parameters reveals seasonal patterns and potential ecological vulnerabilities. By scrutinizing seasonal variations, we not only gain a deeper understanding of this stream's ecological health but also contribute valuable insights for its sustainable management. Moreover, this research underscores the importance of continued water quality monitoring to protect and preserve this critical aquatic ecosystem, which is integral to the well-being of both aquatic life and human populations in the region. Moreover, timely monitoring of water quality will be helpful in the management of this precious natural resource. The data obtained could also form a baseline and reference point while evaluating further changes that might be caused by nature or human settlement. The variation in water quality parameters from upstream to downstream among sites of the Vaishav stream supports to identification of the source of pollution and also helps to decide to manage and control this precious resource from further deterioration. Besides that, the stream needs immediate attention as it serves as the source of drinking water for the citizens of south Kashmir.

Anthropogenic influences, such as demographic shifts, consumer behavior, industrialization, and urbanization, alongside population growth, have intensified environmental pressures. These activities introduce pollutants like pesticides and organic compounds into aquatic environments, posing significant risks to aquatic organisms. Modern agricultural methods, while enhancing crop production, have contributed to widespread pollution of water bodies. Urban and domestic sewage, often released with minimal or no treatment, further exacerbates water pollution. The increasing pollution of rivers and other water bodies has emerged as a critical concern in recent years, with adverse effects on the development, growth, behavior, and reproduction of aquatic fauna. In regions like Jammu and Kashmir, untreated effluents from households, industries, and other sources directly degrade water quality, impacting aquatic biota, particularly fish populations. Similarly, mining activities alter stream morphology, leading to habitat loss for fishes. This alteration disrupts breeding and spawning sites, and food sources, and ultimately affects fish populations and community composition. The impacts of mining on fish biodiversity can be direct, such as habitat destruction, and indirect, including changes in channel morphology and water quality deterioration. The effects of sand mining on aquatic ecosystems include increased turbidity, changes in temperature, and oxygen levels, and alterations in sediment composition, all of which can harm fish populations and their habitats. Human activities like urbanization, population growth, unemployment, and negligence exacerbate the degradation of aquatic habitats. These factors contribute to challenges in maintaining a balance between human needs and environmental preservation. Overpopulation, in particular, strains resources and drives environmental degradation, including deforestation, soil degradation, and species endangerment. Pollutants such as household runoff, solid wastes, pesticides, and fertilizers further degrade water quality, impacting both aquatic ecosystems and human access to safe drinking water. In-stream sand mining causes habitat destruction, sedimentation, and channel destabilization, negatively affecting aquatic life and ecosystem functions. Anthropogenic activities in the stream catchment area were found to reduce fish diversity and abundance; with landscape features significantly influencing fish abundance.It is concluded that the fish diversity and abundance were reduced due to various anthropogenic activities operating in and around the stream catchment area. Besides that, the landscape features had amajor effect on the fish abundance.Mitigating these anthropogenic threats requires concerted efforts in environmental management, sustainable resource use, and policy interventions to preserve water quality and aquatic biodiversity. Our study provides baseline data which may be helpful for the conservation and management of fish species, and in formulating fishery policy.

Research on fisheries assumes critical importance in the face of increasing contamination of aquatic ecosystems by numerous anthropogenic disturbances, leading to the continuous decline and disappearanceof fish populations worldwide due to improper and delayed conservative measures. Such research aids policymakers in devising appropriate measures to conserve and manage fish populations, emphasizing the necessity of regular monitoring of abiotic factors influencing habitat stability. To save and conserve freshwater fish diversity sustainable fishery practices must be developed in the region for proper documentation necessitating the assessment of anthropogenic deterioration and the implementation of effective conservation and restoration measures. Detailed information on stream fish communities, particularly in critical ecosystems like the Vaishav Stream, is crucial for designing conservation strategies and mitigating threats to fish populations.Therefore, comprehensive studies on fish diversity and anthropogenic pressures in streams like the Vaishav Stream are imperative for generating baseline data, guiding conservation efforts, and ensuring the long-term sustainability of freshwater ecosystems. Addressing the root causes of pollution and habitat degradation is essential for ensuring the long-term health and sustainability of aquatic ecosystems and the communities that depend on them. Further research is needed to explore the ecological effects of these variations and develop strategies for sustainable water resource management that can be supportive to ecologists, limnologists, policymakers, and other stakeholders in developing long-term management programs and conservation strategies for water resources. It is concluded that continuous monitoring of water quality parameters is needed to sustain this freshwater ecosystem from further deterioration. Hence this study provides the policymakers with a structured method to assess the potential of negative impacts for forthcoming alteration in water quality in this stream ecosystem and will uncover major alarming elements that could alter the stream's ecological stability shortly.

Through this research, the current status of fish diversity in the Vishav stream has been documented. The data gathered enhances our understanding of species distribution, habitat configuration, and the impact of human and external pressures on the ecosystem's natural balance. The analysis of physico-chemical parameters has provided insight into pollution levels and helped identify point and non-point sources of pollution in the stream. The scientific information generated will support the development of adaptive management techniques for the long-term sustainability of the stream. This study is expected to contribute significantly to understanding the overall health and productivity of the stream ecosystem. The data gathered can serve as a baseline and reference point for evaluating future changes resulting from natural or human influences. This study highlights the urgent need to preserve the stream's ecology and aquatic life. The findings will contribute to sustainable fisheries management and natural resource protection on a national scale, emphasizing the need for further research to develop strategies for enhancing the region's fishing resources.

The results of this study provide vital information for the protection of freshwater fish in the Vishav stream and serve as a reference for enhancing fish diversity conservation and management efforts. The research highlights the significance of environmental assessment techniques in raising awareness about the factors leading to water quality degradation. Additionally, it stresses the utility of the water quality index for categorizing stream water and determining its suitability for various purposes. The study also recommends strategies to streamline water quality assessments, reduce the number of sampling sites, and minimize associated risks and costs. Regular monitoring of water quality is essential for the effective management of this vital natural resource. Continuous water purification and monitoring will support the sustainable management of this critical resource, with the collected data offering a benchmark for future studies and contributing to the conservation of aquatic ecosystems.

CHAPTER 8

REFERENCES

-
- Acharjee, M.L. and Barat, S. (2010). Impact of fishing methods on conservation of ichthyofauna of river Relli in Darjeeling Himalaya of West Bengal. *Journal of environmental biology*, 31(4), 431-434.
- Adeyemo, O.K., Adedokun, O.A., Yusuf, R.K. and Adeleye, E.A. (2008). Seasonal Changes in Physico-Chemical Parameters and Nutrient Load of River Sediments in Ibadan City: Nigeria. *Global Nest Journal*, 10,326-336.
- Adla, K., Dejan, K., Neira, D., & Dragana, S. (2022). Degradation of ecosystems and loss of ecosystem services. *Academic Press*, 281-327
- Agarwal NK, Singh, G. (2012). Documentation of fishes andphysico-chemical characters of a stream Indrawati- aspring fed tributary of river Bhagirathi at Uttarkashi (Central Himalaya, Garhwal). *Environment Conservation Journal*, 13(3), 117-124.
- Ahmad, M. F., Ahmad, F. A., Alsayegh, A. A., Zeyaullah, M., AlShahrani, A. M., Muzammil, K., & Hussain, S. (2024). Pesticides impacts on human health and the environment with their mechanisms of action and possible counter measures. *Heliyon.*
- Ahmad, S. (2019). Text book for environmental science and ecology. *Sankalp Publication*, 1.
- Ahmed, I., Ahmad, Z., & Ahmad, I. (2017). Current status of fish fauna of river Jhelum and Dal lake of Kashmir Valley. *Bulletin of Pure & Applied Sciences-Zoology*, 36(2), 85-92.
- Ahmed, R., Ahmad, S. T., Wani, G. F., Ahmed, P., Mir, A. A., & Singh, A. (2022). Analysis of landuse and landcover changes in Kashmir valley, India—a review. *GeoJournal*, 87(5), 4391-4403.
- Ahmed, S. F., Kumar, P. S., Kabir, M., Zuhara, F. T., Mehjabin, A., Tasannum, N., & Mofijur, M. (2022). Threats, challenges and sustainable conservation strategies for freshwater biodiversity. *Environmental Research*, 214, 113808.

- Ahmed, W., Ahmed, I., Dar, N. A., & Farah, M. A. (2024). Spatio-temporal evaluation of physico-chemical parameters of snow-fed River Poonch in Northwest Himalayan region of India. *Applied Water Science*, 14(5), 91.
- Akbulut, A., & Ak-bulut, N. E. (2010). The study of heavy metal pollution and accumulation in water, sediment, and fish tissue in Kızılırmak River Basin in Turkey. *Environmental monitoring and assessment*, 16, 521-526.
- Akpor, O.B, Ohiobor, G.O., Olaolu., DJAiB. & Bioengineering (2014). Heavy metal pollutants in wastewater effluents: sources, effects and remediation, 2(4):37-43.
- Alemu, T. A. (2023). The Impact of Improper Solid Waste Management on Public Health of African Cities. *The Case of Addis Ababa City, Ethiopia (Doctoral dissertation, The University of Texas at Arlington).*
- Alinnor, I. J. (2005). Assessment of elemental contaminants in water and fish samples from Aba River. *Environmental monitoring and assessment*, 102, 15-25.
- Allan, J. D., (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 35(1), 257–284.
- Allan, J. D., Castillo, M. M., & Capps, K. A. (2021). Stream ecology: structure and function of running waters. *Springer Nature*.
- Allan-Andreolli, M., Giovannini, M., Fatone, F., Kyamunyogonya, M. and Yatuha, J. (2015). A Basic Bottom-Up Approach for Small Systems of Safe-Water Supply: A Decentralized Case Study in Uganda. *Journal of Water Supply: Research and Technology-AQUA*, 64, 105-116.
- APHA, 2017. Standard Methods for the Examination of Water and Wastewater. 23th Edn., American Public Health Association, American Water Works Association, Water Environment Federation Washington, DC., USA., ISBN: 087553287X, 9780875532875, Pages: 26.

- APHA, 2017. Standard Methods for the Examination of Water and Wastewater. 23th Edn., American Public Health Association, American Water Works Association, Water Environment Federation Washington, DC., USA., ISBN: 087553287X, 9780875532875, Pages: 26.

