University of Natural Resources and Life Sciences, Vienna

Ecoregional and seasonal patterns of Macroinvertebrate communities in near-natural Bhutanese streams

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"Master of Science"
by

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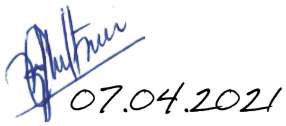
ABSTRACT

The knowledge on aquatic biodiversity of Bhutan in general, and macrozoobenthos in particular, is scarce and needs strengthening. In view of inadequate understanding on community structure of macroinvertebrates, the objective of the present study was to characterize the community structure of macrozoobenthos across two aquatic ecoregions (ER): the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF) to generate baseline information that can be used in conservation and management of riverine ecosystems. The present analysis, based on 46 near-natural sites, indicated distinct macroinvertebrate communities across ecoregions and across seasons within ecoregions. The communities at ecoregional scale were influenced by spatial factors (altitude) whereas within an ecoregion was influenced by local-scale factors (current velocity, riffle proportion etc.). Although EPT diversity was comparable, ER EHBF was associated with higher EPT (Ephemeroptera, Plecoptera, Trichoptera) abundance, whereas higher EPT dominance was associated with ER HSPF. The diversity and dominance of Trichoptera was higher in the ER HSPF, whereas the diversity and dominance of Diptera were higher in ER EHBF. In terms of functional feeding groups, dominance of collectors and scrapers were comparable across the ER HSPF, whereas gathering collectors were predominant across ER EHBF. Across both ecoregions, post-monsoon season was associated with higher diversity, abundance and EPT abundance. The dominance of Diptera became significant during post-monsoon season across ER HSPF, whereas Ephemeroptera and Plecoptera were significantly dominant during pre-monsoon season across ER EHBF. The distinct taxonomic and functional composition of macrozoobenthos, and high diversity of exclusive taxa verifies very clearly the ecoregional approach and lead to the conclusion that future macroinvertebrate-based assessment approaches in Bhutan should be ecoregion- and season specific.

Keywords: ASSESS-HKH, Bhutan, Eastern Himalayan Broadleaf Forests, Himalayan Subtropical Pine Forests, Ecoregions, macroinvertebrates, pre-monsoon, post-monsoon

DECLARATION AND RECOMMENDATION
DECLARATION

I, the undersigned, hereby declare that this research thesis is my original work, and all the sources have been accurately reported and acknowledged. This document has not been previously, in its entirety or in part, submitted to any university in order to obtain academic qualifications.



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RECOMMENDATION

This thesis has been submitted for examination with our recommendation and approval as university supervisors.

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ABBERVIATIONS

AD	Anno Domini
ASSESS-HKH	Development of an Assessment System to Evaluate the Ecological Status of Rivers in the Hindu Kush-Himalayan Region
ASPT	Average Score Per Taxon
EHBF	Eastern Himalayan Broadleaf Forests
EPT	Ephemeroptera, Plecoptera, Tricoptera
EPTO	Ephemeroptera, Plecoptera, Tricoptera, Odonata
ER	Ecoregion
ETHbios	Ethiopian Biotic Scores
EU	European Union
FFGs	Functional feeding groups
GNH	Gross National Happiness
ha	Hectares
HCA	Hierarchical Cluster Analysis
IUCN	International Union for Conservation of Nature
HSPF	Himalayan Subtropical Pine Forests
HKH	Hindu Kush-Himalaya
HKHbios	Hindu Kush-Himalaya Biotic Score
HKHindex	Hindu Kush-Himalaya Multimetric Index
ISA	Indicator Species Analysis
MRPP	Multi Response Permutation Procedure
NEPA	National Environment Protection Act
Nepbios	Nepalese Biotic Index
NMDS	Non-metric Multidimensional Scaling
SASS	South African Scoring System
SDG	Sustainable Development Goal
WFD	The European Water Framework Directive
MW	Megawatt

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1. Status of freshwater ecosystem and biodiversity

The freshwater ecosystems such as rivers, lakes, streams, wetlands and ponds occupies just a small portion of earth's surface area (< 1%), yet provides vital resources for more than 7 billion human population and habitat for approximately 10 % of known global biodiversity (Strayer and Dudgeon 2010; Darwall et al. 2018). However, freshwater ecosystems are facing serious challenges in the era of the Anthropocene because of accelerated human interventions. The review by Dudgeon et al. (2006) categorised global threats to freshwater biodiversity into 5 major groups: (i) modification of the natural flow regime of running water, (ii) overexploitation of biological resources, (iii) introduction of invasive species, (iv) degradation of aquatic habitats by local and catchment level activities, and (v) pollution from point and nonpoint sources. The most recent review by Reid et al. (2019) provided an updated review on threats to global freshwater ecosystems with new threats associated with engineered materials (i.e., nanomaterials, microplastics) and emphasized on the need to minimize these threats to maintain ecological functions for overall benefit of human and biodiversity. However, freshwater ecosystems became increasingly vulnerable to emerging threats with existing ones getting intensified resulting in loss of freshwater habitats and biodiversity (Reid et al. 2019).

The global loss of wetlands is estimated to be 87 % since 1700 AD and the rate of degradation has steadily increased (nearly 4 times) during 20^{th} and early 21^{st} centuries (Davidson 2014). The longitudinal connectivity of rivers and streams are disturbed by dams and weirs whereas, channelization of rivers for navigation, agricultural and urban development disrupted the lateral connectivity. Humans have altered nearly half of world's largest river systems (> 500 km in length), disrupting natural flow, downstream sediment transport and temperature regime with only 51 % of them remaining free flowing (Grill et al. 2019). About 80 % of global sewage discharges are released into rivers without sufficient treatment and as a consequence 15 % of river stretches in Africa, Asia and Latin America are severely suffering from pollution (Tickner et al. 2020). Discharge of organic and inorganic effluents from various sources along river catchments have deteriorated streams and rivers, affecting well-being of human, biodiversity and ecosystem services (Wen et al. 2017; Amoatey and Baawain 2019). The intensity and rate of freshwater ecosystem degradation so far is highest in developing countries (Davidson 2014; Wen et al. 2017; Grill et al. 2019).

Globally, 27 % of species (7965 species) depended on freshwater ecosystem accessed for the IUCN Red List are threatened with high risk of extinction, and among them, gastropods (47 %), decapods (30 %) and fish (28 %) are the ones representing most threatened species (Tickner et al. 2020). In an aquatic ecosystem, exploitation of species and habitat degradation accounts more than 80 % of threats to fishes (World Wildlife Fund 2018) and to overall aquatic biodiversity. Among biogeographic realms, Neotropics is richest in terms of freshwater biodiversity followed by Indo-Malaya. Unfortunately the proportion of threatened species is highest in Indo-Malaya followed by Neotropics (Collen et al. 2014). Since, 1970, the abundance of potamodromous fish declined by 83 % whereas catadromous and anadromous fishes declined by 73 % (Deinet et al. 2020). A total of 118 fish-species associated with freshwater systems from the United States and Europe have become extinct (Dias et al. 2017). The extinction rate of freshwater fauna are higher compared to marine and terrestrial counterparts (Collen et al. 2014; Darwall et al. 2018) and is alarming for fish as it is 112 - 855 times higher than extinction under natural circumstances (Dias et al. 2017; Tedesco et al. 2017). Freshwater invertebrates, with more than 20 % threatened and 30 % data deficient species are rarely targeted in assessment of their conservation status and are usually neglected during aquatic biodiversity conservation programs, receiving just small amount of conservation fund (Strayer 2006; Collier et al. 2016). The extinction and expiration rates of such neglected small organism is expected to be much higher than the larger vertebrates which are usually well studied and documented.

The freshwater ecosystems in Bhutan are small and includes > 9900 km of rivers and a small portion of lakes (4997 ha) and wetlands (1550 ha), which are yet to be properly documented (National Biodiversity Centre 2014; Dorji et al. 2020). However, they are largely pristine and are home to > 100 species of fishes, 448 of aquatic macroinvertebrates species, 75 algae species and 48 amphibians including several endemic taxa, with many more presumed to be undocumented (National Biodiversity Centre 2017; Ugyen Wangchuck Institute for Conservation and Environmental Research 2018).

Like elsewhere, aquatic ecosystems in Bhutan are most vulnerable to anthropogenic impacts (World Bank 2017). Freshwater ecosystems are subjected to habitat destruction from extraction of mineral resources from rivers. Rivers are gradually losing longitudinal connectivity. As of now, four rivers and streams are fragmented by hydropower dams and construction of dams at two rivers are at advanced stages. The muck disposal from most of the infrastructure development ultimately finds entry to rivers and their consequences largely

remains unevaluated. The major drivers of freshwater ecosystem changes are related with rapid urbanization, industrialization and infrastructure development such as hydropower developments (Wangchuk et al. 2017) and small scale pollution (Giri and Singh 2012; Giri and Singh 2013; Rai et al. 2020). These have resulted in localized deterioration of water quality and biodiversity changes. The water quality deterioration issues are mainly associated with water bodies located within major human settlements. Invasive fishes are another concern as they will have serious implications on poorly understood freshwater biodiversity (Gurung et al. 2013).

1.2. Management of freshwater ecosystems

A global framework and actions to protect rapidly declining freshwater ecosystems are lacking despite knowledge about the causes of deterioration and their consequences (Tickner et al. 2020). For example, more than 600 hydropower plants of > 1 MW potential are under various states of construction and > 3000 dams are under planning stage, mostly in South America and Asia (Zarfl et al. 2015). Agriculture accounts for 70 % of global freshwater demand (Darwall et al. 2018) and is expected to increase steadily with increase in human population and impacts associated with global climate change requiring efficient irrigation systems to balance demands with agriculture sector (Flörke et al. 2018). The freshwater demand of cities is expected to increase by 80 % by 2050 affecting average of 0.629 billion population under normal circumstances and 1.26 billion people under consideration of environmental flows (Flörke et al. 2018). The deterioration of rivers and streams by organic pollution is expected to affect additional 1.4 billion people by 2050 (Wen et al. 2017). With increasing threats on freshwater ecosystems (Strayer and Dudgeon 2010; Reid et al. 2019), increasing pressure on water resources mediated by global climate change and population growth (Wen et al. 2017; Flörke et al. 2018), freshwater ecosystems and associated biodiversity are at high risk (Tickner et al. 2020). There are serious global challenges in management of freshwater ecosystems for socioecological gains in 21st century.

In consideration of rapidly dwindling freshwater ecosystem, subsequent loss of biodiversity and socioecological functions, Tickner et al. (2020) stated six priorities actions. Their recommendation are mostly based on causes of freshwater biodiversity loss as identified by Dudgeon et al. (2006) and calls for (i) preserving adequate flows through accelerated adoption of environmental flows within legislation, (ii) substantial reduction of all kinds of pollutants from wastewater prior to discharge, (iii) management of freshwater biotic and abiotic

resources exploitation, (iv) prevention and management of invasive species, (v) restoration of longitudinal connectivity of rivers and (vi) protection and rehabilitation of critical freshwater habitats. The requirement for conservation of freshwater ecosystems is embodied within legislation of many developed countries and some developing countries. These legislations are those focused on four aspects of aquatic ecology, particularly (i) protecting ecological status of rivers, (ii) consideration of free-flowing rivers, (iii) maintenance of environmental flows, and (iv) biological assessment of ecological integrity of freshwater systems for management and conservation purposes.

Bhutan is considered to be pioneer in environmental conservation. Under the unique concept of developmental philosophy, Gross National Happiness (GNH), the National Environment Strategy necessitates a Middle Path Developmental Approach, where priorities of economic development is balanced by need of environmental conservation (National Environment Commission 2019). In realization of threats to freshwater ecosystems from hydropower development (World Bank 2017) the massive hydropower target is under serious consideration to be downscaled by several folds (10,000 MW by 2020 to 6130 MW by 2050) for achieving balanced socioeconomic and conservation goals (Department of Hydropower and Power Systems 2019). The National Environment Protection Act (2007) requires biological assessment of water bodies, whereas The Water Regulations of Bhutan (2014) requires maintenance of environmental flows and installation measures to facilitate upstream migration of fishes.

The constitution of Bhutan mandates minimum of 60 % of the total area under forest coverage at all time, which at present is 71 % of which with 51.44 % is designated as protected areas (Forest Resource Management Division 2020). The terrestrial focused protected area covers 91 % of lakes and 41 % of river stretches (Dorji et al., 2020). While such approach is efficient to safeguard terrestrial ecosystem, they usually provide inadequate protection of aquatic ecosystems, often requiring consideration of freshwater hotspots while designating protected areas (Dorji et al. 2020; Tickner et al. 2020). The main challenges in freshwater conservation in Bhutan are lack of adequate knowledge on ecosystem, technical expertise, research and often funding in areas of freshwater biodiversity to full fill the obligations stipulated in legislations and guide natural resource utilization approaches.

One of the management challenges in global freshwater management are accessibility of information relevant to conservation (Darwall et al. 2018). Initiatives such as Alliance for

Freshwater Life (Darwall et al. 2018) and Freshwater Information Platforms (Schmidt-Kloiber et al. 2019) are intended to share information on freshwater biodiversity, policies and offer a platform for environmental conservationist, policy makers and citizens for better management of freshwater ecosystem. This is important to accomplish targets of international conventions such as Ramsar Convention and Convention on Biological Diversity, and furthermore, freshwater is core for realization of Sustainable Development Goals (SDG) 2020 of United Nations (Tickner et al. 2020). The conservation of freshwater ecosystem should therefore receive highest priority and should receive adequate attention for balanced socioecological gains.

1.3. Biomonitoring approaches

Ecological integrity as defined by Parrish et al. (2003) is perceived as the 'ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region'. The key elements which determine ecological integrity are water chemistry, habitat and biological communities (Barbour et al. 1999). The main purpose of assessment of ecological integrity are to (i) measure the existing status of ecosystem, (ii) monitor trends in ecological changes, and responsiveness of restoration measures, and (iii) make environmental management decisions such as conservation of native biodiversity, land use planning, and prioritization of restoration sites (Brown and Williams 2016). The biomonitoring approach in streams involves usage of information on biological assemblages in test sites to infer the impact of external factors on the ecological integrity of aquatic ecosystems (Li et al. 2010). Several aquatic ecosystem type-specific approaches are being used for biomonitoring worldwide (Birk et al. 2012).

(a) Saprobic system

This is probably the earliest approaches used in biomonitoring of water bodies in Europe focusing mainly on organic pollutions (Moog et al. 2018). However, in consideration of modern water management challenges, the European Water Framework Directive (2000/60/EC) requires reference condition-based assessment. In order to meet the requirements saprobic system has been modified and are still used by the Central and Eastern European countries like Austria, Germany and Czech Republic for monitoring organic pollution (Rolauffs et al. 2004; Moog et al. 2018). The modifications include reference condition-based adjustment of saprobity class in line with five river quality class of waters as defined by the

EU Water Framework Directive (Rolauffs et al. 2004). The HKH field screening similar to Austrian saprobic system is adoption of similar concept by the Hindu Kush Himalayan countries of Bangladesh, Bhutan, India, Nepal and Pakistan and is applicable for accessing impacts of organic pollution and hydromorphological alterations (Hartmann et al. 2010). Although with limited sites, the results of HKH field screening along sites impacted by wastewater from vehicle washing facilities was same to that of HKHbios (Rai et al. 2020).

(b) Diversity indices

The diversity indices are commonly used in developing countries where biomonitoring is yet to receive attention (despite presence of biomonitoring approaches) or in countries without advanced biomonitoring approaches. This approach mainly combines three principal components of biotic composition, namely taxa richness (e.g. Shannon-Wiener Index, Simpson Index, Margalef Index), evenness (e.g. Pielou's Evenness Index) and abundance, assuming higher diversity, uniform distribution of all species and moderate to high numbers of individuals in undisturbed environments (Li et al. 2010). However, the response of abundance of organism is known to be complicated, and may either increase or decrease following improvement of environmental conditions and are not reliable in inferring the ecological conditions of streams (Bednarek and Hart 2005). The Shannon-Wiener Index is known to retain poor information on species richness and abundance from communities because of conceptual and statistical issues, making community comparisons difficult (Barrantes and Sandoval 2009). However, they are commonly used in accessing the biodiversity patterns in an ecosystem. In recognition to limitations, diversity indices are usually used in combination with other approaches rather than using them separately (Li et al. 2010).

(c) Biotic indices

The tolerance or sensitivity of bioindicator species to environmental condition such as eutrophication, heavy metals, organic pollution, pesticides and pH are species-specific and can be used to determine the ecological condition of streams (Beketov 2004; Li et al. 2010). The biotic indices approach is based on assignment of region specific tolerance or sensitivity values to specific bioindicator taxa in accordance to their response to environmental disturbances inferred from actual field observations (Hilsenhoff 1987; Ofenböck et al. 2010; Lakew and Moog 2015a). This approach has undergone several modifications and are gaining importance in Asian and African countries. The Hilsenhoff Index (Hilsenhoff 1987) and Hilsenhoff Family Biotic Index (Hilsenhoff 1988) considers abundance of taxa indicator taxa and sensitivity

scores for determination of final index. The South African Scoring System (SASS) considers average score per taxon (ASPT) based on sensitivity scores across different biotopes sampled (Dickens and Graham 2002). On contrast, HKHbios uses sensitivity scores, weight and sum of weight to determine the final index (Ofenböck et al. 2010). In Ethiopia, assessment of highland stream assessment is based on combination of ETHbios which considers the sum of sensitivity scores and average score per taxon-ETHbios (APST-ETHbios) derived by dividing the ETHbios and number of taxa (Lakew and Moog 2015a). Some of latest addition includes, Zambian Invertebrate Scoring System (ZISS) based on South African Scoring System (SASS) (Dallas et al. 2018) and Euphrates Biotic Scores (EUPHbios) based on HKHbios (Gültekin et al. 2019). These modifications have enabled in development of robust region-specific biotic indices best to suit the areas under investigations. Biological assessment of water quality in Nepal is based on Nepalese biotic index (NEPbios), an adaptation of the biological monitoring working party score/average score per taxon (BMWP/ASPT) system, based on tolerance of macroinvertebrates. (Sharma 1996).

(d) Species traits

The most commonly used trait-based approaches in biomonitoring are the composition of functional feeding groups (FFGs) of macroinvertebrates. In accordance to the River Continuum Concept, the changes in physical characteristics of streams along downstream continuum, results in gradual shift in community composition of functional feeding groups (Vannote et al. 1980). The composition of functional feeding groups and their ratio, provide good judgement of stream characteristics, especially in terms of resource type, food web balance and habitat stability (Cummins 2019). There are other species traits (body size, respiration types, aquatic stages, mobility) but are mostly used in combination with many other attributes (Edegbene et al. 2019). Among them, commonly used is substrate and current preferences, as they aid in detecting hydromorphological alteration such as water abstraction, extraction of sand and gravels and removal of riparian vegetation (Korte 2010). The species traits approach considers segregation of large number of species in relatively small groups, reducing the identification and analysis time (Cummins et al. 2005).