- Aqmal-Naser, M., Iguchi, K. I., & Ahmad, A. B. (2023). Spatial-temporal effects on fish diversity and assemblages in a highly modified environment. *Urban Ecosystems*, *26*(5), 1367-1379.
- Arafat, M. Y., Bakhtiyar, Y., Mir, Z. A., & Islam, S. T. (2022). Assessment of physicochemical parameters of Vishav stream: an important tributary of river Jhelum, Kashmir Himalaya, India. *Environmental Monitoring and Assessment*, 194(3), 158.
- Arthington, A. H., Dulvy, N. K., Gladstone, W., & Winfield, I. J. (2016). Fish conservation in freshwater and marine realms: status, threats and management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26(5), 838-857.
- Arunachalam, M. (2000). Assemblage structure of stream fishes in the Western Ghats (India). *Hydrobiologia*, 430(1/3), 1–31.
- Aryani, N., Suharman, I., Syandri, H., & Mardiah, A., (2019). Diversity and distribution of fish fauna of upstream and downstream areas at Koto Panjang Reservoir, Riau Province, Indonesia. *F1000Research*, 8.
- Atkore, V.M., Sivakumar, K., Johnsingh, A.J.Y. (2011). Patterns of diversity and conservation status of freshwater fishes in the tributaries of River Ramganga in the Shiwaliks of the Western Himalaya. *Research communications (Current Science)*, 100(5): 731-736.
- Atulegwu, P. U., & Njoku, J. D. (2004).The impact of biocides on the water quality. *Int. Res. J. Eng. Sci. Technol*, 1(2), 47-52.
- Atwebembeire, J., Bazira, J., Kagoro, G., Yatuha, J., Andama, M., & Lejju, J. B.b. (2018). The physico-chemical quality of streams and channels draining into River Rwizi, South Western Uganda.
- Awas, M., Ahmed, I., Ahmad, S. M., Al-Anazi, K. M., Farah, M. A., & Bhat, B. (2023). Integrative approach for validation of six important fish species inhabiting River Poonch of north-west Himalayan region (India). *Frontiers in Genetics*, 13, 1047436.

- Azizullah, A., Khan, S., Rehman, S., Taimur, N., & Häder, D. P. (2021). Detergents pollution in freshwater ecosystems. *Anthropogenic Pollution of Aquatic Ecosystems,* 245-270.
- Badoni, A. K. (2018). Fish diversity of a small hill stream Dhunteshwer-Gad of Uttarakhand (India) and need of its conservation. *International Research Journal of Biological Sciences*, 7(8), 16–19.
- Baggio, G., Qadir, M., & Smakhtin, V. (2021). Freshwater availability status across countries for human and ecosystem needs. *Science of the Total Environment*, 792, 148-230.
- Bagra, K., Sarkar, U., Kadu, K., Laskar, B., Nebeshwar-Sharma, K., & Das, D. (2009). Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India. *Check list*, 5(2), 330-350.
- Bakhtiyar, Y., Arafat, M. Y., Andrabi, S., & Tak, H. I. (2020). Zooplankton: the significant ecosystem service provider in aquatic environment. *Bioremediation and Biotechnology, Persistent and Recalcitrant Toxic Substances,* 3, 227-244.
- Balkhi, M. H., & Bhat, F. A., (2022). Fish biodiversity of Jammu and Kashmir and conservation measures. *In Biodiversity CRC Press,* 131-141.
- Balkhi, M.H., (2007). Fish diversity in Jammu and Kashmir and conservation measures. *Kashmir Speaks*, 6:104–115
- Bandyopadhyay, S., & De, S. K. (2018). Anthropogenic impacts on the morphology of the Haora River, Tripura, India. *Géomorphologie: relief, processus, environnement*, 24(2), 151-166.
- Bashir, I., Lone, F.A., Bhat, R.A., Mir, S.A., Dar, Z.A., Dar, S.A. (2020). Concerns and Threats. of Contamination on Aquatic Ecosystems. *Bioremediation and Biotechnology*, 27:1–26.
- Bhat, F. A., Balkhi, M. H., Najar, A. M., & Yousuf, A. R. (2013). Distribution pattern, density and morphometric characteristics of Schizothoracines (Snow trouts) in Lidderriver, Kashmir.Bioscan:. *An International Quarterly Journal of Life Sciences*, 8(2), 363–369.

- Bhat, F. A., Mohammad, I., & Magloo, A. H. (2024) Coldwater Treasures: Exploring the Significance of Snow Trouts in the Highland Ecosystem of the Hindu Kush Himalayan Region. In *Aquaculture and Conservation of Inland Coldwater Fishes* (pp. 139-154). Singapore: Springer Nature Singapore.
- Bhat, F. A., Yousuf, A. R., & Balkhi, M. H. (2020). Diversity of fishes in Jammu and Kashmir state. *Biodiversity of the Himalaya: Jammu and Kashmir State*, 859-887.
- Bhat, F.A., Balkhi, M.H., Yousuf, A.R. (2010). Fish diversity in the Kashmir Himalaya. In: Biodiversity, development and poverty elevation; International day for biological biodiversity. *Department of Botany, University of Kashmir,* 24–27
- Bhat, R. A., Singh, D. V., Qadri, H., Dar, G. H., Dervash, M. A., Bhat, S. A., & Yousf, B. (2022). Vulnerability of municipal solid waste: An emerging threat to aquatic ecosystems. *Chemosphere*, 287, 132-223.
- Bhat, S. U., & Qayoom, U., (2021). Implications of sewage discharge on freshwater ecosystems.
- Bhateria, R., Jain, D. (2016). Water quality assessment of lake water: a review. *Sustainable Water Resources Management*, 2(2), 161–173.
- Biswas, M., & Banerjee, P. (2018). Bridge construction and river channel morphology—a comprehensive study of flow behavior and sediment size alteration of the River Chel, India. *Arabian Journal of Geosciences*, 11(16), 467.

  Borah, S. (2022). Adverse effects of different detergents on fish: A review. *Research & Reviews: Journal of Ecology and Environmental Sciences*, 10(2), 1-15.
- Boyd, C.E., & Tucker, C.S., (1998). Ecology of aquaculture ponds. *In Pond aquaculture water quality management Springer, Boston,* MA, 8-86.
- Brown, J.H. (1984). On the relationship between abundance and distribution of species. *Am. Nat*., 124: 225–279.
- Brraich, O. S., & Malik, I. A. (2016). Fish fauna of wullar Wetland (Ramsar site in Kashmir Himalayas, India). *Iranian Journal of Ichthyology*, 3(3), 218–221.

- Brysiewicz, A., Czerniejewski, P., Dąbrowski, J., Formicki, K., & Więcaszek, B. (2022). Fish Diversity and Abundance Patterns in Small Watercourses of the Central European Plain Ecoregion in Relation to Environmental Factors. *Water*, 14(17), 2697.
- Bukola, D., Zaid, A., Olalekan, E. I., & Falilu, A., (2015). Consequences of anthropogenic activities on fish and the aquatic environment. *Poultry, Fisheries & Wildlife Sciences*, 3(2), 1-12.
- Buss, D. F., & Borges, E. L. (2008). Application of rapid bioassessment protocols (RBP) for benthic macroinvertebrates in Brazil: Comparison between sampling techniques and mesh sizes. *Neotropical Entomology*, 37(3), 288–295.
- Carpenter-Bundhoo, L., Butler, G. L., Bond, N. R., Bunn, S. E., Reinfelds, I. V., & Kennard, M. J. (2020). Effects of a low-head weir on multi-scaled movement and behavior of three riverine fish species. *Scientific Reports*, 10(1), 6817.
- Carvajal-Quintero, J. (2020). *Evaluating determinants of freshwater fishes geographic range sizes to inform ecology and conservation* (Doctoral dissertation, Université Paul Sabatier-Toulouse III; Instituto de ecología AC (Xalapa, Veracruz, Mexique; 1975-.
- Castillo, G. C., Tempel, T., Slater, S. B., Mahardja, B., & Gilbert, M. D. (2023). Community Patterns and Environmental Associations for the Early Life Stages of Fishes in a Highly Transformed Estuary. *Estuaries and Coasts*, 46(2), 562-579.
- Castillo-Rivera, M., Zavala-Hurtado, J.A., Zárate, R. 2002. Exploration of spatial and temporal patterns of fish diversity and composition in a tropical estuarine system of Mexico. *Reviews in Fish Biology and Fisheries*, 12, 167–177.
- Chakraborty, S. K., & Chakraborty, S. K. (2021). Biodiversity: Concept, Theories, and Significance in River Ecology. Riverine Ecology: Biodiversity Conservation, Conflicts and Resolution, 2, 35-185.
- Chandra, A., Gupta, Y., Dinakaran, J., Raina, N., Hanif, M., Meena, A., & Rao, K. S. (2024). Climate Change and Biodiversity in the Himalaya: Trends and Perception. *In Biodiversity Hotspot of the Himalaya Apple Academic Press*, 439-458.

- Chaudhari, B. R. (2022). Status of Fish Diversity in Lower West Rapti River, Banke. *Banke.*
- Chen, Y. Y., Li, R., Li, C. Q., Li, W. X., Yang, H. F., Xiao, H. (2018). Testing the validity of two putative sympatric species from Sinocyclocheilus (Cypriniformes: Cyprinidae) based on mitochondrial cytochromeb sequences. Zootaxa, 4476, 130–140.
- Chen, Y., Shan, X., Jin, X., Johannessen, A., Yang, T., & Dai, F. (2018). Changes in fish diversity and community structure in the central and southern Yellow Sea from 2003 to 2015. *Journal of Oceanology and Limnology*, 36, 805-817.
- Chiu, M. C., Leigh, C., Mazor, R., Cid, N., & Resh, V. (2017). Anthropogenic threats to intermittent rivers and ephemeral streams. *In Intermittent rivers and ephemeral streams Academic Press*, 433-454.
- Coffin, M. R. S., Knysh, K. M., Roloson, S. D., Pater, C. C., Theriaul, E., Cormier, J. M., & van den Heuvel, M. R. (2021). Influence of nutrient enrichment on temporal and spatial dynamics of dissolved oxygen within northern temperate estuaries. *Environmental Monitoring and Assessment*, 193, 1-16.
- Craswell, E. (2021). Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem. *SN Applied Sciences*, 3(4), 518.
- Cude, C.G. (2001). Oregon water quality index a tool for evaluating water quality management effectiveness. *J Am Water ResourAssoc*, 37(1), 125–137.
- Danáčová, M., Földes, G., Labat, M. M., Kohnová, S., & Hlavčová, K. (2020). Estimating the effect of deforestation on runoff in small mountainous basins in Slovakia. *Water*, 12(11), 3113.
- Das, S. M., & Subla, B. A. (1964). Ichthyofauna of Kashmir part II. Speciation of Kashmir Fishes. *Ichthyological,* 3, 57–62.
- Dawodu, B., Aderolu, Z., Elegbede. I.O., Adekunbi,F., 2015.Consequences of Anthropogenic Activities on Fish and the Aquatic Environment Poultry. Fisheries & Wildlife Sciences, 3(2):1-12.