(e) Multimetric approaches

The multimetric approaches consists of combination of multiple metrics into single unit (multimetric index) to reflect comprehensive picture of disturbances from multiple anthropogenic stressors (Macedo et al. 2016; Silva et al. 2017). Metrics are biological attributes

(e.g., richness, composition, feeding guilds, tolerance) that serves as ecological measures and shows clear response (increase or decrease) to human perturbations. They are better than single metrics, which usually fails to adequately capture anthropogenic disturbances because of high seasonal and annual variations (Maloney and Feminella 2006). This makes multimetric approach robust tool in accessing the status and trends of aquatic ecosystems (Martins et al. 2020). This approach based on macroinvertebrate is now important tool in ecological assessment of rivers worldwide, including Africa (Masese et al. 2009; Raburu et al. 2009; Aura et al. 2010; Edegbene et al. 2019), Asia (Nguyen et al. 2014; Shiyun et al. 2017; Arman et al. 2019) and South America (Couceiro et al. 2012; Macedo et al. 2016; Silva et al. 2017; Martins et al. 2020). Multimetric index have been developed for individual rivers (Masese et al. 2009; Raburu et al. 2009), hydrological basins (Silva et al. 2017; Martins et al. 2020) and even for ecoregions (Stubauer et al. 2010; Kosnicki et al. 2016).

1.4. Modules for development of biomonitoring programmes

The biomonitoring approach involves several steps critical to achieve the objectives. They include setting a reference conditions based on stream typologies, identification of biological quality elements and standardization of field and laboratory methods for easy comparison of test sites (Borja et al. 2004; Hering et al. 2010; Solheim et al. 2019).

(a) Reference condition

The reference condition approach is common and effective technique used in biomonitoring to access the ecological integrity of freshwater ecosystems (Bowman and Somers 2005; Lakew and Moog 2015b). It involves comparison of biotic composition of degraded sites with that of a reference condition to access the deviation (Lakew and Moog 2015b). However, considering paucity of streams without any anthropogenic influence (pristine streams) since Anthropocene and for better clarification, the best reference condition precisely refers to minimally disturbed conditions (Stoddard et al., 2006). In present context, these sites are referred as near-natural sites. More specifically, reference condition is defined by selected physical, chemical and biological attributes to represents the most near pristine sites within a region (Lakew and Moog 2015b).

There are several approaches for development of reference conditions such as through judgement of experienced professional, and deducing reference from historical and paleolimnological records and have their own advantages and disadvantages (Economou 2002; Stoddard et al. 2006). In regions, without adequate near-natural sites, a *posteriori* classification

of organisms is conducted through multivariate analysis and is exclusively based on similarities in assemblages (Barbour et al. 1999; Bowman and Somers 2005). Another is a *a priori* classification, mostly based on multimetric analysis to differentiate biotic assemblages into more homogenous groups based on similarities in physiochemical and geographical attributes in area where there are adequate reference sites (Barbour et al. 1999; Bowman and Somers 2005). Both approaches is based on reference condition approach (Lakew and Moog 2015b) and requires further consideration of stream typologies for success of monitoring, restoration and conservation program (Borja et al. 2004; Hering et al. 2010; Solheim et al. 2019).

(b) Freshwater typology

The typology establishes type-specific reference conditions to remove natural variability for meaningful interpretation of ecological condition (Borja et al. 2004; Solheim et al. 2019). It is critical component for implementation of monitoring, assessment and reporting in the European Union as part of the Water Framework Directive. Specific freshwater typologies represents rivers or lakes with similar environmental conditions (limited natural variability) in terms of geomorphological, hydrological, physicochemical and biological characteristics allowing the establishment of a baseline, from which anthropogenic impact can be detected (Solheim et al. 2019). With typologies, aquatic ecosystems are classified into specific types (units) with homogenous biotic and abiotic characteristics (Borgwardt et al. 2019). The stream typologies in the European Union are defined on basis of ecoregions, subjected to further categorization based on identified type descriptors (Sandin and Verdonschot 2006).

Freshwater ecoregions are similar in terms of assemblage patterns of freshwater communities (Abell et al. 2008). This distinctiveness in assemblage of freshwater biota is as consequences of similar environmental conditions within ecoregion mediated by relatively homogenous geological and soil characteristics, vegetations cover and climatic conditions. The ecoregion-approach of freshwater delineation is an important tool for delineation of freshwater biodiversity which requires conservation and management priorities (Abell et al. 2008) and is therefore the essential basis for all assessment systems based on biological quality elements. Only communities within one ecoregion (subdivided in bioregional units) are to be compared with each other, because ecoregional differences in faunal or floral composition would likely be misinterpreted as deviations based on anthropogenic disturbance and lead to wrong results.

This approach is further homogenised by type descriptors. Among various abiotic factors, type descriptors such as altitude, catchment size and geology are considered for defining typologies as they explain the natural variability of organisms and abiotic characteristics (Sandin and Verdonschot 2006; Solheim et al. 2019). The type descriptors should be stable attributes which do not respond to human alterations and should explain the natural variability of biocoenosis and supporting abiotic elements (Solheim et al. 2019). The HKH region is delineated into five ecoregions, with five altitude class, four catchment class and three geological typologies with a theoretical maximum of 60 stream typologies in each ecoregion (Stubauer et al. 2010).

(c) Biological quality elements (BQEs)

Among various organisms used in assessment of water quality, algae, macrophytes, fish and benthic invertebrates are most commonly used groups (Li et al. 2010; Moog et al. 2018). The ecological requirements and tolerances of benthic algae are well known and are excellent indicators to describe the effects of nutrient enrichments, as their response to nutrient is fast (Moog et al. 2018). This makes them good short-term indicators of trophic level. They are primary producers and acts as foundation of aquatic food webs (Li et al. 2010). On contrast, aquatic macrophytes are good indicator of long-term trophic status and changes in hydrological regimes (Moog et al. 2018). Fishes are visible to naked eye, occupies higher trophic level and respond to wide range of environmental stressors such as acidification, nutrient enrichment, chemical pollution, overexploitation and introduced species (Li et al. 2010). They respond strongly to hydromorphological alteration of aquatic environments (Moog et al. 2018).

Macroinvertebrates are excellent candidates for biomonitoring because they are ubiquitous and are represented by diverse sedentary species with relatively long life cycle exhibiting varied responses to disturbances, sufficient enough to reflect long-term impacts of anthropogenic perturbations (Bonada et al. 2006; Hartmann et al. 2010; Korte et al. 2010). Moreover, they are visible to naked eye, require simple sampling equipment and have well documented species traits (Bonada et al. 2006; Carter et al. 2017). Furthermore, the assemblage pattern of macroinvertebrate reflects impacts of flow alteration and degradation of in-stream habitats, which is not possible to detect through conventional chemical monitoring (Ofenböck et al. 2010). Therefore, unlike chemical monitoring which just give snapshot of environmental condition, biological quality elements reflect the prevailing ecological condition, long-term

changes in physical and chemical environment, and temporal variation of ecological conditions of stream ecosystems (Hodkinson and Jackson 2005).

(d) Standardized field protocols and laboratory approaches

In order to realize adequate bioassessment objectives application of standardized field and laboratory practice is necessary (Clarke and Hering 2006; Nichols and Norris 2006). The biases from misidentification of taxa by less experienced personnel alters the assessment results (Clarke and Hering 2006). The temporal occurrence of taxa also depends on factors other than pollution or stress (Clarke and Hering 2006) and different sorting method is known to alter classification of sites (Nichols and Norris 2006). In consideration of same issues Hering et al. (2010) recommended standardised approaches, training on field sampling and identification and if possible to restrict sampling to single season to overcome natural variability of environmental conditions. Moreover, the sampling technique used for biomonitoring should be same as prescribed within the biomonitoring manual to eliminate methodical bias (Clarke and Hering 2006). The HKH assessment tools are robust product of European partners with experiences on European Projects (AQEM, STAR) and Asian collaborators with knowledge on local conditions (Stubauer et al. 2010). However, considering paucity of their application in Bhutan, calibration of field and laboratory expertise for standardized application is necessary.

1.5. Macrozoobenthos (MZB) adaptations and roles

(a) Adaptation, requirements, functional feeding groups and the River Continuum Concept

Macrozoobenthos are invertebrates living in or on the sediment and are ubiquitous in freshwater system around world, except in most harsh, temporary or extremely polluted waterbodies (Hauer and Resh 2017). The classification of macroinvertebrates into functional feeding groups (FFGs) by Cummins (1973), application of this approach for development of the River Continuum Concept by Vannote et al. (1980) and subsequent enhanced understanding on FFGs since inception, plays an important role in understanding their roles in an ecosystem process (Ramírez and Gutierrez-Fonseca 2014; Merritt et al. 2017). As an alternative to conventional classification which is based on type of food consumed, FFGs approach is instead focused on morphobehavioral adaptation which determines mode of food acquisition (Ramírez and Gutierrez-Fonseca 2014; Merritt et al. 2017). It is also referred to as a trophic guild, as it involves classification of organisms using similar food materials into same groups (Boyero et al. 2011).

Accordingly, macroinvertebrates are categorized into seven major FFGs that include (i) detrital shredders, with adaptations to feed coarse particulate organic matter (CPOM) originating from terrestrial leaf inputs, (ii) herbivore shredders, which have adaptation to feed on living aquatic plants, particularly leaves of rooted vegetation, (iii) gathering collectors, which is capable of feeding feeds on fine particulate organic matters (FPOM, < 1 mm size) accumulated on stream beds, (iv) filtering collectors, which captures fine materials either through filtering fans or constructed filtering nets, (v) scrapers, which have scraping mouth to graze on periphyton growing on substrate, (vi) predators, which consume whole or part of living animal with mouth parts which are well adapted to handle preys, and (vii) herbivore piercers, which can extract cell content from filamentous algae (Cummins 1973; Ramírez and Gutierrez-Fonseca 2014; Merritt et al. 2017; Cummins 2019).

In accordance the River Continuum Concept, physical features of stream changes along the longitudinal continuum, consequently changing the macroinvertebrate composition and diversity (Vannote et al. 1980) adapted to interactive effect of environmental characteristics (Poff 1997; Schmera et al. 2013). The adaptation of macroinvertebrates is reflected e.g., by mode of food acquisition, oxygen requirements and substrate preferences. The microhabitat within streams offers heterogenous hydraulic condition, resulting from combination of hydromorphological characteristics such as flow velocity, substrate and depth (Barbero et al. 2013; Mishra and Nautiyal 2013). Active filter feeding such as Ephemeroptera prefer fine inorganic substrate with lower velocities so their gill movement enable uptake of fine organic particulate matters (Vilenica et al. 2018). The net spinning passive filter feeding caddisfly (Hydropsychidae) requires large and stable substrate to cling, and high water velocity that ensures continuous supply of drifting food materials (Georgain and Trop 1992), whereas Simuliidae have pre-mandibular fans to filter the food particles (Cummins 2016). Macrozoobenthos possess diverse functional and behavioural respiratory adaptation in response to difference in oxygen requirements and tolerance to hypoxic conditions (Connolly et al. 2004).

Members of the insect orders Ephemeroptera, Plecoptera, Tricoptera and Odonata (EPTO) have tracheal gills for exchange of gaseous and majority of them are highly sensitive to anthropogenic stress and require clean water to ensure survival, growth and reproduction (Chapman et al. 2004). The combination of morphological adaptations in form of clinging tool (claws), frictional devices (serrated spines, setae, pads), adhesive pads (suckers), streamlined and dorsoventrally flattened bodies enables them to withstand drifts in torrential mountain

streams (Ditsche-Kuru et al. 2012; Jindal and Singh 2020). These groups represent major proportion of macroinvertebrate richness and abundances in near-natural streams (Dorji et al. 2014; Wangchuk and Dorji 2018).

The burrowing Oligochaetes and Chironomids have diverse feeding strategies and have haemoglobin which enable them to survive in extremely low level of oxygen usually associated with stagnant or slow flowing water as it facilitates deposition of food materials in fine sediment dominated substrate (Chapman et al. 2004; Sánchez-Morales et al. 2018). However, some members of Diptera (Blephariceridae) are indicative of clean water (Ofenböck et al. 2010) where as members of EPT particularly few families of Ephemeroptera (Baetidae and Caenidae) and Trichoptera (e.g. some members of the Hydropsychidae) are tolerant to anthropogenic stressors (Thorne and Williams 1997; Beketov 2004; Czerniawska-Kusza 2005; Tripole et al. 2008; Masese and Raburu 2017).

The assemblage pattern of macroinvertebrates is determined through interactive effects of physical characteristics of streams. Macroinvertebrates are exothermic and stream temperature plays important in regulating metabolism, development, reproductive physiology and emergence (Milner et al. 2001; Miserendino et al. 2018) and is important factor determining assemblage structure of macroinvertebrate (Shah et al. 2020a). The stream characteristics such as catchment area, discharge, stream order, current velocity, width and depth reflects the changes along the river continuum (Vannote et al. 1980) and are found to play most important role in influencing taxonomic assemblages of macroinvertebrates (Malmqvist and Maki 1994; Heino et al. 2007). Some studies found altitude (Thapa et al. 2020), latitude (Nautiyal and Mishra 2012), substrate (Nautiyal and Mishra 2012; Mishra and Nautiyal 2013) and stream size (Paavola et al. 2003; Al-Shami et al. 2013; Dalu et al. 2017) as an important factors shaping the assemblage pattern of macroinvertebrates.

The riparian vegetation is important component of healthy stream and are known to support diverse communities of macroinvertebrates because of constant supply of allochthonous leaf litter and thermal regulation through shading (Sponseller et al. 2001; Rios and Bailey 2006). The species richness are known to decrease with altitude (Ormerod et al. 1994; Suren 1994), and increase in stream width (Gurung and Dorji 2014) and catchment area (Malmqvist and Maki 1994). However, macroinvertebrate assemblages are a result of interaction of environmental variables acting at different spatial scale (catchment or local-scale) in stream continuum and varies from one region to another (Heino et al. 2007; Schmera

et al. 2013). While investigating near-natural streams from Finland, Heino et al. (2007) found that across ecoregions spatial-scale environmental factors are important in determining community structure whereas, local-scale environmental factors were main drivers of macroinvertebrate assemblages within an ecoregion.

The instream physicochemical properties and hydromorphological settings are subjected to temporal variation because of changes in flow regime, sometimes often resulting in extreme environmental conditions (Nilsson and Renöfält 2008). The diversity and abundance-based metrics are widely used to understand seasonal variation in macroinvertebrate. The diversity and abundance of macroinvertebrates in near-natural streams of Bhutan (Wangchuk and Dorji 2018) and Nepal (Shah et al. 2020b) are found to be consistent among pre-monsoon and post-monsoon seasons. This understanding can be further strengthened by evaluating the changes in composition and richness of macroinvertebrates in accordance to the sensitivity scores of HKHBios (Ofenböck et al. 2010).

(b) Roles in freshwater ecosystems:

Macrozoobenthos have multiple roles in instream ecological process. In headwater streams, shredders plays important role in maintaining energy flow through the breakdown of leaf litters (Masese et al. 2014). Similarly, collectors are responsible for cleaning organic loads in stream bed and water column through processing of fine organic matters (Bundschuh and McKie 2016). The excessive growth of primary producers in streams are controlled by grazers (Alvarez and Peckarsky 2005), whereas predators maintain trophic level through top down control of prey (Ramírez and Gutierrez-Fonseca 2014). The burrowing nature, faecal excreta and food loss through sloppy feeding enhance nutrient cycling within an ecosystem (Covich et al. 1999). Macroinvertebrates are important component of foodweb in aquatic-terrestrial ecosystem and serves as link between primary producers and predators such as fish frogs, lizards, spiders, and insectivorous birds and bats (Chan et al. 2008; van Oosterom et al. 2013; Recalde et al. 2016; Sundar et al. 2020). Inadequate management and conservation of streams and subsequent loss of macroinvertebrate can alter ecosystem functioning (Cao et al. 2018) and possibly modify terrestrial food web (Patra et al. 2010).

1.6. Ecosystem surrogates and indicator taxa

The application of ecosystem surrogates i.e. processes or components of ecosystem as indicator of ecosystem integrity is one commonly used approach (Hunter et al. 2016). However, continuous increase in usage and discrepancies of term surrogacy, led panel of international

scientists to classify ecological surrogates, into indicator surrogates and management surrogates (Hunter et al. 2016). This distinction is made on basis of purpose of application of ecosystem surrogates. The indicator taxa are component of indicator surrogates because measurement of their population is focused to obtain information about the environmental condition of a particular ecosystem. For e.g., absence/lower diversity and number of EPT taxa indicates deteriorating water quality. On contrast, umbrella species/flagship species are management surrogates, because they focus on management of ecosystem (Hunter et al. 2016). They are proxy to other organisms i.e., conservation of particular species ensures ecological integrity of environment (predator-prey relationship).

The concept of indicator taxa is based on the fact that a species occurring within a particular environment are best indicators of prevailing environmental conditions, thereby, indicating conservation and management needs (Legendre 2013). Another advantage of this approach is effectiveness in monitoring, both in terms of time and costs, as found in ants (Souza et al. 2016). According to Legendre (2013) a taxon which is found predominantly in single group or within few groups of a typology and occurring within most of sites belonging that particular group serves as an excellent indicator. They can be single species or groups of species, the latter being more relevant as they reflect overall facets of environmental condition (Carignan and Villard 2002; Lindenmayer and Likens 2011; Siddig et al. 2016). Therefore, large scale studies to enhance understanding on macroinvertebrates in streams relatively free from anthropogenic stressors is important for monitoring, management and conservation of freshwater resources and associated biocoenosis.

1.7. Problem statement

The aquatic ecosystems in Bhutan are least studied when compared to terrestrial ecosystem, despite being more vulnerable to greater anthropogenic threats (World Bank 2017). In the area of aquatic macroinvertebrates, studies are very limited. Furthermore, with exception of ASSESS-HKH project, most of the studies focused only on specific stressors or individual stream. Some of the studies includes assessment of impacts of pollution (Giri and Singh 2012; Rai et al. 2020), land use (Lhundup and Dorji 2014), urban growth (Giri and Singh 2013), hydropower development (Wangchuk et al. 2017) and others (Gurung & Dorji, 2014; Wangchuk & Dorji, 2018). Moreover, even with legal requirements on bioassessment, only limited studies have applied HKH tools in assessment of ecological integrity of streams (Dorji, 2016; Rai et al., 2020; Wangchuk et al., 2017).