- Day, F. (1878). Scientific results of the second ysark and mission, based upon the collection.
- DeGuzman, I., Altieri, P., Elosegi, A., Pérez-Calpe, A. V., von Schiller, D., González, J. M., & Larrañaga, A., (2022). Water diversion and pollution interactively shape freshwater food webs through bottom-up mechanisms. *Global change biology*, 28(3), 859-876.
- Deinet, S., Scott-Gatty, K., Rotton, H., Twardek, W. M., Marconi, V., McRae, L. (2020). The living planet index (LPI) for migratory freshwater fish. Technical report. *World Fish Migration Foundation*, 30.
- Delgado, C. L., Wada, N., Rosegrant, M. W., Meijer, S., & Ahmed, M. (2003). Fish Supply and demand in changing global markets. *International Food Policy Research Institute and World Fish Centre technical report*, 62, 226.
- Dubey, V.K. Sarkar, U.K. Pandey, A. Sani, R. Lakra, W.S., (2012). The Influence of Habitat on the Spatial Variation in Fish Assemblage Composition in an Unimpacted Tropical River of Ganga Basin, India. *Aquat. Ecol*., 46, 165–174.
- Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Lévêque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L., & Sullivan, C. A. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society*, 81(2), 163–182.
- Dufour, A., & Bartram, J. (Eds.). (2012). Animal waste, water quality and human health. *IWA publishing*.
- Effah, E.M. (2019). Assessment of the ecological and human health implications of heavy metals and microbial load content of the Ankobra River, Ghana (Doctoral dissertation, University of Cape Coast).
- Ehrlich, P. R., & Wilson, E. O. (1991). Biodiversity studies: Science and policy. *Science*, 253(5021), 758–762.

- Ekka, A., Pande, S., Jiang, Y., & der Zaag, P. V. (2020). Anthropogenic modifications and river ecosystem services: a landscape perspective. *Water*, 12(10), 2706
- El-Sheekh, M. M. (2017). Impact of water quality on ecosystems of the Nile River. The Nile River, 357-385.
- Faisal, Anwar, A., Wulan, S, D., Islamiya, H. A. T., Raja Ahmad, R. A., & Salimah Alias, N. (2024). Understanding the impact of mining activities and human capital improvement on achieving sustainable development goals; evidence from East Luwu, Indonesia. *Cogent Economics & Finance*, 12(1), 238-6401.
- Fang, S.O., F., Delling, F., & Ahlander, E. (1999).The fishes of the Kashmir valley. *In L.e.d. Swedmar, L. A. B. Gotebofrgs&Swedmar (Eds.), Nyman, River Jhelum, Kashmir valley. Impacts on the aquatic environment*, 99–162.
- FAO. (2022). The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation. Rome, FAO.*
- FAO. The State of World Fisheries and Aquaculture 2020. Sustainability in Action. *Rome: FAO*.
- *Fernandes, I., M., Lourenco, L. S., Ota, R. P., Moreira, M. M. M., & Zawadzki, C. H. (2013). Effects of local and regional factors on the fish assemblage structure in Meridional Amazonian streams. Environmental Biology of Fish, 96, 837–848.*
- Filoso, S., Bezerra, M. O., Weiss, K. C., & Palmer, M. A. (2017). Impacts of forest restoration on water yield: A systematic review. *PloS one*, 12(8), 183-210.
- Flowra, F.A., Flowra, Islam, M.A., Jahan,S.N 1.M., Hussain,M.A., Alam, M.M., Bashir, F.A., Mazlan,A.G., Simon , K.D. (2013). Status and decline causes of fish diversity of Baral River, Natore, Bangladesh. *International Journal of Bioflux society*, 6(4):352-357.
- Fodor, L., Bota, I. O., Abbas, Y., Fodor, M., & Ciuce, C. (2011). Electricity and fishing-a dangerous mix. *Burns*, 37(3), 495-498.

- Fortin-Hamel, L., & Chapman, L. J. (2024). Interactive effects of sedimentary turbidity and elevated water temperature on the Pugnose Shiner (Miniellus anogenus), a threatened freshwater fish. *Conservation Physiology*, 12(1).
- Froese, R., & Pauly, D. (2020). Fishbase. *World Wide Web electronic publication*.
- Froese, R., Pauly, D., (2019). Fish Base. *World Wide Web Electronic Publication. eds*.
- Ganaie M. I., Dev A., Mayer I. A., Ahmed P., and Ganaie S. A. (2023). Quality assessment of drinking water sources in the upper Jhelum basin of Kashmir Himalaya, J&K, India. International Journal of River Basin Management, 21(3), 513-524.
- Garg, R. K., Rao, R. J., & Saksena, D. N. (2009). Water quality and conservation management of Ramsagar reservoir, Datia, Madhya Pradesh. *Journal of Environmental Biology*, 30(5), 909.
- Garner, G., Malcolm, I. A., Sadler, J. P., & Hannah, D. M. (2017). The role of riparian vegetation density, channel orientation and water velocity in determining river temperature dynamics. *Journal of Hydrology*, 553, 471-485.
- Garzanti, E., Vezzoli, G., Andò, S., Paparella, P., & Clift, P. D. (2005). Petrology of Indus River sands: a key to interpret erosion history of the Western Himalayan Syntaxis. *Earth and Planetary Science Letters*, 229(3-4), 287-302.
- Gebrekiros, S. T. (2016). Factors affecting stream fish community composition and habitat suitability. *Journal of Aquaculture and Marine Biology*, 4(2), 00076.
- Gerhard, P., Moraes, R., & Molander, S. (2004). Stream fish communities and their associations to habitat variables in a rain forest reserve in southeastern Brazil. *Environmental Biology of Fishes*, 71(4), 321–340.
- Ghimire, S., & Koju, N. (2021). Fish diversity and its relationship with environmental variables in Kamala River, Nepal. *Journal of Biological Diversity*, 22(11).
- Giri, S. (2021). Water quality prospective in Twenty First Century: Status of water quality in major river basins, contemporary strategies and impediments: A review. *Environmental Pollution*, 271, 116332.

- Goswami, U. C., Basistha, S. K., Bora, D., Shyamkumar, K., Saikia, B., & Changsan, K. (2012). Fish diversity of North East India, inclusive of the Himalayan and Indo Burma biodiversity hotspots zones: A checklist on their taxonomic status, economic importance, geographical distribution, present status and prevailing threats. *International Journal of Biodiversity and Conservation*, 4(15), 592-613.

- Gowher, T., Jamali, M. M., Mir, R. A., Majeed, M., & Mir, S. J.(2023) Anthropogenic factors and their effects on the fish fauna of the Lidder River in Pahalgam, Anantnag district (Jammu and Kashmir). International Journal of Fauna and Biological Studies ; 10(4): 40-44.
- Gray, J. (2023). Evaluation of habitat features responsible for variations in the abundance of endangered Nooksack dace (Rhinichthys cataractae sp. cataractae) and the role of habitat restoration in their recovery (Doctoral dissertation, University of British Columbia).
- Green, N. S., Li, S., Maul, J. D., & Overmyer, J. P. (2022). Natural and anthropogenic factors and their interactions drive stream community integrity in a North American river basin at a large spatial scale. *Science of The Total Environment*, 835, 155344.
- Griffith, W., & McClelland, J. (1847). Journals of travels in Assam, Burma, Bootan, Affghanistan and the neighbouring countries. Bishop's college Press, 2.
- Guo, Q., Liu, X., Ao, X., Qin, J., Wu, X., & Ouyang, S. (2018). Fish diversity in the middle and lower reaches of the Ganjiang River of China: Threats and conservation. Pl*oS one*, 13(11), 20-51.
- Gupta C, Langer S, Uttam S. (2022) The Spatial and Temporal Disparity of Fish Assemblage and its Association with Environmental Factors through Multivariate Statistical Analysis in Jammu and Kashmir's Himalayan River System. *Curr World Environ*; 17(3).
- Häder, D. P., Banaszak, A. T., Villafañe, V. E., Narvarte, M. A., González, R. A., & Helbling, E. W. (2020). Anthropogenic pollution of aquatic ecosystems: Emerging problems with global implications. *Science of the Total environment,* 713, 136586.

- Hamid, A., Bhat S. U., & Jehangir A. (2020). Local determinants influencing stream water quality. *Applied Water Science*, 10(1), 1–16
- Hamid, A., Bhat, Sami, U., & Jehangir, A. (2021). Assessment of ecological characteristics of macroinvertebrate communities and their relationship with environmental factors in a stream ecosystem. *Chemistry and Ecology,* 37(10), 746–766.
- Hamid, A., Dar, N.A., Bhat, S.U., and Pandit, A.K. (2013).Water Quality Index: A Case Study of Vishav Stream, Kulgam, Kashmir. *International Journal of Environmental Bioenergy.* 5(2):108-122
- Hamid, A., Khan, M. U., Yaqoob, J., Umar, A., Rehman, A., Javed, S., Sohail, A., Anwar, A., Khan, M.S. & Ali, A. (2016). Assessment of mercury load in river Ravi, urban sewage streams of Lahore Pakistan and its impact on the oxidative stress of exposed fish. *J Bio Environ Sci*, 8(4), 63-72.
- Hamid, J., & Singh, K. R. (2019). Diversity of Fishes in river Vaishav: The left tributary of River Jhelum of Jammu and Kashmir. India. *Journal of Emerging Technologies and Innovative Research,* 5(6), 47-58.
- Hamid, S.A., Bhat, S.U., and Bhat, A.J. (2016). Environ metric techniques in water quality assessment and monitoring: a case study. *Environment Earth Sciences*, 75, 1–13
- Heckel, J. J. (1838). FischeausCaschmirgesammelt und herausgegeben von Carl Freiherrn von Hügel, beschrieben von JJ Heckel. Wien. FischeausCaschmirgesammelt und herausgegeben von Carl Freiherrn von Hügel, beschrieben von JJ Heckel, 1-112.
- Heckel, J. J. (1844). FischeKashmir'in Von Hugel's.Kashmir und das Reich der Siek, 4, abth., 2,351–384.
- Hickman, R. E., & Gray, B. J. (2010). Trends in the quality of water in New Jersey streams, water years 1998-2007. *U. S. Geological Survey*.
- Hora, S.L. (1936). Yale North Indian Expedition, Article XVIII. Report on fishes, Part I, Cobitidae. *Mem. Conn. Acad. Sci.,* 10, 299-321.