Despite having abundant freshwater resources, in many cases, they are inaccessible and scarce because of the rugged terrain and topography (National Statistics Bureau 2014). In some cases, the situation is further worsened by impacts of climate change, as evidenced by reduced flow and drying up of source, and ultimately affecting domestic and agricultural water supplies (National Environment Commission and Asian Development Bank 2016). Therefore, with increasing population, anthropogenic activities and impacts of global climate change, pressure on freshwater ecosystems is expected to increase steadily. This requires understanding on biological quality elements (macroinvertebrates in present case), existing assessment tools and more research on alternative approaches on monitoring, management and conservation freshwater resources and associated organisms.

CHAPTER 2: OBJECTIVES, RESEARCH QUESTIONS AND HYPOTHESES

2.1. General objective

This study aims to characterize the assemblage structure of macroinvertebrates in near-natural Bhutanese streams across two ecoregions (ER), namely the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF) to generate baseline information that can be used in conservation and management of riverine ecosystems.

2.2. Specific objectives

The specific objectives of the present study are to:

1) Determine macroinvertebrate assemblages of streams draining through two ecoregions (spatial aspects): the Himalayan Subtropical Pine Forests (geographic zone: Southern Mountains and Georges of Bhutan) and the Eastern Himalayan Broadleaf Forests (geographic zone: Inner Valleys and Passes in Western and Central Bhutan) and analyse the factors influencing the ecoregion-specific community composition.
2) Identify ecoregion-specific macroinvertebrate communities in response to seasonal changes (temporal aspects) in near-pristine sites of streams flowing through the Himalayan Subtropical Pine Forests and the Eastern Himalayan Broadleaf Forests.

2.3. Research questions

The objective of the study will address the following research questions:

1) How do macroinvertebrate communities in the Himalayan Subtropical Pine Forests and the Eastern Himalayan Broadleaf Forests differ at the ecoregional scale? Which factors are responsible for ecoregion-specific compositions of macroinvertebrates communities? Which are the indicator taxa for near-natural streams of the Himalayan Subtropical Pine Forests and the Eastern Himalayan Broadleaf Forests?

2) What effect does season have on ecoregion-specific assemblage patterns of benthic macroinvertebrates? Which are the season-specific indicator taxa for streams of the Himalayan Subtropical Pine Forests and the Eastern Himalayan Broadleaf Forests?

2.4. Hypotheses

The following hypotheses are proposed for assessment of ecoregional objective (i.e., spatial-scale aspects):

H1: The community structure of macroinvertebrates in the Eastern Himalayan Broadleaf Forests (EHBF) of Bhutan will show higher overall diversity, abundance, EPT abundance, EPT dominance and EPT taxa diversity than the Himalayan Subtropical Pine Forests.

H2: Due to higher elevation and resource availability, the functional feeding groups (FFGs) the Eastern Himalayan Broadleaf Forests (EHBF) will show pre-dominance (dominance and abundance) of shredders and gathering collectors as compared to the Himalayan Subtropical Pine Forests.

The following hypotheses are proposed for assessment of temporal-scale objective within a particular ecoregion (temporal aspects):

H3: Pre-monsoon ecoregion-specific assemblage patterns of macroinvertebrates will show higher total abundance, taxa diversity, EPT abundance, EPT dominance and EPT diversity. Diptera abundance, dominance, and taxa diversity will increase during post-monsoon season.

H4: The dominance and abundance of shredders and gathering collectors will increases during post-monsoon season, because of increased resource availability (leaf litter).

H5. The assemblage pattern of macroinvertebrates across season corroborates with the expectations for first to third order streams in accordance with the River Continuum Concept.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study area and sites

Bhutan is a small, landlocked, and mountainous country located in the Eastern Himalayan Region of the Hindu Kush Himalaya (HKH). The North-South axis is just 170 km broad with altitudinal gradient ranging from less than 100 m in the southern foothills to > 7500 m in the high mountains (Tempa et al. 2019). The rivers and streams are perennial and flows through valleys until they exit to India through southern foothills. Based on altitude and climate, Bhutan is divided into six agroecological zones (Table 1). The rainfall is unimodal , with peak summer monsoon from June to September accounting 72 % of annual rainfall (National Centre for Hydrology and Meterology 2019) with peak discharge during monsoon (National Centre for Hydrology and Meterology 2018).

Table 1. Agro-ecological Zones of Bhutan (Gyamtsho, 1996).

Agro-ecological Zone	Altitude Range (m)	Annual Rainfall (mm)	Air Temperature (° C)		
			Minimum	Maximum	Mean
Alpine	3,600 – < 4,600	< 650	-1	12	6
Cool Temperate	2,600 – < 3,600	650 – 850	1	22	10
Warm Temperate	1,800 – < 2,600	650 – 850	1	26	13
Dry Subtropical	1,200 – < 1,800	1,200 – 1,800	3	29	17
Humid Subtropical	600 – < 1,200	1,200 – 2,500	5	33	20
Wet Subtropical	150 – < 600	2,500 – 5,500	12	35	24

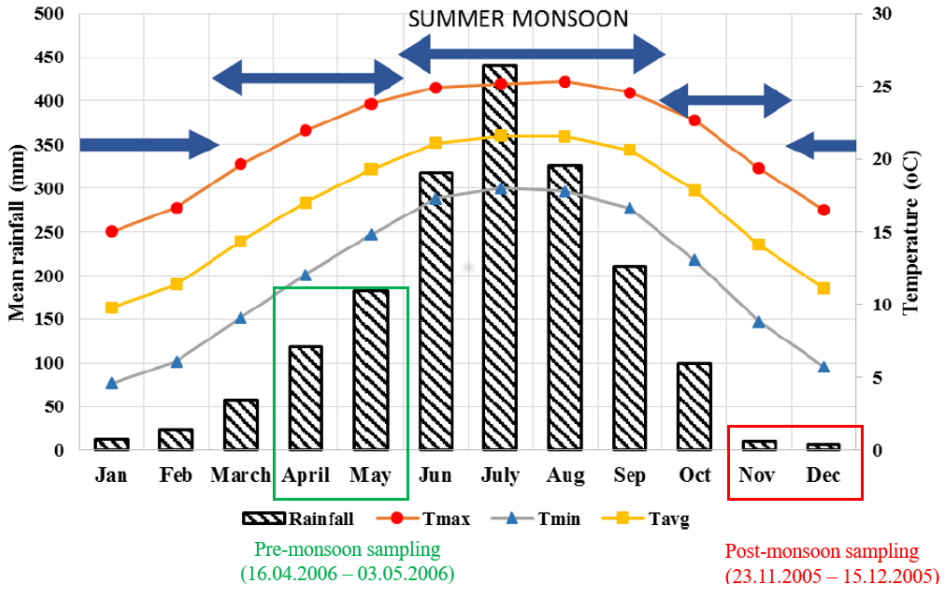


Figure 1. Monthly variation of rainfall (mm) and temperature in Bhutan from 1996 – 2013 (Adopted from NCHM, 2019, "Report on the analysis of historical climate and climate projection for Bhutan, Page 8", Tmax = maximum temperature, Tmin = minimum temperature, Tavg = average temperature) and seasonal sampling period. Discharge has similar trends.

A total of 46 reference sites from 24 rivers and streams (Figure 2, Table 2) flowing through Aiechhu, Mangdechhu, Punatshangchhu, and Wangchhu hydrological basins (National Environment Commission 2016) in Central and Western Bhutan were considered for the purpose of this study. Of these, 12 streams (21 sites; 11 pre-monsoon and 10 post-monsoon) flow through the Himalayan Subtropical Pine Forests (HSPF) and the remaining 12 streams (25 sites; 15 pre-monsoon and 10 post-monsoon) flows through the Eastern Himalayan Broadleaf Forests (EHBF). This delineation of ecoregion follows the Global 200 terrestrial regions and is adjusted for common application as aquatic ecoregions in HKH countries (Stubauer et al. 2010). In accordance with the major agroecological zones, the Himalayan Subtropical Pine Forests (HSPF) corresponds to the Subtropical Agroecological Zone (< 1800 m.s.l.) whereas the Eastern Himalayan Broadleaf Forests (EHBF) corresponds to the Temperate Agroecological Zone (> 1800 – < 3600 m.s.l.).

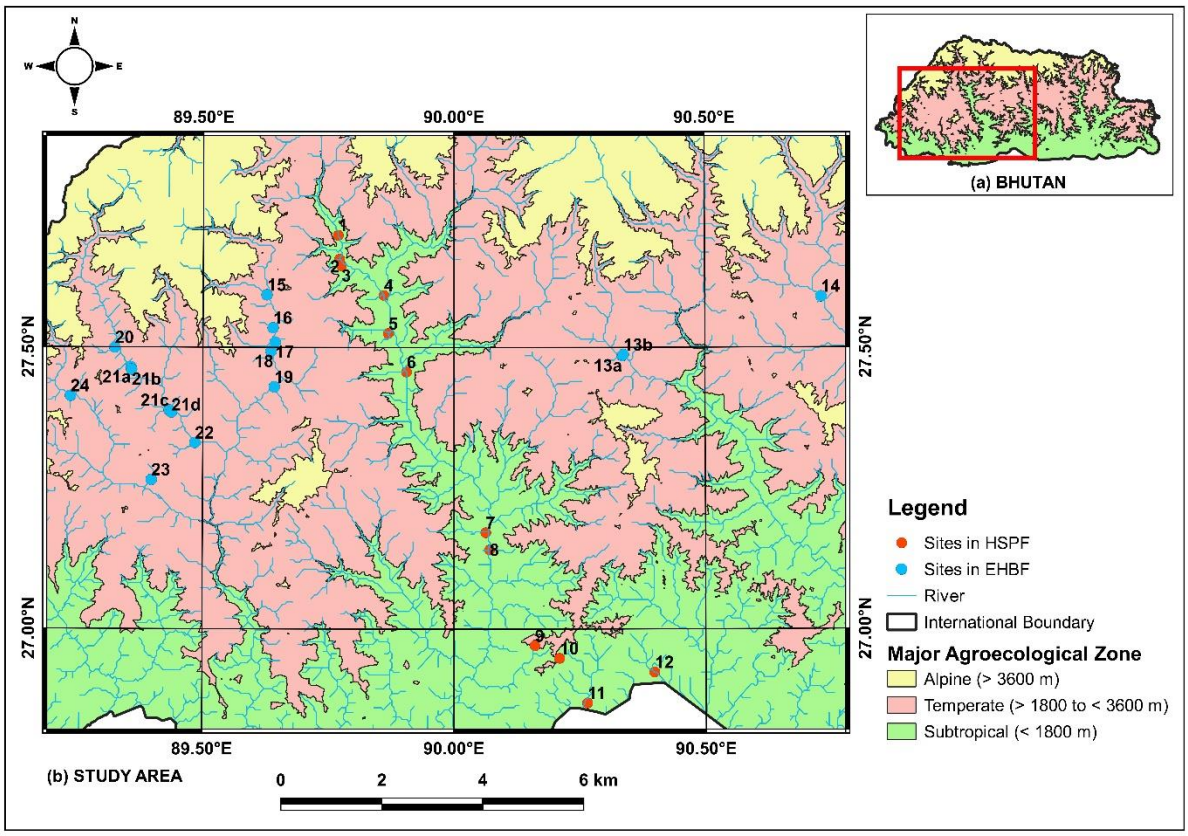


Figure 2. Location of sampling sites across Western and Central Bhutan along two ecoregions: the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forest (EHBF) and the corresponding Major Agroecological Zone (map credit: Changlu, NRCR&LF, Bhutan). Name of rivers and corresponding pre-monsoon and post-monsoon sites are given in Table 2.

Table 2. Geographical classification of the sampling sites across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF).

Sl. No.	River/Streams	Ecoregion	Hydrological Basin	Latitude (Decimal deg.)	Longitude (Decimal deg.)	Altitude (m)	Sampling date		Total sites
							Pre-monsoon	Post-monsoon	
1	Mochhu	HSPF	Punatshangchhu	27.699167	89.769167	1467	25.04.2006	28.11.2005	2
2	Dungkhar Rongchhu	HSPF	Punatshangchhu	27.65675	89.771944	1378	24.04.2006	28.11.2005	2
3	Jichulum Rongchhu	HSPF	Punatshangchhu	27.645078	89.775589	1374	25.04.2006	24.11.2005	2
4	Ngakhuchhu	HSPF	Punatshangchhu	27.592444	89.860278	1224	24.04.2006	-	1
5	Toebirongchhu	HSPF	Punatshangchhu	27.524747	89.869167	1239	24.04.2006	-	1
6	Nahichhu	HSPF	Punatshangchhu	27.456417	89.905611	1200	-	29.11.2005	1
7	Nyarachhu	HSPF	Punatshangchhu	27.171167	90.063333	537	18.04.2006	25.11.2005	2
8	Neychhu	HSPF	Punatshangchhu	27.140528	90.070889	524	18.04.2006	25.11.2005	2
9	Ragchhu	HSPF	Punatshangchhu	26.970278	90.160722	1750	19.04.2006	25.11.2005	2
10	Darachhu	HSPF	Aiechhu	26.947944	90.209722	1759	18.04.2006	27.11.2005	2
11	Kamikhola	HSPF	Aiechhu	26.868694	90.264944	324	19.04.2006	26.11.2005	2
12	Bhurchhu	HSPF	Aiechhu	26.923389	90.398194	376	20.04.2006	27.11.2005	2
13a	Lamchelachhu	EHBF	Mangdechhu	27.485360	90.335257	2493	23.04.2006	-	1
13b	Lamchelachhu	EHBF	Mangdechhu	27.487192	90.337489	2473	23.04.2006	-	1
14	Chamkharchhu	EHBF	Mangdechhu	27.590108	90.73192	2615	22.04.2006	-	1
15	Cherichhu	EHBF	Wangchhu	27.593278	89.627194	2614	16.04.2006	23.11.2005	2
16	Dreychhu	EHBF	Wangchhu	27.534605	89.639553	2492	16.04.2006	13.12.2005	2
17	Tabachhu	EHBF	Wangchhu	27.509089	89.643706	2415	17.04.2006	14.12.2005	2
18	Thimphuchhu	EHBF	Wangchhu	27.492969	89.635591	2319	03.05.2006	-	1
19	Olarongchhu	EHBF	Wangchhu	27.429856	89.642069	2267	01.05.2006	15.12.2005	2
20	Balakhachhu	EHBF	Wangchhu	27.499435	89.32425	2512	28.04.2006	06.12.2005	2
21a	Pachhu	EHBF	Wangchhu	27.464438	89.356511	2369	28.04.2006	-	1
21b	Pachhu	EHBF	Wangchhu	27.460485	89.357855	2356	29.04.2006	-	1
21c	Pachhu	EHBF	Wangchhu	27.388064	89.433014	2226	-	07.12.2005	1
21d	Pachhu	EHBF	Wangchhu	27.384493	89.437501	2220	28.04.2006	07.12.2005	2
22	Isunachhu	EHBF	Wangchhu	27.330514	89.484528	2175	28.04.2006	06.12.2005	2
23	Naguchhu	EHBF	Wangchhu	27.264722	89.397861	2722	01.05.2006	08.12.2005	2
24	Channachhu	EHBF	Wangchhu	27.413194	89.236278	2874	30.04.2006	07.12.2005	2

3.2. Data sources and selection of reference sites

The data for the purpose of this study was obtained from the data repository of ASSESS-HKH Project maintained by the University of Natural Resources and Life Science (BOKU), Vienna, Austria. The ASSESS-HKH Project was funded by the European Union (April, 2005 to April 2008) to develop ecoregion-specific bioassessment tools for common application across five HKH countries, particularly, Bangladesh, Bhutan, India, Nepal and Pakistan (http://www.assess-hkh.at/mains/about.php, Ofenböck et al. 2010).

The database contained biological and environmental information of 75 sampling sites spread over two ecoregions of Bhutan, i.e., the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF) collected over pre-monsoon and post-monsoon seasons. A total of 46 sites falling under the water quality class (WQC) I and II in accordance with HKH field screening for mountainous ecoregions (Hartmann et al. 2010) were selected. These sites were considered as near-natural sites for this study.

3.3. Field method

The field sampling across selected sites (n = 46) were conducted during post-monsoon (23.11.2005 – 15.12.2005) and pre-monsoon season (16.04.2006 – 03.05.2006, site-specific date on Table 2). The HKH field screening requires usage of a square net (25 cm) for multi-habitat sampling, which is composed of 20 subsamples (1.25 m^2) from each site of 100 m length, with each subsample reflecting at least 5 % (0.0625 m^2) of substrate coverage.

The HKH field screening method is a rapid bioassessment tool designed to detect organic pollution and estimate water quality class (WQC) of rivers (sampling sites). The WQC is determined in accordance with the outcome of HKH field screening decision support table (Figure 3) and based on site-specific characteristics, particularly (i) sensory characteristics, (ii) ferrous sulphate reduction, and (iii) biological communities (fungi, bacteria, periphyton, and macroinvertebrates) with more emphasis on macroinvertebrates.

The indicator for macroinvertebrates includes features such as overall species richness, dominance of organism in according to five categories of sensitivity scales derived from HKHbios (Table 7) and 26 additional macroinvertebrate-based indicators (Figure 3, benthic macroinvertebrates). The evaluation of site-specific characteristics can be recorded in HKH field screening decision support table by assigning scores against all the water quality class (I to VI). Finally, the scores against each water quality class are summed and one with highest

point provides estimate of water quality class as: excellent (I), good (II), moderate (III), poor (IV), bad (V), and no higher life (VI).

Figure 3. HKH field screening protocol for mountainous ecoregions (Hartmann et al. 2010)

Screening Protocol (Mountains) for assessing the river quality of streams in the ASSESS-HKH region						
Decision support table	river quality classes					
Multiple choices possible	I	II	III	IV	V	VI
Sensory features	To be ticked/counted if not in accordance with natural river type					
Non natural turbidity, Suspended solids			+	+	++	
Non natural colour		+	+	+	++	
Foam		+	+	+	+	
Odour (water)		+	++	++	++	
Waste dumping		+	+	+	+	
Ferro-sulphide reduction – (water velocity< 0,25 m/s)	-					
Mud reduced but with aerobic surface		+	+++	++		
Mud reduced but with anaerobic surface				++	+++	+++
Lower surface of stones (% cover black dots)		< 25 %	25-75 %	75-100 %	100%	100%
Upper & lower surfaces of stones				+	++	++
Ferro-sulphide reduction – (water vel.) 0,25-0,75 m/s)	-	-				
Mud reduced but with aerobic surface			+	+++	+	+
Mud reduced but with anaerobic surface				+	++	++
Lower surface of stones (% cover black dots)			< 50 %	50-100 %	100%	100%
Upper & lower surfaces of stones					+++	+++
Ferro-sulphide reduction – (water velocity > 0,75 m/s)						
Lower surface of stones (% cover black dots)			< 25 %	25-50 %	50-100 %	50-100 %
Upper & lower surfaces of stones					+++	+++
Bacteria, fungi, periphyton						
Sewage fungi & bacteria (visible to the naked eyes)	(-)	(-)	few	medium	many +++	many +++
Sulphur bacteria (visible to the naked eyes)	(-)	(-)	(-)	+	+++	+++
Stones with algal vegetation (periphyton) in thin layers	++	++				
% of thick, significant layers of algae	< 25 %	25-75 %	75-100 %	75-100 %	few	
Filamentous green algae	none to few	filaments, tufts	large tufts	(large) tufts	+	
Benthic macro-invertebrates						
Species richness	medium/high	(very) high	medium	few	very few	+++none**
Dominance of very sensitive organisms (8 to 10)*)	+++					
Dominance of sensitive organisms (6 to 8)*)	+	+++	+			
Dominance of medium tolerant organisms (4 to 6)*)			+++	+		
Dominance of tolerant organisms (3 to 4)*)			+	+++	+	
Dominance of extremely tolerant organisms (1 to 2)*)					+++	
Rhithrogena spp.	+++	++				
Perlidae	++	+				
Plecoptera	++	+				
Euphaeidae	++	+				
Stenopsyche spp.	++	+	+			
Rhyacophilidae	+++	++	+			
Caenis spp.	+	++	++			
Heptageniidae	++	++	+			
Psephenidae	++	+++	+			
Glossosomatidae	++	+++	+			
Sphaeriidae	+	+	++			
Simuliidae	+	++	++			
Psychomyiidae	+	+++	++			
Tabanidae	+	++	+++			
Potamidae	+	++	++	+		
Libellulidae / Corduliidae		+	+++	++		
Hydropsychidae (medium to many)		+	+++	+		
Planorbidae		++	+++	+		
Lymnaeidae		+	+++	++		
Physa spp.			+	++		
Leeches (more than naturally occurring)	-	-	+	+++	+	
Chironomids with red colour		very few	few	medium	+++many	none
Bezzia-Group				+	++	
Psychodidae white				+	+++	
Air-breathing animals, e. g. rat-tail maggots					+++	+++
Oligochaeta / Tubificidae (mud-worms)	0 to very few	few	few/ medium	medium/ many	many	none
Sum of columns						
*) check scores in the HKHbios list on the back page **) if only airbreathing organisms						

Figure 4. Post-monsoon sampling site at Cherichhu, Thimphu (Eastern Himalayan Broadleaf Forests) and project officials (national and international) processing the samples (23.11.2005). Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

Figure 5. Post-monsoon sampling by national and international project officials at Naguchhu, Paro (Eastern Himalayan Broadleaf Forests) and an Ephemeridae larva (08.12.2005). Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

Figure 6. Post-monsoon sampling by national and international project officials at Neychhu, Tsirang (Himalayan Subtropical Pine Forests, 25.11.2005). Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

Figure 7. Post-monsoon sampling by national and international project officials at Nyarachhu, Wangdue (Himalayan Subtropical Pine Forests) and Heptageniidae larvae (25.11.2005). Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

3.4. Biological data

46 near-natural sites (WQC I and II in accordance with HKH Field Screening Method) were considered for final analysis. One of the important criteria for consideration of indicator species is clear and well known taxonomic resolution for better interpretation and communication for fulfilling purpose of conservation and management (Pearson 1994; Hilty and Merenlender 2000). In view of this, taxonomic resolution of 40 taxa were upgraded at genera level, thereby narrowing the list of taxa from 248 (from 75 sites) to 208. The near-natural sites (n = 46) recorded a total of 35,416 individuals belonging to 186 taxa, 180 genera, 101 families and 14 taxonomic groups (Table 4, Annexure 1). The biological data were then categorised in three major groups (ecoregion and ecoregion-specific samples) and their corresponding comparison pairs (Table 3).

Table 3. Summary of sites and taxa distribution in accordance with major groups and comparison pairs.

Major group	Comparison pairs	# of sites	Abundance	# of taxa	# of genera	# of families
Ecoregion	HSPF	21	7211	122	120	69
	EHBF	25	28,205	130	126	64
HSPF	Pre-monsoon	11	2730	80	79	47
	Post-monsoon	10	4481	96	96	61
EHBF	Pre-monsoon	15	10,001	88	88	52
	Post-monsoon	10	18,204	89	87	53
Total		**46**	**35,416**	**186**	**180**	**90**

Table 4. Overall summary of taxa from reference sites (n = 46) in accordance with taxonomic groups (site-wise distribution of macroinvertebrates are in Annexure 2 and Annexure 3).

Taxonomic groups	Individuals	Relative abundance (%)	Families	Genera	Taxa
Coleoptera	1671	4.71	12	19	19
Diptera	12,984	36.66	16	34	34
Ephemeroptera	9237	26.08	11	31	33
Heteroptera	65	0.18	4	4	4
Hydrachnidia	7	0.02	1	1	1
Lepidoptera	33	0.09	1	1	1
Megaloptera	35	0.09	1	1	1
Mollusca	1	0.002	1	1	1
Nematoda	1	0.002	1	1	1
Odonata	92	0.26	5	6	6
Oligochaeta	1809	5.11	6	7	10
Plecoptera	207	0.58	5	12	12
Trichoptera	9210	26.00	23	59	60
Turbellaria	64	0.18	3	3	3
Total	**35416**	**100**	**90**	**180**	**186**

3.5. Site characteristics

The environmental variables considered from the ASSESS-HKH Project included 148 quantitative variables, among which 97 variables were selected for analysis. These environmental variables were categorised into six major groups (Table 5, Table 6): (i) geographical variables (3 variables); (ii) catchment characteristics (15 variables), (iii) floodplain characteristics (18 variables), (iv) hydrological properties (12 variables), (v) morphological characteristics (39 variables), and (vi) physicochemical parameters (10 variables).

The geographical variables and catchment variables are broadly categorised as spatial-scale environmental variables, whereas floodplain characteristics, hydrological characteristics, morphological features and physiochemical characteristics were broadly categorised as local-scale environmental variables (Heino et al. 2007).

Table 5. List of selected environmental variables (geographical, catchment, floodplain, hydrological and physicochemical characteristics). Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

(i) Geographical Variables		**(iii) Floodplain characteristics**		2	Estimated discharge (cumecs)
1	Latitude	1	Width of the floodplain (m)	3	Stream width (m) average
2	Longitude (dec. degree)	2	Valley slope (%)	4	Stream width (m) minimum
3	Altitude a.s.l. (m)	3	Slope of the river course (thalweg) (%)	5	Stream width (m) maximum
(ii) Catchment characteristics		4	Width of wooded riparian vegetation (m)	6	Mean depth (m)
1	Catchment area (km²) at sampling site	5	Average density of wooded riparian vegetation	7	Maximum depth (m)
2	Distance to source (km)	**Floodplain land use (10% steps, rounded)**		8	Mean depth at bankfull discharge (m)
Catchment geology (10% steps)		6	Deciduous native forest	9	Mean current velocity (m/s)
3	Acid silicate rocks	7	Coniferous native forest	10	Maximum current velocity (/s)
4	Flysch & molasse	8	Mixed native forest	11	Minimum current velocity (m/s)
Catchment land use (10%)		9	Open grass-/bushland (natural)	12	Relation riffles/pools (% pools)
5	Deciduous native forest	10	Non-native forest	**(v) Physicochemical characteristics**	
6	Coniferous native forest	11	Terraces (hilly region)	1	pH
7	Mixed native forest	12	Crop land (tillage, lowland)	2	Conductivity (µS/cm)
8	Wetland (mire, reeds)	13	Clear-cutting	3	Total hardness (mmol/l)
9	Open grass-/bushland (natural)	14	Urban sites (residual)	4	Chloride (mg/l)
10	Terraces (hilly region)	15	Urban sites (industrial)	5	Ammonium (mg/l)
11	Crop land (tillage, lowland)	16	Partial cutting	6	Nitrite (mg/l)
12	Clear-cutting	17	Villages	7	Nitrate (mg/l)
13	Urban sites (residual)	18	Shading at zenith (at noon)	8	Orthophosphate (µg/l)
14	Urban sites (industrial)	**(iv) Hydrological characteristics**		9	Total phosphate (µg/l)
15	Stone quarry and landslides	1	Mean annual discharge (MQ) (cumecs)	10	Temperature (°C) water

Table 6. List of selected morphological characteristics. Source: ASSESS-HKH Project Repository, BOKU University, Vienna.

Morphological characteristics			
1	Number of debris dams	**Proportion of bed fixation**	
2	Number of logs	20	Concrete without seams
3	No. of dams at sampling site	21	Stones
4	Cumulative height	22	Gabions
5	Maximum height	23	No bed fixation
6	No. of other transverse structures	**Habitat characteristics (mineral microhabitats in %)**	
7	Cumulative height	24	Hygropetric sites
8	Maximum height	25	Megalithal > 40 cm
		26	Macrolithal > 20 cm to 40 cm
Proportion of bank fixation (left)		27	Mesolithal > 6 cm to 20 cm
9	Concrete without seams	28	Microlithal > 2 cm to 6 cm
10	Concrete with seams	29	Akal > 0.2 cm to 2 cm
11	Stones	30	Psammal > 6µm to 2 mm
12	Stone plastering with interstices	31	Pelal < 6 µm
13	Gabions	**Habitat characteristics (biotic microhabitats in %)**	
14	No bank fixation	32	Macro-algae
		33	Micro-algae
Proportion of bank fixation (right)		34	Submerged macrophytes
15	Concrete without seams	35	Emergent macrophytes
16	Concrete with seams	36	Coarse particulate organic matter (CPOM)
17	Stones	37	Fine particulate organic matter (FPOM)
18	Gabions	38	Sewage bacteria
19	No bank fixation	39	Debris

3.6. Statistical analysis

The statistical analysis are based on categorisation of data into three major groups with respective comparison pairs based on two grouping factors, namely the ecoregions and seasons (Table 3). They major groups are (i) ecoregions – to compare the macroinvertebrate community composition between two ecoregions, namely the HSPF and the EHBF, (ii) HSPF – to compare ecoregion-specific pre-monsoon and post-monsoon assemblage from the HSPF, and (iii) EHBF – to compare ecoregion-specific seasonal changes in macroinvertebrate communities from the EHBF.

3.6.1 Multivariate comparison of community composition

The multivariate comparison of macroinvertebrate communities was performed on PC-ORD (Version 5.33) through multi response permutation procedure (MRPP) and non-metric multidimensional scaling (NMDS). Multi response permutation procedure (MRPP) is a non-parametric solution used to test hypothesis that the overall macroinvertebrate communities within comparison pairs of a group are same (McCune and Grace 2002). The agreement value

(A) gives indication of within group heterogenicity from expected by chance and values $A > 0$ indicates more similarities within group, with 1 indicating identical communities. The value of $A > 0.30$ indicates very high within-group similarity (McCune and Grace, 2002). The probability of observed differences is indicated by p value.

The ordination of macroinvertebrate assemblages from different groups were analysed by non-metric multidimensional scaling (NMDS). The NMDS analysis were undertaken with Sørensen (Bray-Curtis) distance measure in autopilot mode with medium speed and thoroughness, with 50 runs of real data, 50 runs of random data, and 200 iterations. The relationship between the taxa assemblage and environmental variables were examined through a NMDS biplot at specific joint plot cut-off value ($r^2 = 0.20$ for the ecoregion; $r^2 = 0.25$ for the HSPF and $r^2 = 0.50$ for the EHBF). NMDS is highly suitable for ecological data as it explains similarities and dissimilarities, without requiring normality, even when datasets are arbitrary, discontinuous, questionable scales or have large number of zero values (McCune and Grace 2002).

In order to reduce the noise and influence of rare taxa on ordination because of their idiosyncratic occurrences, and to subsequently improve information for statistical analysis and maximize interpretability of an ordination, rare taxa were eliminated prior to analysis (Dodson et al. 2005; Poos and Jackson 2012). In this case, taxa found across < 5 % of group-specific sites (ecoregion, HSPF and EHBF) were defined as rare, regardless of abundance (McCune and Grace 2002; Dodson et al. 2005; Pond et al. 2008). Subsequently for ecoregion ($n = 47$), taxa occurring across ≤ 2 sites were removed, whereas for the HSPF ($n = 21$) and the EHBF ($n = 25$), all taxa restricted to single site were removed.

The final dataset for multivariate analysis across ecoregion included 106 taxa (of 186) belonging to106 genera (of 180), 52 families (of 90) and 14 taxonomic groups (of 12). The final dataset for seasonal multivariate analysis within the HSPF included 79 taxa (of 122) belonging to 78 genera (of 120), 46 families (of 69) and 11 taxonomic groups (of 14) whereas final dataset for seasonal multivariate analysis within the EHBF included 95 taxa (of 130) belonging to 94 genera (of 126), 49 families (of 64) and 9 taxonomic groups (of 10). The multivariate analysis were further performed on presence absence data to reduce influence of taxa abundance and to ensure more linear relationships with distance measure, i.e. Sørensen distance measure in current analysis (McCune and Grace 2002).

3.6.2. Indicator species analysis (ISA)

The macroinvertebrate taxa indicative of particular groups in accordance with grouping criteria (ecoregions or seasons) based on major groups (ecoregions, HSPF and EHBF) were determined through Indicator Value (IV) of taxa obtained through indicator species analysis (Dufrene and Legendre 1997). The IV of taxa is determined by specificity and fidelity, and ranges from 0 to maximum of 100, which is attained when a taxon is recorded in specific pairs of particular major groups (specificity) and is present in all the sites of that pairs (fidelity). The statistical significance ($p < 0.05$) of indicator values of all taxa within a group was tested with Monte Carlo test at 4999 permutations. Finally, significant taxa ($p < 0.05$) with indicator value ≥ 60 were considered as an excellent indicator whereas significant taxa ($p < 0.05$) with indicator value ≥ 40 to < 60 were considered as good indicators.

Prior to ISA, hierarchical cluster analysis (HCA) was performed through Sørensen (Bray-Curtis) as distance measure with flexible beta as group linkage method (beta = − 0.25) to inspect the clustering of sites in accordance with macroinvertebrate composition. The Sørensen distance measure is considered as one of the most effective distance measure method available for analysis of ecological data whereas flexible beta (beta: − 0.25) prevents clustering distortion and lessen the chaining tendency (McCune and Grace 2002; Talal and Santelmann 2019). The grouping level of 6 for the ecoregion, 3 for the HSPF and 2 for the EHBF were considered for clustering to optimize interpretability and reduce information loss (Talal and Santelmann 2019). The dataset exclusive of rare taxa for respective groups were transformed to presence absence data and were subjected to HCA and ISA on PC-ORD (Version 5.3.3).

3.6.3. Comparison of biocoenosis and biological metrics

The comparison of macroinvertebrate composition within major groups (ecoregion, HSPF, EHBF) are based on six categories of biological variables. They are (i) ten most dominant taxa, (ii) frequently occurring taxa, (iii) exclusive taxa, (iv) diversity metrics (v) composition and diversity metrics based on HKH sensitivity class, (vi) composition and diversity metrics based on taxonomic groups and (vii) functional feeding groups.

Dominant taxa: The site-specific abundance data are expressed as relative abundance (% per 1.25 m) and taxa with highest mean relative abundance (% per 1.25 m) across a comparison pairs are considered as dominant taxa, and subsequently expressed as dominance (%). This was done to improve overall reflection of macroinvertebrate assemblages by weighing down the influence of few taxa occurring in high abundances (exclusively in certain

sites) and to reflect contribution taxa occurring at lower abundance, but with higher frequency of occurrences. Only top ten dominant taxa from comparison pairs of major groups are considered.

Frequently occurring taxa: They are taxa with most frequent occurrences across sites belonging to particular comparison pairs. Ten most frequently occurring taxa are considered across each comparison pairs. The frequently occurring taxa are determined through PC-ORD (Version 5.3.3).

Exclusive taxa: They are defined as taxa with occurrence across site(s) of particular comparison pairs and are absent across sites of subsequent comparison pairs.

Diversity metrics: The diversity metrics considered are Shannon's Diversity Index (*H*), Simpson's Diversity Index (*D*), Pielou's Evenness (*J*) and taxa richness (*S*). In addition, abundance (individuals/1.25 m^2) of macroinvertebrates are also considered as separate metrics. These metrics were calculated in PC-ORD (version 5.3.3) using abundance data from complete taxa list.

HKH sensitivity metrics: The HKH field screening decision support table categorizes taxa from HKH region into five sensitivity classes (Hartmann et al. 2010) based on sensitivity scores (HKHbios) assigned to macroinvertebrates in accordance to their response to anthropogenic stress (Ofenböck et al. 2010). The 10-point sensitivity score ranges from 1 (highly tolerant organism to pollution) to 10 (highly sensitive organisms to pollution). The five sensitivity classes used in HKH field screening are: (i) very sensitive organisms, (ii) sensitive organisms, (iii) medium tolerant organisms, (iv) tolerant organisms and (v) extremely tolerant organisms (Table 7).

For mountainous ecoregions, sensitivity scores are available for 186 taxa as they showed clear response to perturbations (Ofenböck et al. 2010). Out of 186 taxa from Bhutanese reference sites (n = 46, WQC – I and II), scores were available for 158 taxa, whereas 28 taxa were unscored. The unscored taxa were one without clear preferences to disturbances gradient (Ofenböck et al. 2010) and hence were considered for analysis to see composition. The sensitivity metrics considered includes taxa composition and richness in accordance with sensitivity classes, including unscored. The main analysis for composition is based on site-specific relative abundance data and is expressed as dominance (%). Also included is analysis based on abundance.

Table 7. Sensitivity class of macroinvertebrates in HKH region (Hartman et al. 2010)

Sl. No.	HKH sensitivity classes	HKHbios
1	Very sensitive organisms (macroinvertebrates)	9 and 10
2	Sensitive organisms	7 and 8
3	Medium tolerant organisms	5 and 6
4	Tolerant organisms	3 and 4
5	Extremely tolerant organisms	1 and 2

Taxonomic composition: The metrics for taxonomic composition includes composition and richness of EPT (Ephemeroptera, Plecoptera and Trichoptera), Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Diptera and Oligochaeta. Considering lower abundance (n = < 100 individuals) and diversity (S = < 7) from all sites (n = 46), the remaining taxonomic groups (Heteroptera, Hydrachnidia, Lepidoptera, Megaloptera, Mollusca, Nematoda, Odonata and Turbellaria) was categorised as others. The metrics for taxonomic composition includes taxa composition and taxa richness. This main analysis for composition is based on site-specific relative abundance data and is expressed as dominance (%). Also included is analysis based on abundance.