- Horton, R. K. (1965). An index number system for rating water quality. *J Water Pollut Control Fed*, 37(3), 300-306.
- Hou, Y., Yang, Z., An, R., Cai, L., Chen, X., Zhao, X., Zou, X. (2019): Water flow and substrate preferences of Schizothorax wangchiachii (Fang, 1936). *Ecological Engineering*, 138, 1-7.
- Hu, M.L., X. I. H. B., Hua, Q., Zhang, J., Zhou, H., Ge, G., & Ai, Z. (2014). Preliminary investigations on fish resources of yihuang Mergus squamatus nature reserve in jiangxi province. *Nanchang U: Nat. Sci*, 38(05), 502.
- Huang, S., Xu, H., Shang, D., Liu, J., Tang, Q., & Liu, R. (2021). Phosphorus fractions and release factors in surface sediments of a Tailwater River in Xinmi City, a case study. Sustainability, 13(10), 5417.
- Hubbell, S. P. (2001). The unified neutral theory of biodiversity and biogeography. *Princeton University Press.*
- Husain, M. (2000). Systematic Geography of Jammu and Kashmir. *Rawat Publications, Jaipur,* 271.
- Hussain, A.Q, &Pandit, A.K. (2011). An Ecological Study of Doodhganga and its Drainage Basin-A Lotic System of Kashmir. *Shodhganga,* 39-40.
- Hussain, J., & Rashid, G. (2021). Impacts of some anthropogenic activities on the morphology of the River Jhelum, Kashmir Himalaya, India.
- Hussain, J., Rashid, G., & Singh, R. (2022). Impacts of Sand Mining on Riverine Ecosystems: A Short Review, 2(3):105-108.
- Irfan, S., & Alatawi, A. M. M. (2019). Aquatic ecosystem and biodiversity: a review. *Open Journal of Ecology,* 9(1), 1-
- Islam S. T., Bhat S. U., Hamid A., Pandit A. K., and Sabha I., **(2023)** Impact of land-use patterns on water quality characteristics of Rambiarrah stream in Kashmir Himalaya. International Journal of River Basin Management, 1-18
- Islam, M. M., Lenz, O. K., Azad, A. K., Ara, M. H., Rahman, M., & Hassan, N. (2017). Assessment of spatio-temporal variations in water quality of Shailmari River,

Khulna (Bangladesh) using multivariate statistical techniques. *Journal of Geoscience and Environment Protection,* 5(1), 1-26.

- Islam, M.A., Abdulla-Al-Asif, A.A., Samad, A.M.,1, Sarker, B., Ahmed, M., Satter, A., Hossain, A. (2017). A comparative study on fish biodiversity with conservation measures of the Bhairabriver, Jessore, Bangladesh. *Asian Journal of Medical and Biological Research,* 3 (3), 357-367.
- Islam, S. T., Bhat, S. U., Hamid, A., Pandit, A. K., & Sabha, I. (2024). Impact of land-use patterns on water quality characteristics of Rambiarrah stream in Kashmir Himalaya. *International Journal of River Basin Management*, 22(3), 411-428.
- Itoo, Z. A., Reshi, Z. A., Basharat, Q., Majeed, S. T., & Andrabi, K. I. (2015). Identification and characterization of EctomycorrhizalCortinarius species (Agaricales, Basidiomycetes) from temperate Kashmir Himalaya, India, by ITS barcoding. *Advances in Molecular Biology*.
- Jaccard ,P. (1912). The distribution of the flora in the alpine zone. New Phytologist, 11(2): 37-50.
- Jaiswal, D., Pandey, U., & Pandey, J. (2021). Ecosystem responses to pollution in the Ganga River: Key issues to address river management. *Water Pollution and Management Practices*, 221-253.
- Jaiswal, M., Hussain, J., Gupta, S. K., Nasr, M., & Nema, A. K. (2019). Comprehensive evaluation of water quality status for entire stretch of Yamuna River, India. *Environmental monitoring and assessment*, 191(4), 1-17.
- Jamal, S., & Ahmad, W. S. (2020). Assessing land use land cover dynamics of wetland ecosystems using Landsat satellite data. *SN Applied Sciences*, 2, 1-24.
- Jamsheed, H., & Singh, K. R. (2019). Diversity of Fishes in river Viashaw: The left tributary of River Jhelum of Jammu and Kashmir. India. *Journal of Emerging Technologies and Innovative Resesrch*, 5(6).
- Jan, S., Gul, S., Iqbal, G., & Bhat, F. A. (2023). Risk Factors in the Natural Habitat of Fish: A Review. *Asian Journal of Agricultural Extension, Economics & Sociology*, 41(9), 691-698.

- Jayaram, K. C. (1999). The freshwater fishes of the Indian region. Narendra Publishing House. Delhi, 551.
- Jayaraman, S., & Brindha, N. (2024). An evaluation of the ganga river's carbon flow and its impact on india's nutritional and climate change, 26(2), 05216.
- Johal, M., Krishan-Tandon, K., Kumar-Tyor, A., & Kumar-Rawal, Y. (2002). Fish diversity in different habitats in the streams of lower Middle Western Himalayas. Polish Journal of Ecology, 50(1), 45-56.
- Jun, Y. C., Kim, N. Y., Kim, S. H., Park, Y., Kong, D., & Hwang, S. (2016). Spatial distribution of benthic macroinvertebrate assemblages in relation to environmental variables in Korean nationwide streams. *Water*, 8(1), 27–46.
- Kamboj, N., Pandey, A., Shoaib, M., & Kumar, R. (2012). Environmental impact assessment of illegal Ganga mining at Kangri village, district Haridwar (Uttarakhand) India. *Journal of sustainable environmental research*,1: 67-71.
- Kanth, T. A., & Hassan, Z. (2012). Morphometric analysis and prioritization of watersheds for soil and water resource management in Wular catchment using geo-spatial tools. *Int J Geol Earth Environ Sci*, 2(1), 30-41.
- Kar, D. (2003). Fishes of Barak drainage, Mizoram and Tripura. In: Kumar, A., Bohra, C. & Singh, L. K. (Eds.). Environment, Pollution and Management. *APH Publishing Corporation*, 203-211.
- Kar, D. (2003a). Fishes of Barak drainage, Mizoram and Tripura.
- Kar, D., & Sen, N. (2007). Systematic list and distribution of fishes in Mizoram, Tripura and Barak drainage of northeastern India. *ZOOS'PRINT JOURNAL*, 22(3), 2599-2607.
- Kar, D., Nagarathna, A. V., Ramachandra, T. V., & Dey, S. C. (2006). Fish diversity and conservation aspects in an aquatic ecosystem in Northeastern India. ZOOS'Print Journal, 21(7), 2308-2315.
- Kattel, G. R. (2022). Climate warming in the Himalayas threatens biodiversity, ecosystem functioning and ecosystem services in the 21st century: is there a better solution. *Biodiversity and Conservation*, 31(8), 2017-2044.

- Katwate, U., Baby, F., Raghavan, R., & Dahanukar, N. (2014). The identity of Pethia punctata, a senior synonym of P. muvattupuzhaensis (Teleostei: Cyprinidae). Zootaxa, 3884(3), 201-221.
- Keraga, A. S., Kiflie, Z., & Engida, A. N. (2017). Spatial and temporal water quality dynamics of Awash River using multivariate statistical techniques. African Journal of Environmental Science and Technology, 11(11), 565-577.
- Khan, A., Naz, B. S., & Bowling, L. C. (2015). Separating snow, clean and debris covered ice in the Upper Indus Basin, Hindukush-Karakoram-Himalayas, using Landsat images between 1998 and 2002. *Journal of Hydrology*, 521, 46-64
- Khan, F., Husain, T., & Lumb, A. (2003).Water quality evaluation and trend analysis in selected watersheds of the Atlantic Region of Canada. Environ. *Monit.Assess*., 88, 221-242.
- Khan, I., & Ali, M. (2013).Current status of fish fauna of River Jhelum, Kashmir, J&K. *Open access scientific report*, 2(3), 1–3.
- Khan, M. N., & Mohammad, F. (2014). Eutrophication: challenges and solutions. *Eutrophication: Causes, Consequences and Control*, 2, 1-15.
- Khan, M. N., & Mohammad, F. (2014). Eutrophication: challenges and solutions. *Eutrophication: Causes, Consequences and Control*: 2, 1-15.
- Khanday, S. A., Bhat, S. U., Islam, S. T., & Sabha, I. (2021). Identifying lithogenic and anthropogenic factors responsible for spatio-seasonal patterns and quality evaluation of snow melt waters of the River Jhelum Basin in Kashmir Himalaya. Catena, 196, 104853.
- Khanday, S.A., Romshoo, S.A., Jehangir, A., Sahay, A., & Chauhan, P. (2018). Environmetric and GIS techniques for hydrochemical characterization of the Dal lake, Kashmir Himalaya, India. *Stoch Environ Res Risk Assess*, 32(11), 3151-3168.
- Khatri, N., & Tyagi, S. (2015). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in life science*, 8(1), 23-39.

- Knobeloch, L., Salna, B., Hogan, A., Postle, J., & Anderson, H. (2000). Blue babies and nitrate-contaminated well water. *Environmental health perspectives*, 108(7), 675-678.
- Koehnken, L., Rintoul, M. S., Goichot, M., Tickner, D., Loftus, A. C., & Acreman, M. C. (2020). Impacts of riverine sand mining on freshwater ecosystems: A review of the scientific evidence and guidance for future research. *River Research and Applications*, 36(3), 362-370.
- Kreiling, A. K., O'Gorman, E. J., Pálsson, S., Benhaïm, D., Leblanc, C. A., Ólafsson, J. S., & Kristjánsson, B. K. (2021). Seasonal variation in the invertebrate community and diet of a top fish predator in a thermally stable spring. *Hydrobiologia*, *848*(3), 531-545.
- Kullander, S.O., Fang, F., Delling, B. and Ahlander, E. (1999): The fishes of the Kashmir valley, 99-162.
- Kumar, A. B., Smrithy, R., & Sathasivam, K. (2012). Dolphin-assisted cast net fishery in the Ashtamudi Estuary, south-west coast of India. *Indian Journal of fisheries,* 59(3), 143-148.
- Kumar, A., C. Bohra, L.K. Singh, () . Environment, Pollution and Management. *APH Publishing Corporation, New Delhi*, 203-211.
- Kumar, A., Qureshi, T. A., Parashar, A., & Patiyal, R. S. (2006). Seasonal variation in physico-chemical characteristics of Ranjit Sagar reservoir, Jammu & Kashmir. *Journal of Ecophysiology & Occupational Health,* 6(3&4), 159-163
- Kumar, M., & Mishra, G. V. (2024). Causes and Impacts of Water Pollution on Various Water Bodies in the State of Rajasthan, India: A Review. *Environment and Ecology*, 42(2A), 645-654.
- Kumar, M., Sharif, M., & Ahmed, S. (2020). Impact of urbanization on the river Yamuna basin. *International Journal of River Basin Management*, 18(4), 461-475.
- Kumarmm, R., Parvaze, S., Huda, M.B., Allaie, S.P.J.E.M. (2022). The changing water quality of lakes—a case study of Dal Lake, Kashmir Valley, 194(3), 228.

- Larentis, C., Kotz Kliemann, B. C., Neves, M. P., & Delariva, R. L. (2022). Effects of human disturbance on habitat and fish diversity in Neotropical streams. *Plos one*, 17(9), e0274191.

- Lawson, R. G., & Jurs, P. C. (1990). New index for clustering tendency and its application to chemical problems. *Journal of chemical information and computer sciences,* 30(1), 36–41.

- Lévêque, C., Oberdorff, T., Paugy, D., Stiassny, M. L. J., & Tedesco, P. A. (2008). Global diversity of fish (Pisces) in freshwater. Hydrobiologia, 595(1), 545–567.