Functional feeding groups (FFGs): The composition of macroinvertebrates in accordance with functional feeding groups (FFGs) are compared among comparison pairs of major groups. Of 186 taxa, FFGs were assigned to 183 taxa and were categorized into six functional groups, namely filtering collectors, gathering collectors, scrapper, shredders, predators and filamentous algae piercers (Merritt et al. 1996; Merritt et al. 2008; Dominguez and Fernández 2009; Jiang et al. 2010; Hudson et al. 2012; Moog 2017; Merritt et al. 2019). For those taxa with multiple functional feeding groups, the most dominant functional feeding groups were considered, and subsequently assigned with dominant FFGs. The functional feeding groups of three higher level taxa could not be ascertained (Diptera Gen. sp., Trichoptera Gen. sp. and Sciaridae Gen. sp.). Therefore, only five dominant FFGs i.e., filtering collectors, gathering collectors, scrapper, shredders, and predators are discussed. The taxa abundance was transformed as site-specific relative abundance prior to analysis and are expressed as dominance (%) for main analysis. Also included is analysis based on abundance. The relative abundance of taxa without FFGs and piercers were insignificant (< 0.25 % in total across all comparison pairs) and were categorized as others.

In order to visualize the differences in community structure, NMDS analysis were undertaken with Sørensen (Bray-Curtis) distance measure in autopilot mode with medium speed and thoroughness, with 50 runs of real data, 50 runs of random data, and 200 iterations.

The relationship of taxa assemblage and selected variables (functional feeding groups and selected environmental variables) were examined through a NMDS biplot at specific joint plot cut-off value (r^2 = 0.15 for the ecoregion; r^2 = 0.20 for the HSPF and r^2 = 0.25 for the EHBF). The NMDS was performed on presence-absence data of each groups after removal of rare taxa as defined earlier. The functional analysis of stream macroinvertebrates was conducted to determine the sources of food resource for macroinvertebrates (Cummins et al. 2005; Cummins 2019).

Table 8. Use of functional feeding groups (FFGs) as surrogates for stream ecosystem attributes (Cummins et al. 2005; Cummins 2017).

Ecosystem attributes	FFG surrogate ratios	Criteria	Interpretation
Autotrophy **Heterotopy index (P/R)** *Definition:* Gross primary production compared to total community respiration (primary production/respiration)	Scraper to shredders + total collectors	Autotropic: > 0.75	Stream energetics driven by periphytic algal + any vascular plant production as compared to riparian plant litter inputs
Filtering collector index ($FPOM_{suspended}/FPOM_{storage}$) *Definition:* Suspended FPOM transported in the current compared to FPOM in storage (entrained) in or on the sediments	Filtering collectors to gathering collectors	> 0.50 indicates $FPOM_{suspended}$ load > $FPOM_{storage}$	FPOM food for filtering collectors at higher density and/or better quality than storage FPOM

The descriptive and statistical analysis to ascertain differences in biological metrics and environmental variables across ecoregion were accessed through non-parametric Mann-Whitney *U* test (independent samples) whereas among seasons were performed through non-parametric Wilcoxon signed-rank test (related samples) on SPSS (Version 24).

CHAPTER 4. RESULTS

4.1. Physio-chemical and hydromorphological characteristics

4.1.1. Ecoregion-specific comparison of physio-chemical and hydromorphological characteristics

The statistical analysis of selected physico-chemical and hydromorphological characteristics indicated minor differences in the parameters among ecoregions, with exception of water temperature, total hardness and chloride (Table 9). Among the ecoregions, significantly higher water temperature (U = 34, p = 0.000, Figure 8a) and chloride concentration (U = 60, p = 0.035) were associated from the HSPF whereas total hardness was significantly higher across the EHBF (U = 77.5, p = 0.039, Figure 8b).

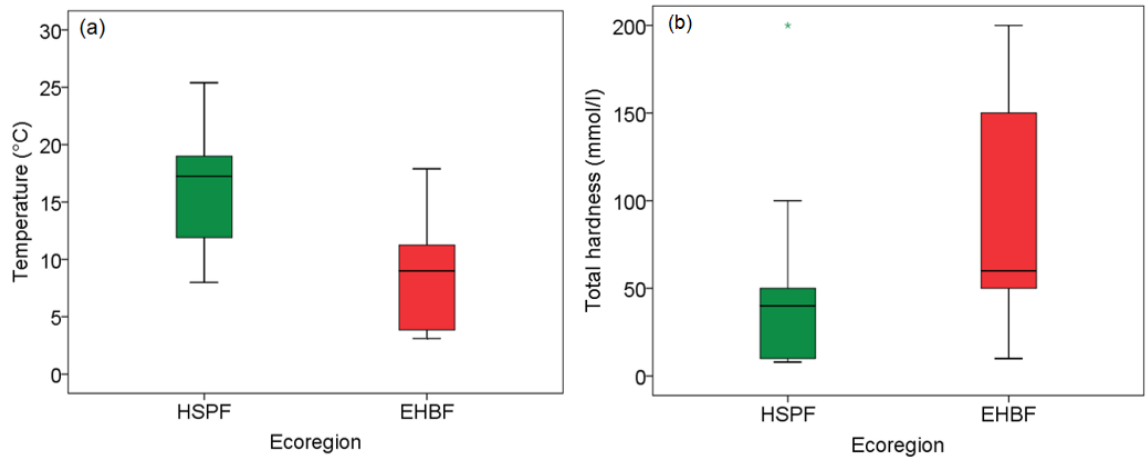


Figure 8. Ecoregion-specific variation of (a) temperature, and (b) total hardness.

Table 9. Mean value, standard deviation, p value from paired sample t- test ($p < 0.05$) of selected physico-chemical and hydromorphological characteristics across ecoregion.

Variables	HSPF		EHBF		p
	n	Mean ± SD	n	Mean ± SD	
pH	18	7.49 ± 0.41	22	7.61 ± 0.51	0.693
Conductivity (µS/cm)	18	67.56 ± 57.85	24	59.46 ± 45.56	0.859
Temperature (°C)	14	16.86 ± 4.93	24	8.75 ± 4.57	**0.000**
Total hardness (mmol/l)	14	46.86 ± 50.98	19	89.47 ± 65.36	**0.039**
Chloride (mg/l)	11	0.21 ± 0.19	15	0.10 ± 0.00	**0.035**
Ammonium (mg/l)	14	0.46 ± 0.66	17	0.24 ± 0.15	0.821
Nitrite (mg/l)	14	0.20 ± 0.53	19	0.02 ± 0.00	0.094
Nitrate (mg/l)	13	0.48 ± 0.68	18	0.19 ± 0.04	0.067
Average stream width (m)	21	6.46 ± 7.25	25	12.99 ± 16.59	0.214
Mean depth (cm)	21	28.19 ± 16.82	25	34.64 ± 15.61	0.183
Mean velocity (m/s)	21	0.33 ± 0.16	25	0.44 ± 0.24	0.107

4.1.2. Season-specific comparison of physio-chemical and hydromorphological characteristics across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF)

The temperature of water, total hardness and average streams width across both ecoregions were higher during pre-monsoon season as compared to post-monsoon season (Table 10).

Table 10. Mean value, standard deviation of selected physico-chemical and hydromorphological characteristics across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF).

Variables	HSPF, Pre-monsoon		HSPF, Post-monsoon	
	n	Mean ± SD	*n*	Mean ± SD
pH	11	7.38 ± 0.41	7	7.68 ± 0.36
Conductivity (µS/cm)	11	64.72 ± 64.12	7	72.00 ± 50.90
Temperature (°C)	11	17.96 ± 4.44	3	12.80 ± 5.31
Total hardness (mmol/l)	11	55.09 ± 54.81	3	16.67 ± 11.54
Chloride (mg/l)	11	0.21 ± 0.19	-	-
Ammonium (mg/l)	11	0.20 ± 0.12	3	0.14 ± 1.03
Nitrite (mg/l)	11	0.02 ± 0.00	3	0.84 ± 1.03
Nitrate (mg/l)	11	0.20 ± 0.00	2	2.00 ± 0.00
Average stream width (m)	11	6.51 ± 7.25	10	6.40 ± 7.64
Mean depth (cm)	11	25.45 ± 20.30	10	31.2 ± 12.29
Mean velocity (m/s)	11	0.33 ± 0.18	10	0.32 ± 0.14

Variables	EHBF, Pre-monsoon		EHBF, Post-monsoon	
	n	Mean ± SD	*n*	Mean ± SD
pH	15	7.61 ± 0.52	7	7.61 ± 0.50
Conductivity (µS/cm)	15	59.33 ± 33.51	9	59.66 ± 63.24
Temperature (°C)	15	11.77 ± 2.81	9	3.70 ± 0.63
Total hardness (mmol/l)	15	108.00 ± 60.49	4	20.00 ± 20.00
Chloride (mg/l)	15	0.10 ± 0.00	-	-
Ammonium (mg/l)	15	0.25 ± 0.16	2	0.20 ± 0.00
Nitrite (mg/l)	15	0.02 ± 0.00	4	0.02 ± 0.00
Nitrate (mg/l)	15	0.20 ± 0.00	3	0.14 ± 0.10
Average stream width (m)	15	13.2 ± 14.89	10	12.68 ± 7.61
Mean depth (cm)	15	36.18 ± 18.53	10	32.60 ± 10.38
Mean velocity (m/s)	15	0.41 ± 0.27	10	0.49 ± 0.21

4.2. Ecoregion-specific composition of macroinvertebrate communities

4.2.1. Ecoregion-specific organization of macroinvertebrate communities

The comparison of macroinvertebrate communities through multi-response permutation procedure (MRPP) indicated significant differences in community composition of macroinvertebrates in accordance with groupings based on aquatic ecoregions (A = 0.1620, p = 0.0000).

Table 11. Pairwise comparisons among ecoregion and seasons within ecoregions using the multi-response permutation procedure (T = test statistic, A = chance-corrected within-group agreement, p = probability of a smaller or equal delta < 0.05)

Group: comparison pairs	T	A	p
Ecoregion: HSPF vs EHBF	− 12.3578	0.1620	0.0000
HSPF: Pre-monsoon vs post-monsoon	− 5.6433	0.1544	0.0000
EHBF: Pre-monsoon vs post-monsoon	− 12.730	0.3523	0.0000

Ecoregion-specific organization of macroinvertebrate communities as function of environmental parameters

The non-metric multidimensional scaling (NMDS) ordination of macroinvertebrate communities from two ecoregions provided optimal 3-dimensional solution (final stress = 19.56347, final instability = 0.01236). The NMDS ordination showed two distinct communities in accordance with ecoregion (Figure 9) indicating differences in macroinvertebrate communities across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF).

The ordination accounted for 79.5 % of cumulative variance of which NMDS axis 1, axis 2 and axis 3 represented 36.2 %, 31.2 % and 12.1 % of total variations, respectively. NMDS axis 1 and axis 2 explained most of the variation (67.4 %).

The community composition at broader-scale (i.e., Bhutan/ecoregions) was mostly influenced by spatial-scale environmental variables. The most strongly corelated environmental variables with axis 1 were altitude (r = – 0.608), longitude (r = 0.541), coniferous native forest at catchment (r = – 0.405) and latitude (r = – 0.356). The environmental variables with strong negative association with axis 2 were total hardness (r = – 0.560), altitude (r = – 0.542), latitude (r = – 0.473) and coniferous native forest at catchment (r = – 0.397), whereas longitude was positively correlated (r = 0.212).

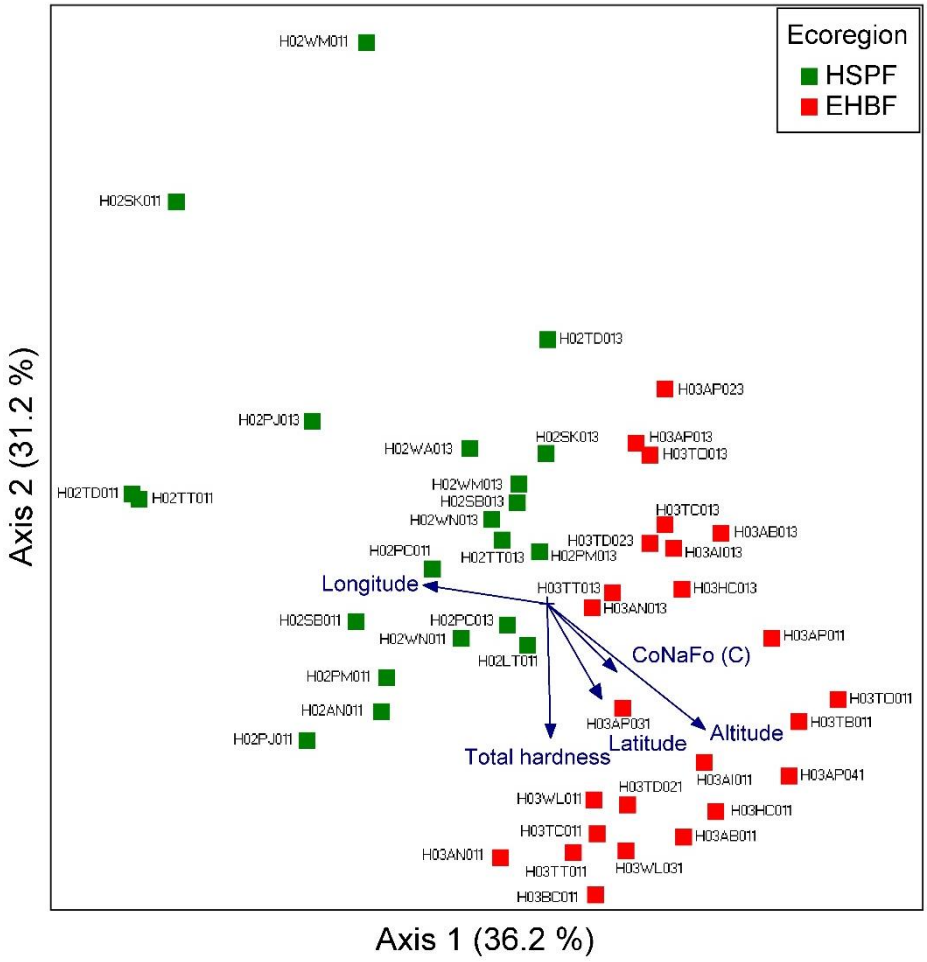


Figure 9. NMDS joint plot of benthic macroinvertebrates communities collected from Bhutan (n = 46) as function of environmental parameters with grouping based on ecoregion. Final stress for 3-dimensional solution = 19.56347, final instability = 0.01236, joint plot cut-off value: r^2 = 0.20, HSPF = Himalayan Subtropical Pine Forests, EHBF = Eastern Himalayan Broadleaf Forests, and CoNaFo (C) = percentage of coniferous native forest at catchment.

Ecoregion-specific organization of macroinvertebrate communities as function of composition of functional feeding groups

This difference in macroinvertebrate community composition among ecoregions in accordance with FFGs visualized as NMDS ordination provided optimal 3-dimensional solution (final stress = 16.72199, final instability = 0.01674) and explained 80.3 % of variation in community composition (axis 1 = 21. 4 %, axis 2 = 26.4, and axis 3 = 32.4). The NMDS axis 2 and axis 3 explained most of cumulative variance (58.8 %) and clearly indicated existence of distinct communities in accordance with FFGs (Figure 10). This community difference was most importantly influenced by scrappers and mean water depth. The scrapers positively correlated with axis 2 (r = 0.386) and negatively with axis 3 (r = − 0.164). The mean

depth positively correlated with axis 2 (r = 0.224) and showed strong negative correlation with axis 3 (r = − 0.428).

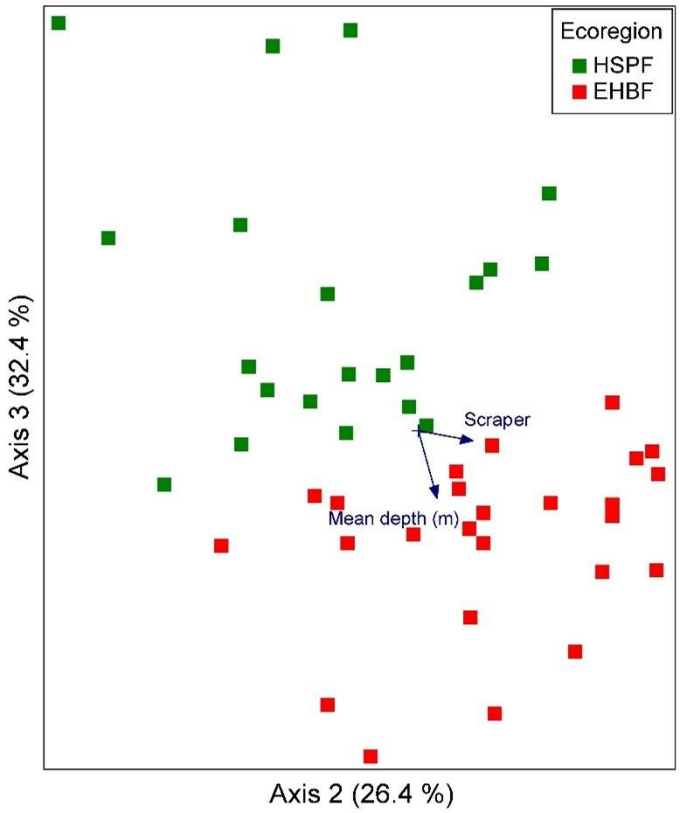


Figure 10. NMDS joint plot of macroinvertebrate communities collected from Bhutan (n = 46) as function of composition of functional feeding groups with grouping based on ecoregion. Final stress for 3-dimensional solution = 16.72199, final instability = 0.01674, joint plot cut-off value r^2 = 0.15, HSPF = Himalayan Subtropical Pine Forests and EHBF = Eastern Himalayan Broadleaf Forests.

4.2.2. Ecoregion-specific overview of abundance, composition and taxa richness

Of 186 taxa, 122 taxa were enumerated from the Himalayan Subtropical Pine Forests (HSPF) and 130 taxa were recorded from the Eastern Himalayan Broadleaf Forests (EHBF). These ecoregions shared 66 taxa in common taxa with Jaccard's Similarity Index of 0.35 and Sørensen's Similarity Index of 0.52.

The general abundance of macroinvertebrate was greater across the EHBF for all categories taxonomic groups, with exception of those categorized as others. In terms of composition (dominance), only Diptera, Oligochaeta and Plecoptera was higher across the EHBF. The HSPF were diverse in terms of Coleoptera, Trichoptera, and EPT, whereas the EHBF was diverse in terms of Diptera, Ephemeroptera and Oligochaeta (Figure 11, Table 12).

Detailed statistical analysis on dominance, abundance and taxa richness is given in section 4.2.6 and 4.2.8.

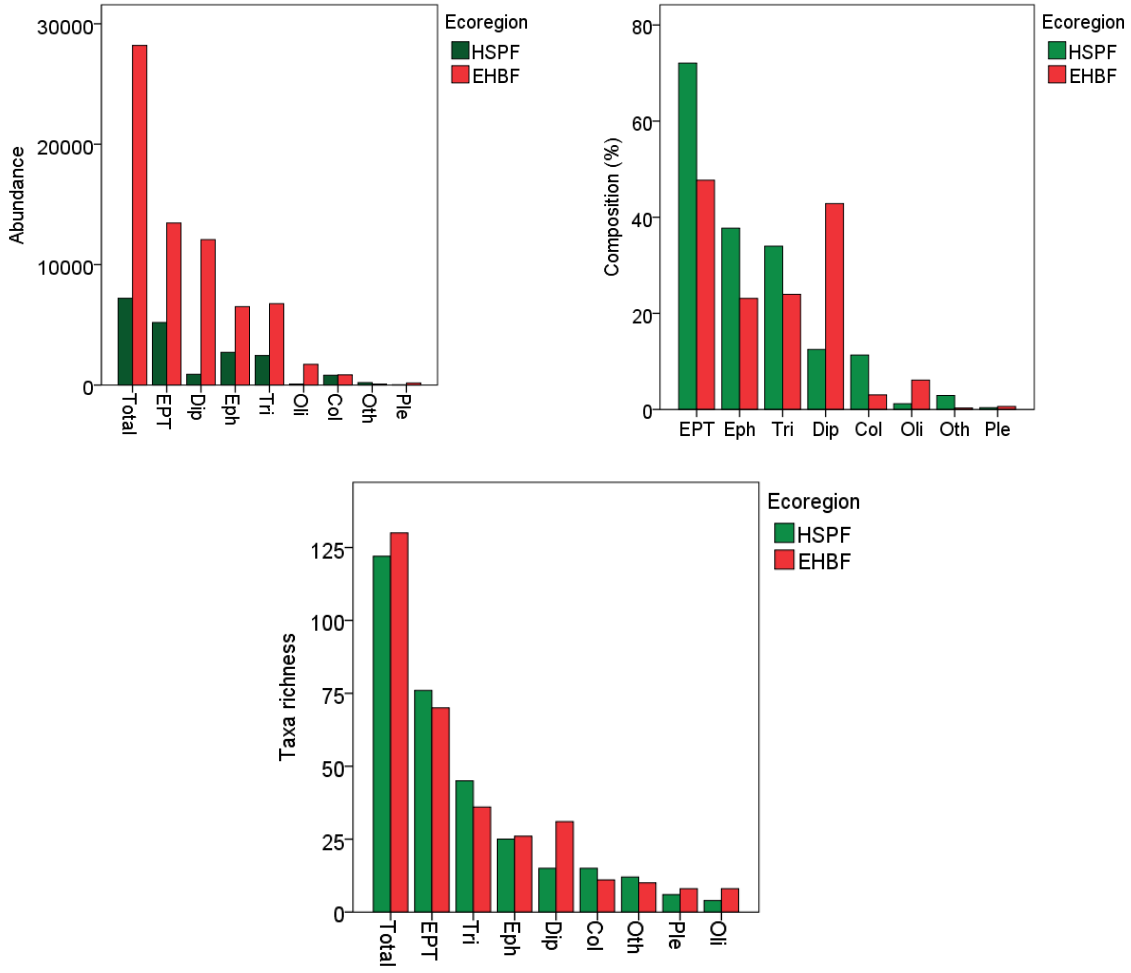


Figure 11. Ecoregion-specific overview of abundance, composition and taxa richness. EPT = Ephemeroptera, Plecoptera and Trichoptera, Eph = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

Table 12. Ecoregion specific overview of abundance, composition and taxa richness.

(a) Abundance

Ecoregion	Coleoptera	Diptera	EPT	Ephemeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
HSPF	817	900	5198	2720	87	27	2451	209	7211
EHBF	854	12084	13456	6517	1722	180	6759	89	28205

(b) Composition (%)

Ecoregion	Coleoptera	Diptera	EPT	Ephemeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
HSPF	11.33	12.48	72.08	37.72	1.21	0.37	33.99	2.90	100
EHBF	3.03	42.84	47.71	23.11	6.11	0.64	23.96	0.32	100

(c) Taxa richness

Ecoregion	Coleoptera	Diptera	EPT	Ephemeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
HSPF	15	15	76	25	4	6	45	12	122
EHBF	11	31	70	26	8	8	36	10	130

4.2.3. Ecoregion-specific comparison of 10 dominant taxa

The ten most dominant taxa enumerated from the HSPF (mean relative abundance per 1.25 m^2 i.e., dominance) were representatives of Trichoptera (28.64 %), Ephemeroptera (18.39 %), Coleoptera (7.41 %) and Diptera (4.76 %). The ten most dominant taxa were *Hydropsyche* sp., *Baeti*s sp., Chironomidae Gen. sp., *Ecdyonurus* sp., *Grouvellinus* sp., *Chimarra* sp., *Lepidostoma* sp., Psephenoidinae Gen. sp., *Cheumatopsyche* sp. and *Brachycentrus* sp. These taxa represented 59.21 % of dominance from the HSPF (Figure 12a). These dominant taxa were common across the ecoregions. Among these, *Hydropsyche* sp. was more frequently occurring taxa with presence across all sites whereas *Brachycentrus* sp. was least common (Figure 12a).

The ten most dominant taxa from the EHBF were represented by Diptera (27.50 %), followed by Ephemeroptera (26.68 %), Trichoptera (8.43 %), and Coleoptera (2.66 %). The ten most dominant taxa were Chironomidae Gen. sp., *Baetis* sp., Simuliidae Gen. sp., *Brachycentrus* sp., *Baetiella* sp., *Cincticostella* sp., *Acentrella* sp., Scirtidae Gen. sp., *Micrasema* sp. and *Ecdyonurus* sp. The ten dominant taxa represented 65.27 % of dominance from the EHBF (Figure 12b). All were common among two ecoregions, except for Scirtidae Gen. sp. and *Micrasema* sp. which are exclusively restricted to the EHBF. Among the ten dominant taxa from the EHBF, *Baetis* sp. and *Baetiella* sp. were the most frequently occurring whereas *Micrasema* sp. had least frequent occurrences (Figure 12b).

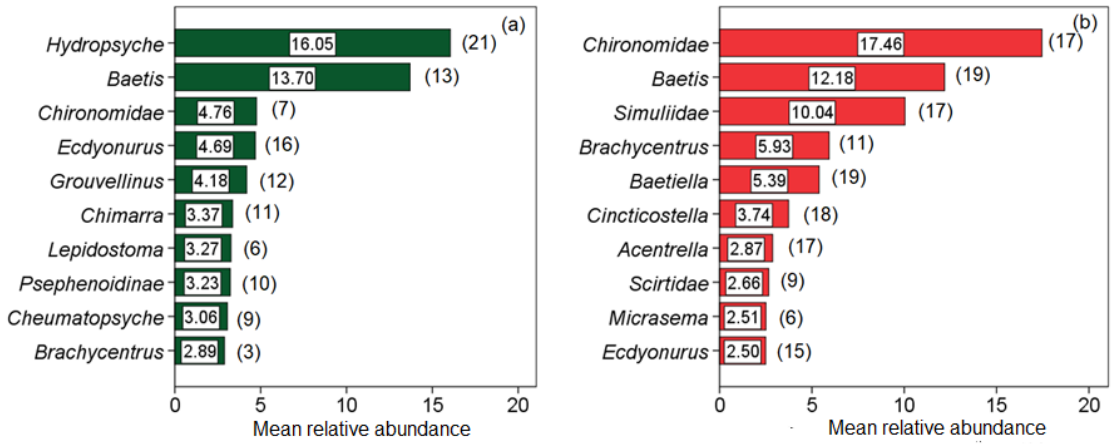


Figure 12. Ten most dominant taxa and their contribution to macroinvertebrate composition from (a) the Himalayan Subtropical Pine Forests (total mean dominance = 59.21 % per 1.25 m^2) and (b) the Eastern Himalayan Broadleaf Forests (total mean dominance = 65.27 % per 1.25 m^2). Ecoregion-specific occurrences given in parenthesis (sites from HSPT: n = 21, sites from the EHBF: n = 25).

4.2.4. Ecoregion-specific comparison of frequently occurring taxa

Ten taxa were recorded from a minimum of 10 sites (*n* = 21) across the HSPF (Figure 13a). *Hydropsyche* sp. were the most frequently occurring taxon and were recorded from all sites. Amongst most common taxa, six taxa, namely *Hydropsyche* sp., *Ecdyonurus* sp., *Baetis* sp., *Grouvellinus* sp., *Chimarra* sp. and Psephenoidinae Gen. sp. were also among the ten most dominant taxa.

With regard to the EHBF, ten taxa were known to occur at least across 15 sites (*n* = 25, Figure 13b). The Baetidae, particularly, the *Baetis* sp. and *Baetiella* sp. were most commonly occurring taxa across the EHBF with occurrences recorded from 19 sites. Among the most frequently occurring taxa from the EHBF, seven taxa, namely Chironomidae Gen. sp., Simuliidae Gen. sp. *Baetis* sp. *Baetiella* sp., *Cincticostella* sp., *Acentrella* sp. and *Ecdyonurus* sp. were also among the ten most dominant taxa.

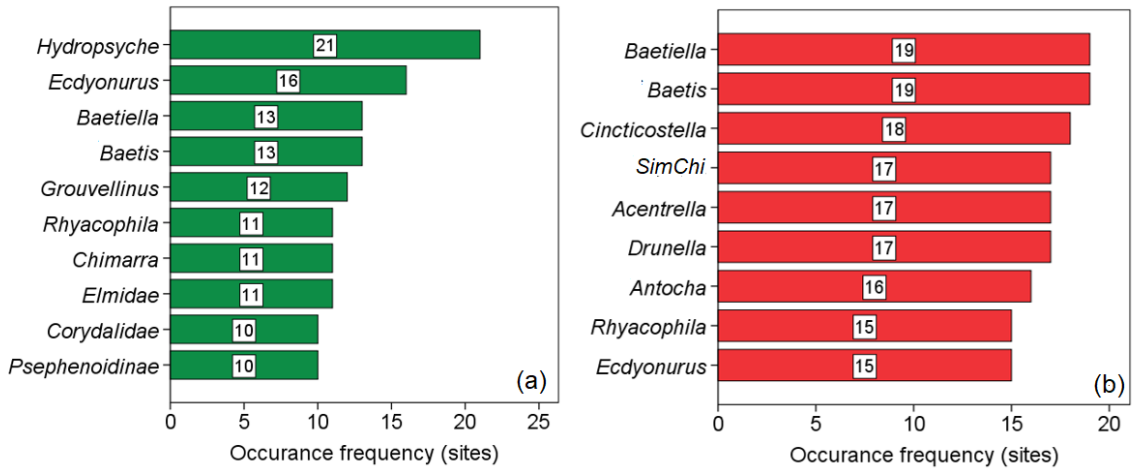


Figure 13. Most frequently occurring taxa from (a) the Himalayan Subtropical Pine Forests (*n* = 21) and (b) the Eastern Himalayan Broadleaf Forests (*n* = 25). *SimChi* = Simuliidae Gen. sp. and Chironomidae Gen. sp. (17 occurrences each).

4.2.5. Ecoregion-specific comparison of exclusive taxa

The total number of exclusive taxa with occurrences within a particular ecoregion was 120 taxa. There were 56 taxa exclusive to the HSPF (Table 13) and contributed to 9.96 % ecoregion-specific dominance (Figure 14) and were dominated by *Crinitella* sp. (1.14 %), *Notacanthurus* sp. (0.87 %) and *Aphelocheirus* sp. (0.70 %). Most of the exclusive taxa were restricted to less than four sites with exception of *Crinitella* sp. (8 sites), Euphaeidae Gen. sp. (7 sites), Pyralidae Gen. sp. (6 sites), *Diplectrona* sp. (5 sites), and *Aphelocheirus* sp., *Oecetis* sp. and *Torleya* sp. (4 sites each).

The 64 exclusive taxa from the EHBF (Table 14) accounted for 16.28 % of ecoregion-specific dominance (Figure 14) and were dominated by Scirtidae Gen. sp. (2.66 %), *Micrasema* sp. (2.50 %), Tubificidae Gen. sp. (2.31 %) and *Apatania* sp. (1.02 %). The most frequently occurring among exclusive taxa were Scirtidae Gen. sp. (9 sites), Limnephilidae Gen. sp. (8 sites), Deuterophlebiidae Gen. sp. and Leptophlebiidae Gen. sp. (7 sites each), and *Micrasema* sp. and *Parapsyche* sp. (6 sites each).

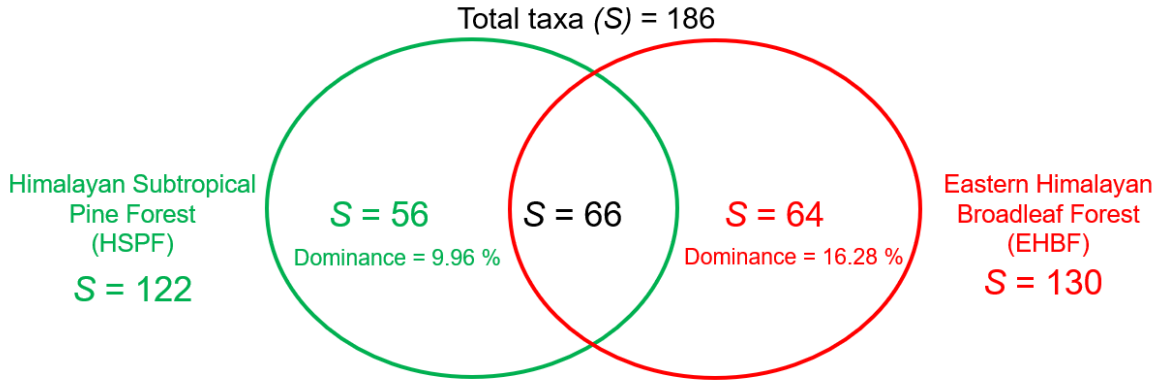


Figure 14. Ecoregion-specific comparison of total taxa, exclusive taxa and their dominance.

Table 13. Taxa with exclusive occurrence across the Himalayan Subtropical Pine Forests (*S* = 56). In order of mean dominance from highest to lowest, column wise top to down from left.

Crinitella sp.	*Oecetis* sp.	*Amynthas corticis*
Notacanthurus sp.	*Horaia* sp.	Cordulegasteridae Gen. sp.
Aphelocheirus sp.	*Torleya* sp.	Goeridae Gen. sp.
Diplectrona sp.	*Limnocentropus* sp.	*Stactobia* sp.
Helicopsyche sp.	*Stenelmis* sp.	*Prosopistoma* sp.
Indosolus sp.	*Zygoptera* Gen. sp.	Peltoperlidae Gen. sp.
Pyralidae Gen. sp.	*Plectrocnemia* sp.	Brachycentridae Gen. sp.
Marilia sp.	*Ecnomus* sp.	Perlidae Gen. sp.
Eulichadidae Gen. sp.	*Limnodrilus* sp.	*Hydroptila* sp.
Limnocentropodidae Gen. sp.	Gyrinidae Gen. sp.	*Psilotreta* sp.
Choroterpides sp.	Hydrachnidia Gen. sp.	*Anisocentropus* sp.
Euphaeidae Gen. sp.	*Choroterpes* sp.	*Apsilochorema* sp.
Wormaldia sp.	*Graphelmis* sp.	*Ugandatrichia* sp.
Euthraulus sp.	*Uenoa* sp.	*Pseudoneureclipsis* sp.
Diplectrona salai	*Neoperla* sp.	Mermithidae Gen. sp.
Abacaria sp.	Trichoptera Gen. sp.	*Pericomini* Gen. sp.
Helodidae Gen. sp.	*Ceratopogonidae* Gen. sp.	*Pisidium* sp.
Perlinae Gen. sp.	*Sericostomatidae* Gen. sp.	*Sphaerius* sp.
Lepidostomatidae Gen. sp.	*Elmomorphus* sp.	

Table 14. Taxa with exclusive occurrence across the Eastern Himalayan Broadleaf Forests (*S* = 64). In order of mean dominance from highest to lowest, column wise top to down from left.

Scirtidae Gen. sp.	Blephariceridae Gen. sp.	Ephydridae Gen. sp.
Micrasema sp.	*Kisaura* sp.	Psychodidae Gen. sp.
Tubificidae Gen. sp.	Diamesini Gen. sp.	*Polycelis* sp.
Apatania sp.	*Arctopsyche* sp.	*Haploperla* sp.
Orthocladiinae Gen. sp.	Heptageniidae Gen. sp.	*Eloeophila* sp.
Leptophlebiidae Gen. sp.	*Potamanthellus* sp.	Polycentropodidae Gen. sp.
Eiseniella sp.	Pediciinae Gen. sp.	Psychomyiidae Gen. sp.
Deuterophlebiidae Gen. sp.	Empididae Gen. sp.	*Bazarella* sp.
Chironomini Gen. sp.	Stactobiini Gen. sp.	*Glossosoma* sp.
Paraleuctra sp.	*Indosorius* sp.	Hydraenidae Gen. sp.
Epeorus unispinosus	*Epiophlebia* sp.	Turbellaria Gen. sp.
Oligochaeta Gen. sp.	*Pseudostenophylax* sp.	*Bidessini* Gen. sp.
Tanypodinae Gen. sp.	Pediciidae Gen. sp.	*Blepharicera* sp.
Parapsyche sp.	Potamanthidae Gen. sp.	*Neophylax* sp.
Indonemoura sp.	Baetidae Gen. sp.	*Corixidae* Gen. sp.
Atherix sp.	Nemouridae Gen. sp.	Rhyacophilidae Gen. sp.
Limnephilidae Gen. sp.	*Limnodrilus hoffmeisteri*	*Ranatra* sp.
Nais variabilis	Clinocerinae Gen. sp.	*Potamia* sp.
Leptocerinae Gen. sp.	Ameletidae Gen. sp.	*Enchytraeus indicus*
Tanytarsini Gen. sp.	*Isonychia* sp.	Heteroptera Gen. sp.
Diamesa sp.	*Agapetus* sp.	
Mesonemoura sp.	*Nemoura* sp.	

4.2.6. Ecoregion-specific comparison of overall taxa diversity, abundance and diversity indices

The diversity and abundance of macroinvertebrates were higher across the EHBF (Figure 15a, 15b, Table 15). However, Shannon's Diversity Index, Simpson's Diversity Index and evenness were higher across the HSPF (Figure 16, Table 15). Statistically, evenness was significantly higher across the HSPF (U = 170.50, p = 0.042), whereas significantly higher abundance was observed across the EHBF (U = 108.00, p = 0.001).