- Li, J.H., Huang, L.L., Zou L.M., Kano, Y., Sato, T., Yahara, T. (2012). Spatial and temporal variationof fish assemblages and their associations to habitat variables in a mountain stream of north Tiaoxi River, China. *Environ Biol Fishes*,93, 403–417
- Limbu, J. H., Rajbanshi, D., Tumbahangfe, J., Subba, A., Tumba, S., & Basnet, R. (2023). Evaluating the influence of environmental variables on fish abundance and distribution in the Singhiya River of Morang District, eastern Nepal. *Journal of Threatened Taxa*, 15(5), 23216-23226.
- Liu, F., Lin, P., Liu, H., & Wang, J. (2021). Spatial and seasonal patterns of fish assemblages in mountain streams of the Ren River, southwest China. *Ecology and Evolution*, 11, 11323–11332.

- Liu, F., Lin, P., Liu, H., & Wang, J. (2021). Spatial and seasonal patterns of fish assemblages in mountain streams of the Ren River, southwest China. Ecology and Evolution, 11(16), 11323-11332.

- Liu, F., Lin, P., Liu, H., & Wang, J. (2021). Spatial and seasonal patterns of fish assemblages in mountain streams of the Ren River, southwest China. Ecology and Evolution, 11(16), 11323-11332.

- Liu, F., Wang, J. W., Liu, H. Z., & Wang, W. J. (2019).Seasonal variations in food resource partitioning among four sympatric gudgeon species in the upper Yangtze River, China. *Ecology and Evolution*, 9(12), 7227–7236.

- Liu, J., Zhang, C., Kou, L., & Zhou, Q.J. (2017). Effects of climate and land use changes on water resources in the Taoer River, 1-13.
- Liu, N., Meng, F., Zhang, L., Qin, Y., Xue, H., & Liang, Z. (2024). Toxicity threshold and ecological risk of nitrate in rivers based on endocrine-disrupting effects: A case study in the Luan River basin, China. *Science of The Total Environment*, 930, 172859.
- Liu, S., Xi, Y., Zhang, C., Zhang, W., Ouyang, L., Giet, W. B. Y., ... & Yao, W. (2024). Determining the Fish Migration Patterns Based on Fish Habitat Assessment at a River Confluence. Ecohydrology, e2724.
- Liu, S., Xi, Y., Zhang, C., Zhang, W., Ouyang, L., Giet, W. B. Y., ... & Yao, W. (2024). Determining the Fish Migration Patterns Based on Fish Habitat Assessment at a River Confluence. Ecohydrology, e2724.
- Liu, X. J. (2017). Diversity of fish species in Suichuan River and Shushui River and conservation value, China. *Environ. Biol. Fish*, 493–507.
- Lone, S. A., Bhat, S. U., Hamid, A., Bhat, F. A., & Kumar, A. (2021). Quality assessment of springs for drinking water in the Himalaya of South Kashmir, India. *Environmental Science and Pollution Research*, 28, 2279-2300.
- Longo, S.B., York, R. (2009). Structural Influences on Water Withdrawals: An Exploratory Macro-Comparative Analysis. *Hum. Ecol. Rev.*,16:75–83.
- Lu, L., Cheng, Q., Xue, Q., Zhang, X., & Yang, L. (2023). Characteristics of Nitrogen in Overlying Water and Sediment of Typical Agricultural Drainage Ditches during Different Periods in a Freezing-Thaw Area of China. *Water*, *15*(15), 2789.
- Lukubye, B., & Andama, M. (2017). Physico-Chemical Quality of Selected Drinking Water Sources in Mbarara Municipality, Uganda. *Journal of Water Resource and Protection*, 9, 707-722.
- Madyise, T., (2013). Case studies of environmental impacts of sand mining and gravel extraction for urban development in Gaborone.

- Mahapatra, B. K., Sarkar, U. K., & Lakra, W. S. (2014). A Review on status, potentials, threats and challenges of the fish biodiversity of West Bengal. J. *Biodivers. Biopros. Dev*, 2(140), 2376-0214.
- Mahazar, A., Shuhaimi-Othman, M., Kutty, A.A.& Desa, M.N. (2013). Monitoring Urban River Water Quality Using Macroinvertebrate and Physico-Chemical Parameters Case Study of Penchala River, Malaysia. *Journal of Biosocial Science*, 13, 474-482.
- Mahmood, T. H., Pomeroy, J. W., Wheater, H. S., & Baulch, H. M. (2017). Hydrological responses to climatic variability in a cold agricultural region. *Hydrological Processes*, 31(4), 854-870.
- Mainali, B., Shumski, A., Bukka, S., Diemler, N., & Wright, R. (2024, June). Multi-parameter optical fiber sensing of humidity, CH4, CO2, and corrosion. In *Optical Waveguide and Laser Sensors III* (Vol. 13044, pp. 123-140). SPIE.
- Mainali, S., Garzon, M., Venugopal, D., Jana, K., Yang, C. C., Kumar, N., & Deng, L. Y. (2021). An information-theoretic approach to dimensionality reduction in data science. *International Journal of Data Science and Analytics*, 12, 185-203.
- Malhotra, Y.R., Dutta, S.P., Gupta,S.C., Shekhar,C., (2003). A disturbing trend Indicating decline in catch and size of *Schizothorax richardsonii* and threats to its Breeding Habitat. *Advanced in fish research*, 3, 109-118.
- Mansour, A.T, Allam, B.W., Srour, T.M., Omar., E.A., Nour, A.M., Khalil, H.S. (2021). The feasibility of monoculture and polyculture of striped catfish and nile tilapia in different proportions and their effects on growth performance, productivity, and financial revenue. *J Mar Sci Eng.*, 9:586.
- Manzoor, J., & Khan, M. (2020). Environmental perspective of stone crushing and quarrying: A case study from Poonch District of Jammu and Kashmir, India. *Current World Environment*, 15(1), 68.
- Mateo-Sagasta J, Zadeh SM, Turral H, & Burke J (2017) Water pollution from agriculture: a global review. Executive summary.

- Mazzariol, S., Corazzola, G., Rubini, S., Quaglio, F., Perolo, A., Gustinelli, A., & Centelleghe, C. (2021). Illegal fishing with electrofishing devices in the Po river basin, Emilia Romagna, Italy. *Scientific Reports*, 11(1), 15270.
- McClelland, J. (1842). On the fresh-water fishes collected by William Griffith, Esq., FLS Madras Medical Service, during his travels under the orders of the Supreme Government of India, from 1835 to 1842. *J Nat Hist*, 2, 560-589.
- McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., Dornelas, M., Enquist, B. J., Green, J. L., He F., Hurlbert, A. H., Magurran, A. E., Marque,t P. A., Maurer, B. A., Ostling, A., Soykan, C. U., Ugland K. I., White, E. P. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology Letters*, 10: 995–1015..
- McIntosh, J. (2008). The ancient Indus Valley: new perspectives. *Abc-Clio*.
- McLaren, S. (2013). 10 Planning and conducting surveys. *Quantitative health research: issues and methods: issues and methods*, 175.
- McLeod, E. (2019). Examining Employee Preferences for Workplace Wellbeing Intervention Designs.
- Mehmood, M. A., Shafiq-ur-Rehman, A. R., &Ganie, S. A. (2017). Spatio-temporal changes in water quality of Jhelum River, Kashmir Himalaya. *Int J Environ Bioener*, 12(1), 1-29.
- Meng, Z., Xu, X., Lin, W., Ge, B., Xie, Y., Song, B. and Cheng, H. (2018). Role of Ambient Ammonia in Particulate Ammonium Formation at a Rural Site in the North China Plain. *Atmospheric Chemistry and Physics*, 18, 167-184.
- Mir, R. A., and Gani, K. M. (2019).Water quality evaluation of the upper stretch of the river Jhelum using multivariate statistical techniques. *Arabian Journal of Geosciences*, 12(14), 1-19.
- Mir, S. A., Bhat, M. S., Mattoo, D., Rather, G. M., & Wani, M. S. (2024). Envisioning spatial justice in health geographies and groundwater governance of Kashmir Himalayas using socio-geospatial approach. *Sustainable Water Resources Management*, 10(2), 73.

- Mir, S. A., Qadri, H., Beigh, B. A., Dar, Z. A., & Bashir, I. (2019). Assessment of nutrient status and water quality index of Rambiara stream, Kashmir Himalaya, India. *Journal of Pharmacognosy and Phytochemistry*, 8(3), 172-180.
- Mir, Z. A., Bakhtiyar, Y., Arafat, M. Y., Khan, N. A., & Parveen, M. (2023). Spatiotemporal variation of physicochemical parameters in Aripal and Watalara streams of Kashmir Himalaya using multivariate statistical techniques. *Environmental Monitoring and Assessment*, 195(6), 743.
- Mishra, L. (2016). Focus group discussion in qualitative research. *TechnoLearn: An International Journal of Educational Technology*, 6(1), 1-5.
- Mishra, S. P., Mishra, D. B., & Mishra, A. K. (2021). Diversity of Fresh Water Fishes and their Conservation Status in Eastern Uttar Pradesh, India. *International Journal for Modern Trends in Science and Technology*, 78, 69-77.
- Misra, K. S. (1949). A note on the systematic position of two Cyprinid fishes of the genus Oreinus McClelland from Kashmir. *J. Zool. Soc. India*, 1(3), 39–40.
- Moniruzzaman, M., Bhowmick, A. R., Karan, S., & Mukherjee, J. (2021). Spatial heterogeneity within habitat indicates the community assemblage pattern and life strategies. *Ecological indicators*, 123, 107365.
- Morales-Marín, L. A., Rokaya, P., Sanyal, P. R., Sereda, J., & Lindenschmidt, K. E. (2019). Changes in stream flow and water temperature affect fish habitat in the Athabasca River basin in the context of climate change. *Ecological Modelling*, 407, 108-718.

  Morman, S A., & Plumlee, G. S. (2013). The role of airborne mineral dusts in human disease. *Aeolian Research*, 9, 203-212.
- Mostafavi, S. M., Rahmani, M., Kaboli, M., & Abdoli, A. (2021). Determinants of fish distribution pattern and habitat preference in protected Karaj River, Iran. *Iranian Journal of Fisheries Sciences*, 20(2), 410-429.
- Mota-Ferreira, M., Filipe, A. F., Filomena Magalhaes, M., Carona, S., & Beja, P. (2021). Spatial modelling of temporal dynamics in stream fish communities under anthropogenic change. *Diversity and Distributions*, 27(2), 313-326.