Table 15. Ecoregion-specific mean and standard deviation of diversity and abundance metrics. Significantly high values in bold ($p < 0.05$).

Biological variables	HSPF	EHBF
Taxa richness (*S*)	20.65 ± 9.23	25.56 ± 8.39
Total abundance (individuals/1.25 m^2)	343.38 ± 305.645	**1128.20 ± 1161.54**
Evenness (*J*)	**0.67 ± 0.14**	0.60 ± 0.17
Shannon's Diversity Index (*H*)	1.95 ± 0.67	1.89 ± 0.62
Simpson's Diversity Index (*D*)	0.74 ± 0.20	0.71 ± 0.20

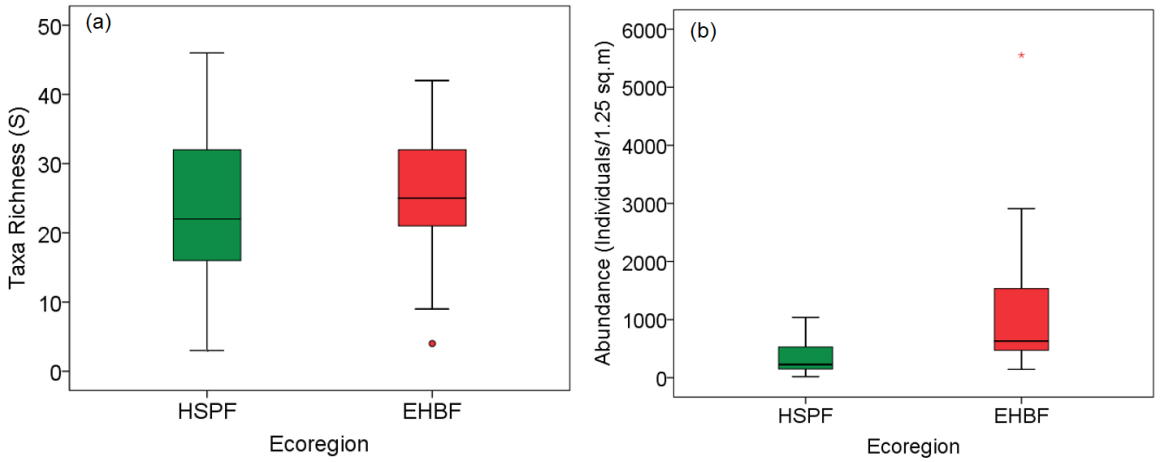


Figure 15. Ecoregion-specific distribution of (a) taxa diversity and (b) abundance (Sampling area:1.25 m^2).

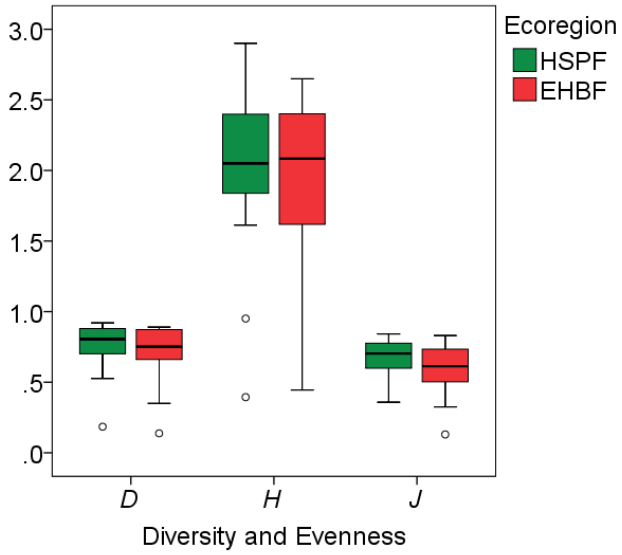


Figure 16. Ecoregion-specific distribution of Shannon's Diversity Index (*H*), Simpson's Diversity Index (*D*) and evenness (*J*) (Sampling area:1.25 m^2).

4.2.7. Ecoregion-specific comparison of dominance and taxa richness by sensitivity class

Within respective ecoregion, the dominance and richness in terms of sensitivity class were dominated by sensitive taxa (Figure 17, Table 16, Table 17). Across ecoregion, the dominance of sensitive taxa was higher across the HSPF whereas dominance of others was higher across the EHBF. Across both ecoregions, combined dominance by very sensitive and sensitive taxa was > 57 %. The diversity of sensitive and medium tolerant taxa was higher across the HSPF whereas diversity of very sensitive, tolerant, extremely tolerant and unscored taxa was higher across the EHBF.

However, dominance of sensitive taxa was significantly higher across the HSPF (U = 159.00, p = 0.022). With regard to extremely tolerant taxa, the EHBF had significantly higher dominance (U = 192.00, p = 0.025) and diversity (U = 189.50, p = 0.020). However, overall diversity of very sensitive taxa was significantly higher across the EHBF (U = 139.50, p = 0.006).

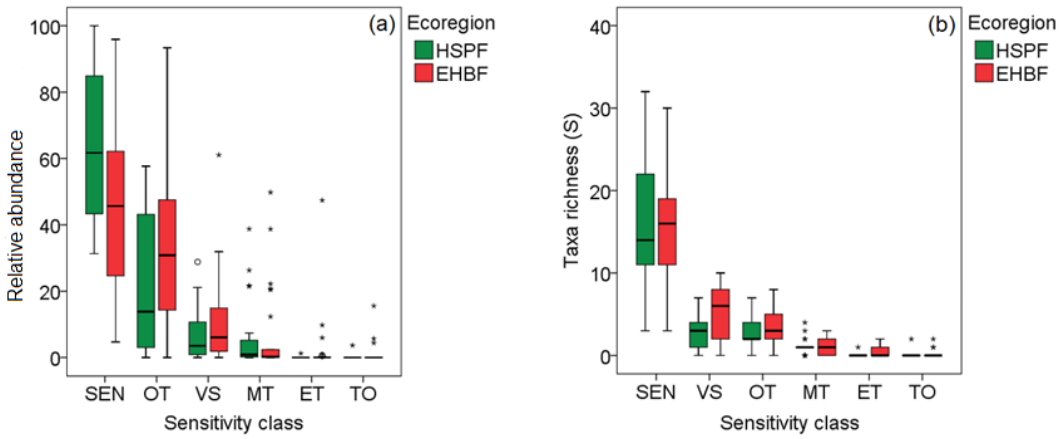


Figure 17. Ecoregion-specific distribution of (a) macroinvertebrates composition and (b) taxa richness in accordance with sensitivity class. SEN = sensitive, OT = Others, MT = medium tolerant, VS = very sensitive, TO = Tolerant and ET = extremely tolerant. Others represents unscored taxa without clear response to organic pollution.

Table 16. Ecoregion-specific dominance and diversity of macroinvertebrates (mean ± SD) in accordance with sensitivity class. Significantly high values in bold (p < 0.05).

Sensitivity class	Mean relative abundance		Mean taxa diversity (S)	
	HSPF	EHBF	HSPF	EHBF
Very sensitive	6.37 ± 7.62	11.18 ± 13.90	2.67 ± 2.058	**5.28 ± 3.26**
Sensitive	**65.26 ± 22.96**	45.83 ± 25.27	15.81 ± 7.88	15.72 ± 6.39
Medium tolerant	6.36 ± 10.92	6.84 ± 13.40	1.14 ± 0.94	1.04 ± 0.98
Tolerant	0.17 ± 0.80	1.02 ± 3.34	0.10 ± 0.44	0.16 ±0.47
Extremely tolerant	0.06 ± 0.27	**2.61 ± 9.59**	0.05 ± 0.218	**0.44 ± 0.77**
Others	21.77 ± 21.91	32.50 ± 24.42	2.71 ± 2.14	3.56 ± 2.00

Table 17. Ecoregion-specific dominance of taxa in accordance with sensitivity class.

Sensitivity class	EHBF	EHSF
Very sensitive	*Rhithrogena* sp. (2.44 %), Agapetinae Gen. sp. (0.78 %), *Drunella* sp. (0.76 %), *Cinygmula* sp. (0.58 %), *Helicopsyche* sp. (0.57 %)	*Micrasema* sp. (2.51 %) *Drunella* sp. (2.39 %), Athericidae Gen. sp. (1.05 %), *Apatania* sp. (1.01 %), *Iron* sp. (1.01 %)
Sensitive	*Hydropsyche* sp. (16.05), *Ecdyonurus* sp. (4.68 %), *Grouvellinus* sp. (4.17 %), *Chimarra* sp. (3.36 %), *Lepidostoma* sp. (3.27 %)	Simuliidae Gen. sp. (10.04), *Baetiella* sp. (5.39 %), *Cincticostella* sp. (3.74 %), *Acentrella* sp. (2.86 %), Scirtidae Gen. sp. (2.66 %)

Medium tolerant	*Brachycentrus* sp. (2.89 %), *Eiseniella tetraedra* (2.74 %), Tabanidae Gen. sp. (0.51 %)	*Brachycentrus* sp. (0.93 %), *Eiseniella* sp. (0.87 %),
Tolerant	*Nais elinguis* (0.16 %)	*Nais elinguis* (0.62 %)
Extremely tolerant	*Limnodrilus* sp. (0.06 %)	Tubificidae Gen. sp. (2.61 %), Oligochaeta Gen. sp. (0.28 %)
Others	*Baetis* sp. (13.70 %), Chironomidae Gen. sp. (4.76 %), Leptoceridae Gen. sp. (1.68 %), Gomphidae Gen. sp. (0.54 %)	Chironomidae Gen. sp. (17.56 %), *Baetis* sp. (12.18 %), Orthocladiinae Gen. sp. (0.92 %)

4.2.8. Ecoregion-specific comparison of dominance, taxa richness and abundance by taxonomic composition

In accordance with taxonomic composition, Ephemeroptera, Plecoptera and Trichoptera (EPT) had highest dominance and diversity within respective ecoregion (Figure 18, Table 18, Table 19). Their combined dominance was > 55 % across both ecoregions. Among ecoregions, the HSPT were more dominant in terms of Coleoptera, EPT and Trichoptera whereas the EHBF was dominant in terms of Diptera, Ephemeroptera, Oligochaeta and Plecoptera. With regards to taxa diversity, the HSPF was diverse in terms of Coleoptera and Trichoptera whereas the EHBF was diverse in terms of Diptera, EPT, Ephemeroptera, Oligochaeta and Plecoptera.

Statistically, dominance of Coleoptera, (U = 188, p = 0.099), EPT (U = 152.00, p = 0.015) and Trichoptera (U = 115.00, p = 0.001) was significantly higher across the HSPF. The EHBF had significantly higher dominance (U = 181.50, p = 0.048) and richness (U = 179, p = 0.041) of Plecoptera and dominance (U = 74, p = 0.0000) and richness (U = 84.50, p = 0.010) of Diptera.

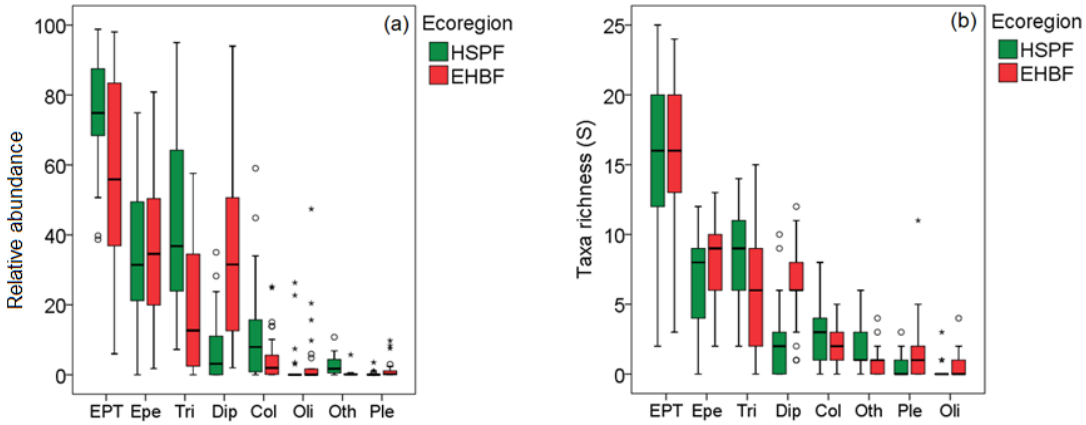


Figure 18. Ecoregion-specific distribution of (a) macroinvertebrates composition and (b) taxa richness in accordance with taxonomic composition. EPT = Ephemeroptera, Plecoptera and Trichoptera, Epe = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

Abundance of Coleoptera were higher across the HSPF whereas abundance of remaining taxonomic groups was higher across the EHBF. Furthermore, abundance of Diptera, EPT, Ephemeroptera, and Plecoptera was significantly higher across the EHBF (Table 20).

Table 18. Ecoregion-specific dominance and diversity of macroinvertebrates (mean ± SD) in accordance with taxonomic composition. Significantly high values in bold ($p < 0.05$).

Taxonomic groups	Mean relative abundance		Mean taxa diversity	
	HSPF	EHBF	HSPF	EHBF
Coleoptera	**12.44 ± 15.89**	5.32 ± 7.55	3.00 ± 2.38	2.00 ± 1.56
Diptera	7.63 ± 10.34	**34.57 ± 26.84**	2.52 ± 2.87	**6.44 ± 2.88**
EPT	**74.17 ± 17.14**	55.67 ± 26.74	14.95 ± 7.15	15.52 ± 5.21
Ephemeroptera	33.39 ± 21.27	36.31 ± 24.45	6.57 ± 4.03	7.92 ± 3.05
Oligochaeta	3.00 ± 7.40	4.27 ± 10.43	0.33 ± 0.73	0.64 ± 0.99
Others	**2.78 ± 2.93**	0.39 ± 1.12	**2.10 ± 1.73**	0.96 ± 1.020
Plecoptera	0.35 ± 0.81	**1.47 ± 2.80**	0.43 ± 0.81	**1.48 ± 2.40**
Trichoptera	**40.44 ± 24.71**	17.66 ± 18.50	7.90 ± 3.72	6.36 ± 4.34

Table 19. Ecoregion-specific dominance of taxa in accordance with taxonomic composition. Highlighted in bold are 10 dominant taxa.

Major Groups	HSPF	EHBF
Coleoptera	***Grouvellinus* sp. (4.20 %), Psephenoidinae Gen. sp. (3.23 %)**, *Elmidae* Gen. sp. (2.04 %), *Eubriinae* Gen. sp. (1.10 %), *Indosolus* sp. (0.51 %)	**Scirtidae Gen. sp. (2.66 %),** Elmidae Gen. sp. (1.85 %), *Grouvellinus* sp. (0.30 %), Psephenoidinae Gen. sp. (0.20 %), *Hydrocyphon* sp. (0.18 %)
Diptera	**Chironomidae Gen. sp. (4.76 %),** *Hexatoma* sp. (0.88 %), *Antocha* sp. (0.53 %), Tabanidae Gen. sp. (0.54 %), *Limoniidae* Gen. sp. (0.27 %)	**Chironomidae Gen. sp. (17.47 %), *Simuliidae* Gen. sp. (10.04 %),** Antocha sp. (1.64 %), Athericidae Gen. sp. (1.06 %), Orthocladiinae Gen. sp. (0.92 %)
Ephemeroptera	***Baetis* sp. (13.70** %), ***Ecdyonurus* sp. (4.68 %),** *Cincticostella* sp. (2.88 %), *Rhithrogena* sp. (2.45 %), *Epeorus* sp. (1.79 %), *Acentrella* sp. (1.14 %), *Crinitella* sp. (1.14 %)	***Baetis* sp. (12.18 %), *Baetiella* sp. (5.39 %), *Cincticostella* sp. (3.74 %), *Acentrella* sp. (2.86 %), *Ecdyonurus* sp. (2.50 %),** *Drunella* sp. (2.39 %), *Epeorus* sp. (1.34 %), *Iron* sp. (1.01 %)
Heteroptera	*Aphelocheirus* sp. (0.69 %)	Corixidae Gen. sp. (0.004 %)
Lepidoptera	Pyralidae Gen. sp. (0.50 %)	-
Megaloptera	Corydalidae Gen. sp. (0.51 %)	Corydalidae Gen. sp. (0.0007 %)
Odonata	Gomphidae Gen. sp. (0.54 %), Euphaeidae Gen. sp. (0.32 %)	Gomphidae Gen. sp. (0.08 %), *Epiophlebia* sp. (0.04 %)
Oligochaeta	*Eiseniella tetraedra* (2.74 %), *Nais elinguis* (0.17 %)	Tubificidae Gen. sp. (2.30 %), *Eiseniella* sp. (0.87 %), *Nais elinguis* (0.62 %), *Oligochaeta* Gen. sp. (0.28 %), *Nais variabilis* (0.17 %)
Plecoptera	Perlinae Gen. sp. (0.18 %)	*Paraleuctra* sp. (0.47 %), *Amphinemura* sp. (0.47 %)
Trichoptera	***Hydropsyche* sp. (16.05 %), *Chimarra* sp. (3.37 %), Lepidostoma sp. (3.27 %), *Cheumatopsyche* sp. (3.06 %), *Brachycentrus* sp. (2.89 %),** *Stenopsyche* sp. (1.96 %), Leptoceridae Gen. sp. (1.67 %)	***Brachycentrus* sp. (5.92 %), *Micrasema* sp. (2.50 %),** *Psychomyia* sp. (1.86 %), Lepidostoma sp. (1.42 %), *Apatania* sp. (1.01 %)

Table 20. Ecoregion-specific comparison of abundance (mean ± SD) in accordance with taxonomic composition ($p < 0.05$).

Taxonomic groups	Abundance (#/1.25 m^2)		Test statistics	
	HSPF	EHBF	*U*	*p*
Coleoptera	38.90 ± 63.93	34.16 ± 44.50	257.50	0.912
Diptera	42.86 ± 87.08	483.36 ± 626.09	62.00	**0.000**
EPT	247.52 ± 227.58	538.24 ± 612.398	153.50	**0.016**
Ephemeroptera	129.52 ± 127.52	260.68 ± 194.93	144.50	**0.009**
Oligochaeta	4.14 ± 10.88	68.88 ± 192.89	207.00	0.142
Others	9.95 ± 16.23	3.56 ± 11.29	151.50	**0.013**
Plecoptera	1.29 ± 3.33	7.20 ± 14.49	174.00	**0.031**
Trichoptera	116.71 ± 135.31	270.36 ± 503.092	245.50	0.708

4.2.9. Ecoregion-specific comparison of dominance and abundance by functional feeding groups

In accordance with functional feeding groups (FFGs), within respective ecoregions, gathering collectors were most dominant (Figure 19). However, within the HSPF, dominance of gathering collectors, scrappers and filtering collectors were almost comparable. Across ecoregions, the dominance of shredders, filtering collectors and scrapers was higher in the HSPF whereas dominance of gathering collectors and predators was high across the EHBF. Shredders were least dominant groups across both ecoregions. The functional analysis of stream macroinvertebrates indicated abundance of suspended FPOM across the HSPF and higher storage FPOM in bed sediments across the EHBF (Table 21). Higher autotropic production was associated with the HSPF.