- Moyle, P. B., &Senanayake, F. R. (1984). Resource partitioning among the fishes of rainforest streams in Sri Lanka. J. *Zool. SocietàLond*., 202, 195–223
- Muhangane, L., Nkurunungi, J.B., Yatuha, J. and Andama, M. (2017). Suitability of Drinking Water Sources from Nyaruzinga Wetland for Domestic Use in Bushenyi Municipality, Uganda. *Journal of Water Resource and Protection*, 9, 1587
- Mukate, S., Panaskar, D., Wagh, V., Muley, A., Jangam, C., & Pawar, R. (2018). Impact of anthropogenic inputs on water quality in Chincholi industrial area of Solapur, Maharashtra, India. *Groundwater for Sustainable Development*, 7, 359-371.
- Mullen, J. A., Bramblett, R. G., Guy, C. S., Zale, A. V., & Roberts, D. W. (2011). Determinants of fish assemblage structure in Northwestern Great Plains streams. *Transactions of the American Fisheries Society*, 140, 271–281.
- Muruganandam, M., Rajamanickam, S., Sivarethinamohan, S., Gaddam, M. K. R., Velusamy, P., Gomathi, R., & Muniasamy, S. K. (2023). Impact of climate change and anthropogenic activities on aquatic ecosystem–A review. *Environmental Research*, 238, 117233.
- Mushtaq, N., Singh, D. V., Bhat, R. A., Dervash, M. A., & Hameed, O. B. (2020). Freshwater contamination: sources and hazards to aquatic biota. F*resh water pollution dynamics and remediation*, 27-50.
- Mushtaq, S. T., Mushtaq, S. A., & Balkhi, M. H. (2018). Ichthyofaunal diversity and cpue (Catch per unit effort) annual diversity and cpue (catch per unit effort) at Watlab Ghat, Wular Lake, Kashmir. *The Bioscan*, 13(2), 683-688.
- Musonge, P. S. L., Boets, P., Lock, K., & Goethals, P. L. M. (2020). Drivers of benthic macroinvertebrate assemblages in equatorial alpine rivers of the Rwenzoris (Uganda).*Water*, 12(6), 1668.
- Mustafa, S. A., Al-Rudainy, A. J., & Salman, N. M. (2024). Effect of environmental pollutants on fish health: An overview. *Egyptian Journal of Aquatic Research*.
- Nagaraju, A, Thejaswi A, & Sreedhar, Y.J.E.S.R.J. (2016). Assessment of groundwater quality of Udayagiri area, Nellore District, Andhra Pradesh, South India using multivariate statistical techniques, 20(4): E1-E7.

- Nagy, J., Kiss, T. (2016). Hydrological and Morphological Changes of the Lower Danube Near Mohács, Hungary. *Journal of Environmental Geography*, 9 (1–2), 1–6
- Naikoo, B. A., Gupta, R., Zuber, S. M. (2015). Diversity of fishes in relation to abiotic status of Vaishav stream Kulgam Kashmir. *International Journal of Science & Nature*, 6(3), 501–505.
- Nair, R. J. (2024). *Teleost Diversity*.
- Negi, R. K., & Mamgain, S. (2013). Species diversity, abundance and distribution of fish community and conservation status of Tons river of Uttarakhand State, India. Journal of Fisheries and Aquatic Science, 8(5), 617-626.
- Negi, R. K., Joshi, B. D., Negi, T., & Chand, P. (2007). A study on stream morphology of some selected streams hill streams of district Nainital with special reference to its biotic communities. *Proceedings of the National Seminar on Limnology at Jiapur, India*, 288-295).
- Ngor, P. B., Grenouillet, G., Phem, S., So, N., & Lek, S. (2018). Spatial and temporal variation in fish community structure and diversity in the largest tropical flood-pulse system of South-East Asia. *Ecology of Freshwater Fish*, 27(4), 1087-1100.

- Ngor, P. B., Grenouillet, G., Phem, S., So, N., & Lek, S. (2018). Spatial and temporal variation in fish community structure and diversity in the largest tropical flood-pulse system of South-East Asia. *Ecology of Freshwater Fish*, *27*(4), 1087-1100.

- Nigrelli, G., Fratianni, S., Zampollo, A., Turconi, L., & Chiarle, M. (2018). The altitudinal temperature lapse rates applied to high elevation rockfalls studies in the Western European Alps. *Theoretical and Applied Climatology*, 131, 1479-1491.
- Nisa, R. U., Gupta, K., Wani, S. M., Allie, K. A., & Kouser, N. (2020). A study on diversity and ecology of ichthyofauna of Rajouri district, Jammu and Kashmir, India. *Records of the Zoological Survey of India*, 363-372.
- Norman, R., Crumlish, M., & Stetkiewicz, S. (2019). The importance of fisheries and aquaculture production for nutrition and food security. *Revue scientifique et technique (International Office of Epizootics)*, 38(2), 395-407.

- Nuissl, H., & Siedentop, S. (2021). Urbanisation and land use change. *Sustainable land management in a European context: a co-design approach*, 75-99.
- Null, C., Stewart, C. P., Pickering, A. J., Dentz, H. N., Arnold, B. F., Arnold, C. D., & Colford, J. M. (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. *The Lancet Global Health*, 6(3), e316-e329.
- Odigie, J. O. (2019). Application of Water Quality and Pollution Tolerance Indexes as Effective Tools for River Management. *Punjab University J. of Zoology*, 34(2), 105-113.
- Ogidi, O. I., & Akpan, U. M. (2022). Aquatic biodiversity loss: impacts of pollution and anthropogenic activities and strategies for conservation. In Biodiversity in Africa: potentials, threats and conservation. *Singapore: Springer Nature Singapore*, 421-448.
- Ogidi, O. I., & Izah, S. C. (2024). Water Contamination by Municipal Solid Wastes and Sustainable Management Strategies. In Water Crises and Sustainable Management in the Global South (pp. 313-339). *Singapore: Springer Nature Singapore*, 313-339.
- Ogunbanwo, O.M., (2022). Comparative Study of Water Quality Parameters of Two Fish Farm Estate in Ikorodu, Lagos State, Southwest Nigeria.
- Okello, C., Antonellini, M., Greggio, N., & Wambiji, N. (2015). Freshwater resource characterization and vulnerability to climate change of the Shela aquifer in Lamu, Kenya. *Environmental Earth Sciences*, 73, 3801-3817.
- O'Mara, K., Venarsky, M., Stewart-Koster, B., McGregor, G. B., Schulz, C., Kainz, M., & Bunn, S. E. (2021). Connectivity of fish communities in a tropical floodplain river system and predicted impacts of potential new dams. *Science of the Total Environment*, 788, 147785.
- Ostrand, K. G., & Wilde, D. R. (2002). Seasonal and spatial variation in a prairie stream-fish assemblage. *Ecology of Freshwater Fish*, 11, 137–149.
- Ouellet, V., St-Hilaire, A., Dugdale, S. J., Hannah, D. M., Krause, S., & Proulx-Ouellet, S. (2020). River temperature research and practice: Recent challenges and

emerging opportunities for managing thermal habitat conditions in stream ecosystems. *Science of the Total Environment*, 736, 139679.

- Pacetti, T., Lompi, M., Petri, C., & Caporali, E. (2020). Mining activity impacts on soil erodibility and reservoirs silting: *Evaluation of mining decommissioning strategies. Journal of Hydrology*, 589, 125107.
- Padmalal D, Maya K, Sreebha S & Sreeja R. Environmental effects of river sand mining: a case from the river catchments of Vembanadlake, Southwest coast of India. Environ. Geol., 2008; 54:879–889.
- Pal, S., & Mandal, I. (2021). Impacts of stone mining and crushing on environmental health in Dwarka river basin. *Geocarto International*, 36(4), 392-420.
- Pandit, A. B., & Kumar, J. K. (2019). Drinking water treatment for developing countries: physical, chemical and biological pollutants. *Royal Society of Chemistry*.
- Pandya, I. Y. (2018). Pesticides and their applications in agriculture. *Asian J Appl Sci Technol*, 2(2), 894-900.
- Paredes del Puerto, J. M., García, I. D., Maiztegui, T., Paracampo, A. H., Rodrigues Capítulo, L., Garcia de Souza, J. R., ... & Colautti, D. C. (2022). Impacts of land use and hydrological alterations on water quality and fish assemblage structure in headwater Pampean streams (Argentina). *Aquatic Sciences*, 84(1), 6.
- Patel, A. and Datar, M. (2014) Seasonal Variations of Physico-Chemical Characteristics of River Betwa in Vidisha District. *International Journal of Environmental Science and Technology,* 3, 2205-2214
- Patil, R., Wei, Y., Pullar, D., & Shulmeister, J. (2022). Effects of change in stream flow patterns on water quality. *Journal of Environmental Management,* 302, 113-991.
- Peterson, D., Hanazaki, N., & Simoes-Lopes, P. C. (2008).Natural resource appropriation in cooperative artisanal fishing between fishermen and dolphins (Tursiops truncatus) in Laguna, Brazil. *Ocean & Coastal Management*, 51(6), 469-475.

- Pielou, E.C., (1966).The measurement of diversity in different types of biological collections. *J Theor. Bid.*, 1 3 : 131 - 144.

- Pirnia, A., Darabi, H., Choubin, B., Omidvar, E., Onyutha, C., & Haghighi, A. T. (2019). Contribution of climatic variability and human activities to stream flow changes in the Haraz River basin, northern Iran. *Journal of Hydro-Environment Research*, 25, 12-24.

- Polat, H. E., & Olgun, M. (2018). Water pollution from livestock wastes and required strategies in efforts to adapt to European Union. *Int. Water Assoc,* 18, 1-9.
  Potić, I., Mihajlović, L. M., Šimunić, V., Ćurčić, N. B., & Milinčić, M. (2022). Deforestation as a cause of increased surface runoff in the catchment: Remote Sensing and Swat Approach—A case study of southern Serbia. *Frontiers in Environmental Science*, 10, 896404.
- Prakash, S. (2021). Present status of fish diversity of Davipatan Division of Uttar Pradesh, India. *International Journal of Zoological Investigations*, 7(2).
- Prakash, V., & Budhwan, R. (2024). Impact of Stone Mining on Vegetation and Biodiversity and Its Restoration Approaches. In Ecological Impacts of Stone Mining: Assessment and Restoration of Soil, Water, Air and Flora. *Singapore: Springer Nature Singapore, 187-228.*
- Qadri, R., & Faiq, M. A. (2020). Freshwater pollution: effects on aquatic life and human health. *Fresh water pollution dynamics and remediation*, 15-26.
- Qadri, S. (2022). Fish Fauna of Kashmir Valley and Their Conservational Measures for Sustainable Fish Production. *In Biodiversity, Conservation and Sustainability in Asia: Prospects and Challenges in South and Middle Asia Springer International Publishing*, 2, 521-528).
- Qayoom, I., Abubakr, A., Gopinath, A., Dar, S. A., & Khurshid, K. (2024). Aquatic Pollution: Concerns and Abatement. *Taylor & Francis Group.*
- Qayoom, U., Bhat, S. U., & Ahmad, I. (2021). Efficiency evaluation of sewage

treatment technologies: implications on aquatic ecosystem health. *Journal of Water and Health*, 19(1), 29-46.

- Qazi, S. A. (2005). Systematic geography of Jammu and Kashmir. *APH Publishing*.
- R Core Team. (2017). R: A language and environment for statistical computing; R foundation for statisticalcomputing. *Vienna: Austria; ISBN*, 3-900051-07-0.
- Rahmanian, N., Ali, S.H.B., Homayoonfard, M., Ali, N.J., Rehan, M., Sadef, Y. and Nizami, A.S. (2015). Analysis of Physiochemical Parameters to Evaluate the Drinking Water Quality in the State of Perak, Malaysia. *Journal of Chemistry*.
- Rai, A., Kolli, M., Cai, C. Y. L., Rai, S., & Girivasan, S. N. (2024). Evaluation of the Smokeless Tobacco Awareness, Attitude, and Response Knowledge (STAARK) Scale With Integrated Risk Assessment for Tailored Intervention. *Cureus*, *16*(10).
- Ramachandra, T. V., & Solanki, M. (2007). Ecological assessment of lentic water bodies of Bangalore. *The Ministry of Science and Technology*, 25, 96.
- Ramanujam, S. N., Manorama, M., & Dey, S. (2010). Ichthyodiversity of Meghalaya: India. *Electronic Journal of Ichthyology*, 6(2), 15-26.
- Ramprasad, C., Sona, K., Afridhi, M., & Kumar, R. (2021). Water quality assessment of the cauvery and vaigai river at upstream and downstream locations: impact of domestic and industrial effluents. *Indian Journal of Ecology*, 48(2), 615-619.
- Randall, D. G., & Naidoo, V. (2018). Urine: The liquid gold of wastewater. *Journal of Environmental Chemical Engineering*, 6(2), 2627-2635.
- Rashid G. & Singh R. (2020). Present Status of Fish Diversity and Their Conservational Measures For Sustainable Fish Production In The Vaishav Stream Of Kashmir Himalaya, India. *Journal of Critical Reviews*, 7:16 (3654- 3663).
- Rashid, I., & Romshoo, S. A. (2013). Impact of anthropogenic activities on water quality of Lidder River in Kashmir Himalayas. *Environmental monitoring and assessment*, 185(6), 4705-4719.
- Rather, M. I., Rashid, I., Shahi, N., Murtaza, K. O., Hassan, K., Yousuf, A. R., & Shah, I. Y. (2016). Massive land system changes impact water quality of the Jhelum River in Kashmir Himalaya. *Environmental monitoring and assessment*, 188(3), 1-20.

- Rather, R. A., Ara, S., Sharma, S., Padder, S. A., Lone, F. A., Mir, S. A., & Baba, T. R. (2022). Seasonal changes and determination of heavy metal concentrations in Vaishav river of the Indian western Himalaya. *Frontiers in Environmental Chemistry*, 3, 1018576.

- Rathnayake, S. W., Sirimanna, S. R., & Dissanayake, C. T. (2022). Variation in fish abundance in different habitats of a tropical lagoon with an attempt to model the effects of physico-chemical parameters on their abundance. *Ocean Science Journal*, 57(1), 91-103.
- Rathore, V., & Dutta, S. P. S. (2015). Fish fauna of river Ujh, an important tributary of the river Ravi, District Kathua, Jammu. *Environment Conservation Journal*, 16(1&2), 81-86.
- Raza, M, Ahamad, A, Mohammad, A., (1978). The valley of Kashmir-a geographical interpretation. *Carolina academic Press, New Delhi*.

References

- Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T., & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological reviews*, 94(3), 849-873.
- Ren, J., Liang, J., Ren, B., Zheng, X., & Guo, C. (2018). New patterns of temporal and spatial variation in water quality of a highly artificialized urban river-course—A case study in the Tongzhou section of the Beiyun River. *Water*, 10(10), 1446.
- Rifat, M. A., Wahab, M. A., Rahman, M. A., Nahiduzzaman, M., & Mamun, A. A. (2023). *Nutritional value of the marine fish in Bangladesh and their potential to address.*
- Rohani, M. F. (2023). Pesticides toxicity in fish: Histopathological and hemato-biochemical aspects–A review. *Emerging Contaminants*, 9(3), 100234.
- Romshoo, S. A., Altaf, S., Rashid, I., & Dar, R. A. (2018). Climatic, geomorphic and anthropogenic drivers of the 2014 extreme flooding in the Jhelum basin of Kashmir, India. *Geomatics, Natural Hazards and Risk*, 9(1), 224-248.

- Romshoo, S. A., Rashid, I., Altaf, S., & Dar, G. H. (2020). Jammu and Kashmir state: an overview. *Biodiversity of the Himalaya: Jammu and Kashmir State*, 129-166.
- Rubel, M.R.I., Hashem, S., Jaman, N., Rana, K.M.S, Ferdousi , K., Hossain, M.S., (2016). A study on the fish biodiversity of Lohalia river of Bangladesh. *International Journal of Environmental Biology*, 6(1): 11-15.
- Sabha, I., Bhat, S. U., Hamid, A., & Rather, J. A. (2019).Monitoring stream water quality of Dagwan stream, an important tributary of Dal Lake, Kashmir Himalaya. *Arabian Journal of Geosciences*, 12(8), 1–17.
- Sabha, I., Hamid, A., Bhat, S. U., & Islam, S. T. (2022).Water Quality and Anthropogenic Impact Assessment Using Macroinvertebrates as Bioindicators in a Stream Ecosystem. *Water, Air, & Soil Pollution*, 233(9), 387.
- Saeed, K., Khan, S., & Haq, F. (2013). Diversity and population status of fish fauna of river Barandu district Buner Khyber Pakhtunkhwa Province Pakistan. *Journal of Biodiversity and Environmental Sciences*, 83.
- Salmiati S., Arman N.Z, and Salim M.R. (2017) Integrated approaches in water quality monitoring for river health assessment: scenario of Malaysian River. *Water Quality https*
- Sanjay, M. C., & Sadguru, P. (2020). Ichthyofaunal diversity of rapti river flowing through shravasti and balrampur districts of Uttar Pradesh (India).
- Saqib, N., Rai, P. K., Kanga, S., Kumar, D., Đurin, B., & Singh, S. K. (2023). Assessment of Ground Water Quality of Lucknow City under GIS Framework Using Water Quality Index (WQI). Water, 15(17), 3048.
- Sareer, F., Yousuf, A. R., & Chishti, M. Z. (2012). Ichthyofauna of Lidder Stream with Emphasis on Haematobiochemical Study of *Schizothorax* sp (Doctoral dissertation).
- Sarma, K., Das, R., Dey, A., Bharali, R. C., & Sarma, D. (2024). Status of Endemic Freshwater Ichthyofauna of Lower Subansiri River under the Threats of Dam Construction and Anthropogenic Disturbances: An Assessment. *In Aquaculture and*

Conservation of Inland Coldwater Fishes (pp. 287-301). Singapore: Springer Nature Singapore.

- Sarwade, A. B., & Kamble, N. A. (2014). Evaluation of physicochemical parameters of river Krishna, Sangli Maharashtra. *Octa Journal of Environmental Research*, 2(4).
- Scharnweber, K., Scholz, C., Schippenbeil, V., Milano, S., & Hühn, D. (2024). Effects of mining activities on fish communities and food web dynamics in a lowland river. *Ecology and Evolution*, 14(3), e11111.
- Schoeman, N. A. (2013). Prevalence, characterisation and potential origin of Escherichia coli found in surface and ground waters utilized for irrigation of fresh produce (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- Schürings, C. (2023). Impacts of Agricultural Land Use Types on the Biodiversity and Health of River Ecosystems: A Large-Scale Analysis. University Duisburg-Essen (Germany).
- Sewak, R., & Saxena, L. (2016). Livestock Waste and Its Impact on Human Health. *International Journal of Agricultural Sciences* ISSN, 2167-0447.
- Shah Masarat , Mushtaq Erum , Islam Tajamul Sheikh Sabha Inam, Qayoom Umara and Bhat Sami Ullah (2020) (Hydrobiological Study of Aripal Stream in Tral Kashmir Valley. *J. Himalayan Ecol. Sustain. Dev*. Vol. 15 ISSN 0973-7502
- Sharma R.C., Singh N., and Chauhan. (2016) the influence of physicochemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: a case study. *Egypt Journal of Aquatic Research* 42(1):11–21
- Sharma, A., & Dutta, S. P. S. (2012) Present and past status of fish fauna of river Basantar, an important tributary of the river Ravi, in Samba district, Jammu (J&K). *Journal of Applied and Natural Science*, 4(1), 123-126.
- Sharma, K.K., Sharma, D, A., Kau, H., Gupta, S., 2016. Ichthyofaunal diversity in some lentic water bodies of Jammu. *International journal of scientific research and modern education*,1(1):23-30.

- Sharma, S., Singh, G., Kaur, P., *et al*. (2017). Assessment of water quality of streams in India using water quality index: A review. *Environmental Science and Pollution Research,* 24(29), 22559-22573.
- Sheikh Tajamul Islam, Sami Ullah Bhat, Aadil Hamid, Ashok Kumar Pandit & InamSabha (2023) Impact of Land-use Patterns on Water Quality Characteristics of Rambiarrah Stream in Kashmir Himalaya, International *Journal of River Basin Management,*
- Sheskin, D. J. (2011).Handbook of parametric and nonparametric statistical procedures (5thed.*). Chapman & Hall/CRC Press,* Boca Raton, FL
- Shinde, S.E, Pathan, T.S, Raut, K.S, & Sonawane, D. (2011). Studies on the Physico-chemical Parameters and Correlation Coefficient of Harsool-savangi Dam, District Aurangabad, India. *Middle-East J. Scientific Res.*, 8(3), 544–554
- Shrestha, S., &Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. *Environmental Modelling & Software*, 22, 464–475.
- Shuai, F., Li, X., Chen, F., Li, Y., & Lek, S. (2017). Spatial patterns of fish assemblages in the Pearl River, China: Environmental correlates. *Fundamental and Applied Limnology*, 329-340.
- Silas, E. G. (1960).Fishes from the Kashmir valley. *Journal of the Bombay Natural History Society*, 57, 66–77.
- Singh J., Yadav P., Pal A. K., and Mishra V. (2020). Water pollutants: Origin and status. Sensors in Water Pollutants Monitoring: Role of Material, 5–20.
- Singh, G., & Agarwal, N. K. (2014). Fish assemblage structure and habitat use of the snow fed stream Assiganga-a major tributary of river Bhagirathi in Central Himalaya (India). *International Journal of Aquatic Biology*, *2*(6), 305-312.
- Singh, H.R., Kumar, N. (2003). Some aspects of ecology of hill-streams: Stream morphology, zonation, characteristics and adaptive features of Ichthyofauna in Garhwal Himalaya. *Advanced in fish research*, 3:119-142.

- Sinokrot, B. A., & Gulliver, J. S. (2000). In-stream flow impact on river water temperatures. *Journal of Hydraulic research*, 38(5), 339-349.
- Sipos, G. Blanka., V. Mezősi., G. Kiss., T. van Leeuwen, B. (2014) Effect of Climate Change on the Hydrological Character of River Maros, Hungary-Romania.*Journal of Environmental Geography*7 (1–2), 49–56.
- Sivamanikandan, P., & John, S. A. (2015). Impact of physico-chemical parameters on bacterial population in Mullaiperiyar River water-Theni district, Tamilnadu, India. *African Journal of Microbiology Research*, 9(1), 26-32.
- Slathia, N., Langer, S., & Jasrotia, R. (2023). Assessment of water quality and its effect on prawn abundance in three tributaries of Shiwalik rivers: Chenab and Ravi of Jammu, India—a case study. *Applied Water Science*, 13(3), 77.
- Smith B, Wilson JB(1996). A consumer's guide to evenness indices. Oikos. 1996;76: 70-82.
- Smith, P., Arneth, A., Barnes, D. K., Ichii, K., Marquet, P. A., Popp, A., & Ngo, H. (2022). How do we best synergize climate mitigation actions to co-benefit biodiversity?. *Global Change Biology*, 28(8), 2555-2577.
- Soo, CL., Nyanti, L., Idris, N.E. (2021). Fish biodiversity and assemblages along the altitudinal gradients of tropical mountainous forest streams. Sci Rep 11, 16922.
- Soranam, R., Palanikani, R., Kanthimathi, M., Devi, K., Sabaridasan, A., & Sajen, S. H. (2022). Environmental Factors Associated with Fish Diversity in Two Tributaries of River Chittar, Southern Western Ghats, Tamil Nadu, India. *Asian Journal of Fisheries and Aquatic Research*, 20(2), 10-23.
- Sultan Shaheema and Kant Ravi.(2016) survey and Study of fish fauna of River Jhelum (j&k).*international journal of multidisciplinary research and development* vol:3 issue:4.
- Sumaila, U. R., Bellmann, C., & Tipping, A. (2016).Fishing for the future: An overview of challenges and opportunities. *Marine Policy*, 69, 173-180.
- Sushama, S. (2014). Biodiversity of Ponnani estuary, Kerala. J. *Aqua. Bio and fisheries*, 2, 785-791.

- Syed, N., Mohite, A., Sadawarte, R., Desai, A., & Shah, T. H. (2019). Design aspects of fi shing crafts and gears of wularlake of kashmir, india. *Journal of Experimental Zoology India*, 23(1), 861–867.
- Talwar, A. K. A., & Jhingran, A. K. (1991). Inland fishes of india and adjacent countries. *Oxford and IBH publishing company pvt.Ltd*, 1(2), 1158, 1.
- Tamang, Jyoti Prakash (2009). Himalayan Fermented Foods: Microbiology, Nutrition, and Ethnic Values. *CRC Press*. ISBN 978-1-4200-9325-4.
- Temesgen, B., Tadesse, Z., &Temesgen, M. (2021) Diversity, distribution and abundance of fish species in upper Awash River Basin, West Showa Zone, Ethiopia. *Cogent Food and Agriculture*, 7(1), 1974181.
- Tesia, C., & Bordoloi, S. (2012). Ichthyofaunal Diversity of Charju River, Tirap District, Arunachal Pradesh, India. Asian Journal of Experimental Biological Science, 3(1), 82-86.
- Tsisiche, A.R., 2018. Effect of land use on ecosystem metabolism and decay rate of Eucalyptus saligna and Neuboutonia macrocalyx leaves in streams draining Upper Mara catchment, Kenya (Thesis). *Egerton University.*
- Tun, T. (2014). Castnet fishing with the help of Irrawaddy Dolphin, Orcaella brevirostris, in Myanmar. In Proceedings of the Design Symposium on Conservation of Ecosystem (The 13th SEASTAR2000 workshop) (Vol. 2, pp. 39-45).Kyoto University Design School.
- Uqab, B., Singh, A., & Mudasir, S. (2017). Impact of sewage on physicochemical water quality of Tawi River in Jammu city. *Environ Risk Assess Remediat* 1: 56–61.
- Usman, M., Sameen, A., Khan, M. I., Rahman, U., Khan, U. M., Anwar, S., .&Sahar, A. (2022). Treatment of Fatty Effluents. In Food Processing Waste and Utilization (pp. 89-115). *CRC Press*
- Vander Laan, J. J., Hawkins, C. P., Olson, J. R., & Hill, R. A. (2013). Linking land use, in-stream stressors, and biological condition to infer causes of regional ecological impairment in streams. *Freshwater Science*, 32(3), 801-820.

- Vander Laan, J. J., Hawkins, C. P., Olson, J. R., & Hill, R. A. (2013). Linking land use, in-stream stressors, and biological condition to infer causes of regional ecological impairment in streams. *Freshwater Science*, 32(3), 801-820.
- Vass, K.K., Raina, H.S., Zutshi, D.P. and Khan, M.A. (1977): Hydrobiolgical studies on River Jhelum. *Geobios*, **4**: 238-242.
- Vaughan, I. P., & Gotelli, N. J. (2019). Water quality improvements offset the climatic debt for stream macroinvertebrates over twenty years. *Nature Communications*, 10(1), 1956.
- Venkatesharaju, K., Ravikumar, P., Somashekar, R.K. and Prakash, K.L. (2010) Physico-Chemical and Bacteriological Investigation on the River Cauvery of Kollegal Stretch in Karnataka. Kathmandu University *Journal of Science, Engineering and Technology*, 6, 50-59.
- Verberk, W. (2012). Explaining general patterns in species abundance and distributions. *Nat Educ. Knowl.*, 3(10), 38.
- Vieira, T. B., & Tejerina-Garro, F. L. (2020). Relationships between environmental conditions and fish assemblages in tropical savanna headwater streams. *Scientific Reports*, 10(1), 2174.
- Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S. E., Sullivan, C. A., Liermann, C. R., & Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, 467(7315), 555–561.
- Wang, C., Shao, J., Ma, B., Xie, J., Li, D., Liu, X., & Huo, B. (2022). Longitudinal Patterns in Fish Assemblages after Long-Term Ecological Rehabilitation in the Taizi River, Northeastern China. *Sustainability*, 14(22), 14973.
- Wang, H., Molinos, J. G., Heino, J., Zhang, H., Zhang, P., & Xu, J. (2021). Eutrophication causes invertebrate biodiversity loss and decreases cross-taxon congruence across anthropogenically-disturbed lakes. *Environment International*, 153, 106494.

- Wang, X., Jin, L., Wang, J., Garrett, E. H., Shuman, J., Yang, K., & Congdon, N. (2016). Attitudes and knowledge concerning corneal donation in a population-based sample of urban Chinese adults. *Cornea*, *35*(10), 1362-1367.
- Wetzel, R.G. (2001): Limnology lake and river ecosystems: 3rd edn. *Academic Press*, San Diego, p 1006.
- Whitfield, A. K., Gillanders, B. M., & Able, K. W. (2024). Climate Change Effects on Fish Populations. In Climate Change and Estuaries (pp. 475-506). *CRC Press.*
- Wilks, S.S. (1932). Certain generalizations in the analysis of variance: Biometrika 24(3-4):471-494.
- Wilson, D. J., Gabriel, E., Leatherbarrow, A. J., Cheesbrough, J., Gee, S., Bolton, E., & Diggle, P. J. (2008). Tracing the source of campylobacteriosis. *PLoS genetics,* 4(9), e1000203.
- Wise, E. J. (1980). Seasonal distribution and life histories of Ephemeroptera in a Northumbrian river. *Freshwater Biology*, 10(2), 101–111.
- Wolda, H. (1988). Insect seasonality: Why? Annual Review of Ecology and Systematics, 19(1), 1–18.
- Wolter, C., Buijse, A. D., & Parasiewicz, P. (2016). Temporal and spatial patterns of fish response to hydromorphological processes. *River Research and Applications*, *32*(2), 190-201.
- Xiang, P., Wang, X., Liu, K., Wu, B., Liang, C., & Song, Z. (2022). Spatio-temporal dynamics of fish assemblage in the Datong and Xiaotong rivers, karst tributaries in the upper Yangtze River drainage: Implications for ecological adaptation and conservation of fish in rivers. *Frontiers in Ecology and Evolution*, *10*, 956555.
- Xiao, J., Lv, G., Chai, N., Hu, J., & Jin, Z. (2022). Hydrochemistry and source apportionment of boron, sulfate, and nitrate in the Fen River, a typical loess covered area in the eastern Chinese Loess Plateau. *Environmental Research*, 206, 112570.
- Xing, Y., Zhang, C., Fan, E., & Zhao, Y. (2016). Freshwater fishes of China: species richness, endemism, threatened species and conservation. Diversity and Distributions, 22(3), 358-370.

- Xingyuan, Z., Fawen, L., & Yong, Z. (2023).Impact of changes in river network structure on hydrological connectivity of watersheds. *Ecological Indicators*, 146, 109848.
- Yang, J., Yan, D., Yang, Q., Gong, S., Shi, Z., Qiu, Q., & Hu, M. (2021). Fish species composition, distribution and community structure in the Fuhe River Basin, Jiangxi Province, China. *Global Ecology and Conservation*, 27, e01559
- Yaseen, S., Pandit, A. K., & Shah, J. A. (2015). Water quality index of fresh water streams feeding Wular Lake, in Kashmir Himalaya, India. International Journal of water *Resources and Environmental Engineering*, 7(4), 50-57.
- Yen, T. P., & Rohasliney, H. (2013).Status of water quality subject to sand mining in the Kelantan River, Kelantan. *Tropical life sciences research*, 24(1), 19.
- Yılmaz, E., & Koç, C. (2016). Organic pollution of the Büyük Menderes River, Turkey and effects on aquaculture. Environmental Science and Pollution Research, 23, 11493-11506.
- Yogesh, K., & Mudgal, L. K. Study on the Fish Species Diversity of the River Narmada in Nimar Region of MP.
- Yousuf, A. R. 1996. Fishery Resources of Kashmir. In: Ecology, Environment and Energy. *(A.H. Khan and A.K. Pandit eds.):*75-120.
- Yousuf, A. R., Bhat, F. A., & Mahdi, M. D. (2006).Limnological features of River Jhelum and its important tributaries in Kashmir Himalaya with a note on fish fauna. *J. Himalayan Ecol. Sustain. Dev.*, 1, 37–50.
- Yousuf, A. R., Bhat, F. A., Mahdi, D., Ali, S., &Ahangar, M. A. (2003).Food and feeding habits of Glyptosternonreticulatum McClelland and Griffth in Torrential Streams of Kashmir Himalayas. *Journal of Research and Development*, 3, 124–133.
- Yu, S. J., Ryu, I. G., Park, M. J., &Im, J. K. (2021).Long-term relationship between air and water temperatures in Lake Paldang, South Korea. *Environmental Engineering Research*, 26(4).
- Zare-Shahraki, M., Ebrahimi-Dorche, E., Bruder, A., Flotemersch, J., Blocksom, K., & Bănăduc, D. (2022).Fish species composition, distribution and community

structure in relation to environmental variation in a semi-arid mountainous river basin, Iran. Water, 14(14), 2226.

- Zhang, C., Liu, F., Liu, H., Wang, C., Lin, P., & Gao, X. (2022). Temporal Changes in Taxonomic and Functional Diversity of Fish Assemblages in the Upper Yangtze River After Impoundment of the Three Gorges Reservoir, China. *Frontiers in Environmental Science*, 413.