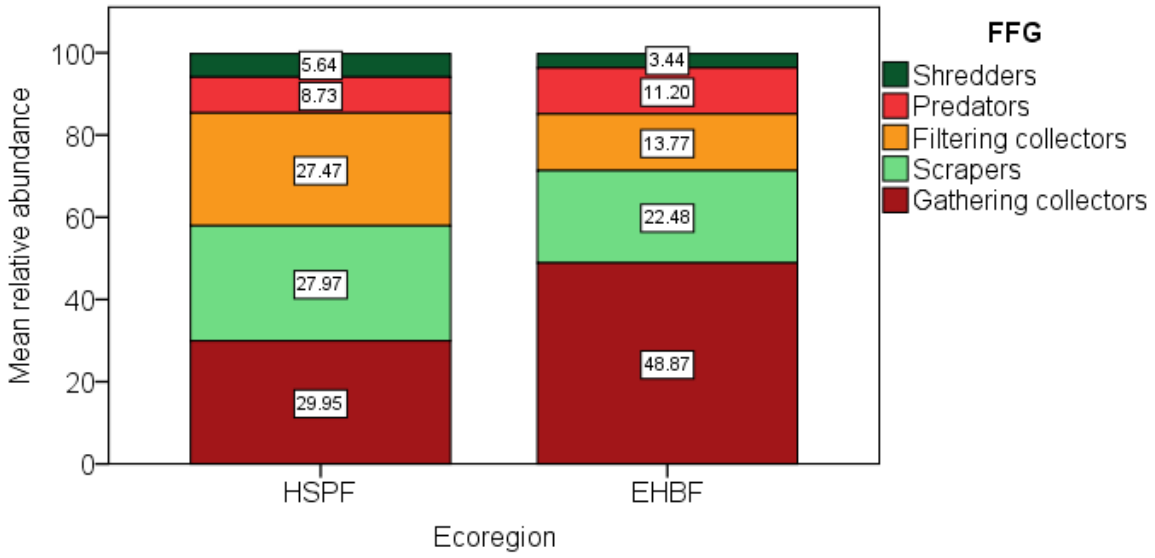


Figure 19. Ecoregion-specific dominance of functional feeding groups.

Table 21. Ecoregion-specific functional analysis of stream macroinvertebrates.

Ecosystem attributes	HSPF	EHBF
Autotrophy heterotopy	0.44	0.34
Filtering collector index	0.92	0.28

The abundance of all functional feeding groups was higher across the EHBF. Statistically, abundance of gathering collectors and predators were significantly higher across the EHBF (Table 22).

Table 22. Ecoregion-specific comparison of abundance (mean ± SD) in accordance with functional feeding groups ($p < 0.05$).

Functional feeding groups	Abundance (#/1.25 m^2)		Test statistics	
	HSPF	EHBF	*U*	*p*
Filtering collectors	58.48 ± 67.69	126.76 ± 243.45	218.50	0.332
Gathering collectors	126.48 ± 161.68	581.12 ± 682.47	80.00	**0.000**
Predators	42.67 ± 76.49	182.60 ± 500.72	149.00	**0.012**
Scrapers	93.67 ± 92.14	199.04 ± 217.92	178.00	0.062
Shredders	20.24 ± 63.68	35.20 ± 96.28	201.5	0.176

4.2.10. Ecoregion-specific indicator taxa

The cluster analysis of macroinvertebrate taxa across all sites from two ecoregions and seasons indicated two major clusters (0 % similarity), with first major clusters giving rise to two subclusters (12.5 % similarity, Figure 20). The first subcluster comprised of majority of pre-monsoon sites from the HSPF (≈ 18 % similarity). The second subcluster comprised of all post-monsoon sites and were further divided into two smaller clusters, first mostly reflecting the post-monsoon communities from the HSPT (≈ 39 % similarity) and second mainly reflecting post-monsoon assemblages from the EHBF (≈ 43 % similarity). The second major cluster comprised of all pre-monsoon sites from the EHBF (≈ 23 % similarity).

The Indicator Species Analysis (ISA) identified 31 significant indicators ($p < 0.05$) across two ecoregions with indicator value (IV) ranging from 19.00 – 69.40, among which 9 taxa were considered as excellent or good indicators (Table 23). Among 15 significant indicators from the HSPF, *Hydropsyche* (IV = 69.40, $p = 0.0002$) were considered excellent indicator, whereas *Chimarra* sp. (IV = 48.70, $p = 0.0002$) and Corydalidae Gen. sp. (IV = 43.90, $p = 0.0010$) were considered as good indicators.

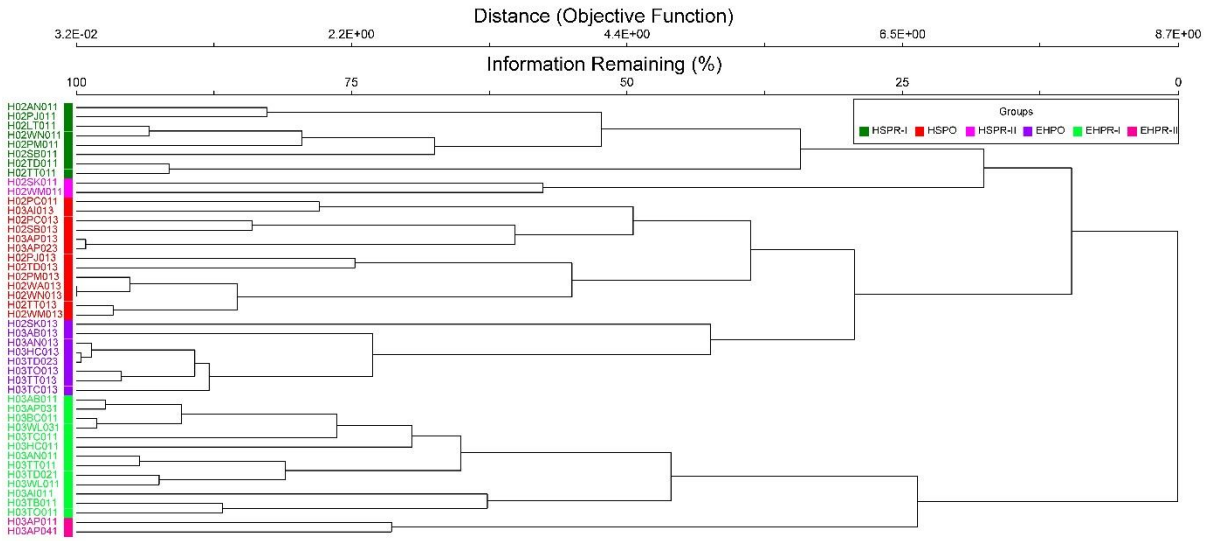


Figure 20. Hierarchical cluster analysis of macroinvertebrate communities across Bhutan (HSPR = Himalayan Subtropical Pine Forests, pre-monsoon sites; HSPO = Himalayan Subtropical Pine Forests, post-monsoon sites; EHPR = Eastern Himalayan Broadleaf Forests, pre-monsoon sites, EHPO = Eastern Himalayan Broadleaf Forests, post-monsoon sites; I and II indicates number of clusters).

There were 16 significant indicators from the EHBF, among which *Drunella* sp. (IV = 53.10, $p = 0.0022$), Simuliidae Gen. sp. (IV = 53.10, $p = 0.0032$), *Cincticostella* sp. (IV = 47.10, $p = 0.0314$), Chironomidae Gen. sp. (IV = 45.60, $p = 0.0412$), *Antocha* sp. (IV = 44.20, $p = 0.0372$) and Tipulidae Gen. sp. (IV = 44.00, $p = 0.0038$) were considered as good indicators. The significant indicator taxa exclusive to particular ecoregion (Table 23) were associated with lower indicator value (< 40).

Table 23. List of ecoregion-specific significant indicator taxa (excellent indicators = IV ≥ 60, good indicators = IV ≥ 40 – < 60, $p < 0.05$, * exclusive taxa to ecoregion, ** exclusive and among 10 dominant taxa for particular ecoregion). HSPF = Himalayan Subtropical Pine Forests, EHBF = Eastern Himalayan Broadleaf Forests.

Ecoregion	Taxa	Indicator value (IV)	Mean	SD	*p*
HSPF	*Hydropsyche* sp.	69.40	40.70	4.50	0.0002
HSPF	*Chimarra* sp.	48.70	19.20	4.83	0.0002
HSPF	Corydalidae Gen. sp.	43.90	17.80	5.08	0.0010
HSPF	*Cheumatopsyche* sp.	39.20	16.70	4.69	0.0030
HSPF	*Crinitella* sp. *	38.10	14.30	4.53	0.0010
HSPF	*Dolophilodes* sp.	34.50	15.30	4.79	0.0068
HSPF	Euphaeidae Gen. sp. *	33.30	12.70	4.36	0.0012
HSPF	*Caenis* sp.	29.00	17.70	5.19	0.0432
HSPF	Pyralidae Gen. sp. *	28.60	11.60	4.10	0.0048
HSPF	Tabanidae Gen. sp.	25.10	12.70	4.27	0.0304
HSPF	Eubriinae Gen. sp.	25.10	12.90	4.46	0.0368
HSPF	*Diplectrona* sp. *	23.80	10.20	3.85	0.0138
HSPF	*Aphelocheirus* sp. *	19.00	8.70	3.61	0.0298
HSPF	*Torleya* sp. *	19.00	8.80	3.71	0.0344
HSPF	*Oecetis* sp. *	19.00	8.80	3.84	0.0424
EHBF	*Drunella* sp.	53.10	29.40	5.05	0.0022
EHBF	Simuliidae Gen. sp.	53.10	29.40	5.23	0.0032
EHBF	*Cincticostella* sp.	47.10	34.50	5.11	0.0314
EHBF	Chironomidae Gen. sp.	45.60	32.50	5.51	0.0412
EHBF	*Antocha* sp.	44.20	30.30	5.53	0.0372
EHBF	Tipulidae Gen. sp.	44.00	22.60	5.18	0.0038
EHBF	*Iron* sp.	38.10	24.90	5.12	0.0272
EHBF	Athericidae Gen. sp.	38.10	24.90	5.27	0.0318
EHBF	Scirtidae Gen. sp. **	36.00	15.20	4.74	0.0032
EHBF	Limnephilidae Gen. sp. *	32.00	14.20	4.35	0.0028
EHBF	Deuterophlebiidae Gen. sp. *	28.00	12.80	4.39	0.0112
EHBF	Leptophlebiidae Gen. sp. *	28.00	12.90	4.50	0.0138
EHBF	*Paraleptophlebia* sp.	27.90	15.40	4.86	0.0284
EHBF	*Micrasema* sp. **	24.00	11.50	4.05	0.0212
EHBF	*Parapsyche* sp. *	24.00	11.60	4.21	0.0284
EHBF	*Atherix* sp. *	20.00	10.20	3.82	0.0466

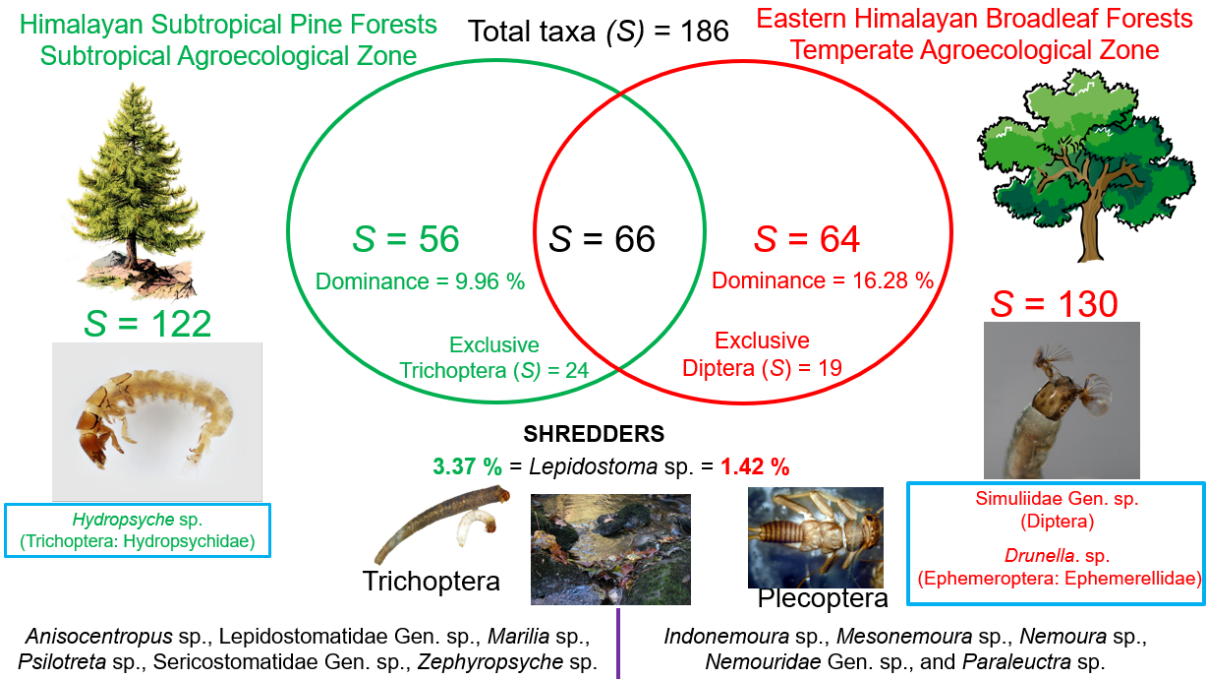


Figure 21. Summary of macroinvertebrate community composition and differences across the Himalayan Subtropical Pine Forests (HSPF, green font) and the Eastern Himalayan Broadleaf Forests (EHBF, red font). Indicator taxa are highlighted in blue rectangles.

4.3. Season-specific composition of macroinvertebrate communities within an ecoregion

The community composition of macroinvertebrate was different across seasons (Figure 22a), across seasons within an ecoregion (i.e., pre-monsoon vs post-monsoon season in particular ecoregion; Figure 22b) and within a particular season across ecoregions (i.e., pre-monsoon season of the HSPF vs pre-monsoon season of the EHBF, and post-monsoon season of the HSPF vs post-monsoon season of the EHBF; Figure 22b).

This section contains analysis of season-specific composition of macroinvertebrates assemblages in particular ecoregion (HSPF and EHBF). The comparison of macroinvertebrates across ecoregions within a particular season can be made through by comparing season-specific metrics from section 4.3.1 and 4.3.2.

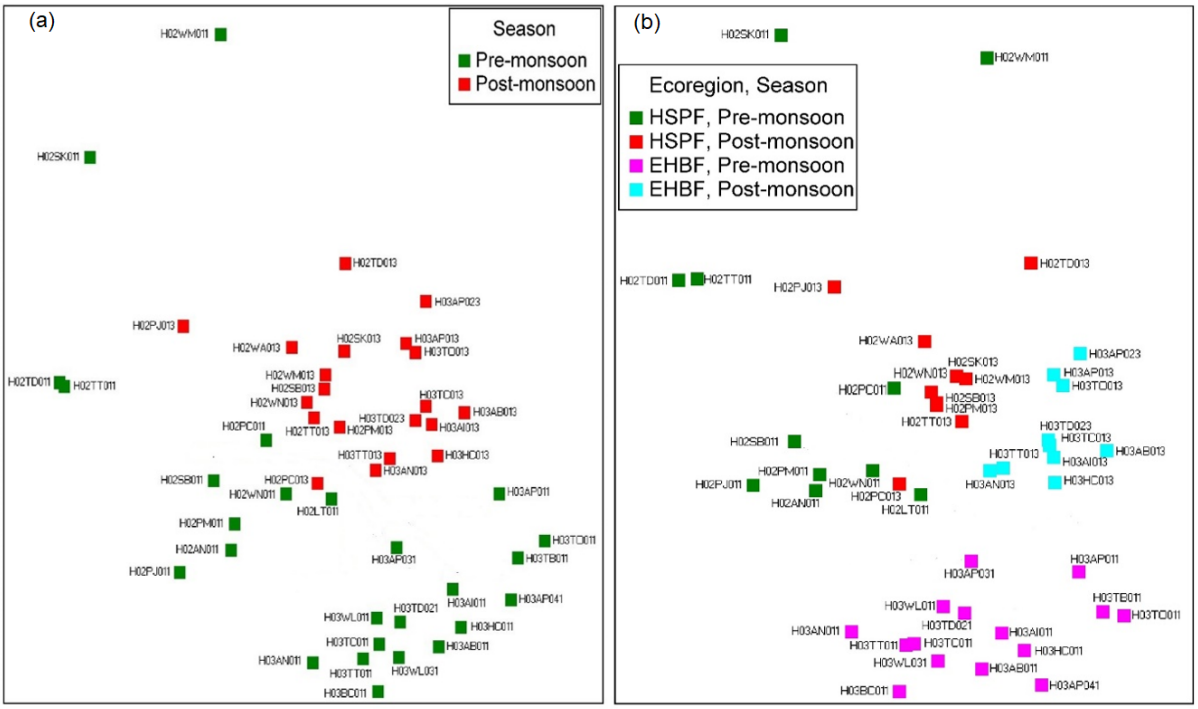


Figure 22. NMDS ordination of benthic macroinvertebrates communities collected from Bhutan (n = 46) as function of environmental variables with grouping based on (a) season and (b) ecoregion-specific season. HSPF = Himalayan Subtropical Pine Forests, EHBF = Eastern Himalayan Broadleaf Forests.

4.3.1. Season-specific comparison of macroinvertebrate communities across the Himalayan Subtropical Pine Forests (HSPF)

4.3.1.1. Season-specific organization of macroinvertebrate communities across the HSPF

The comparison of macroinvertebrate communities across the HSPF through multi-response permutation procedure (MRPP) indicated significant differences in assemblages between pre-monsoon and post-monsoon seasons (A = 0.1544, p = 0.0000).

Season-specific organization of macroinvertebrate communities across the HSPF as function of environmental parameters

The NMDS ordination provided optimal 3-dimensional solution (final stress = 16.64540, final instability = 0.00029) and indicated distinct macroinvertebrate communities across two seasons (Figure 23). The ordination explained 78.9 % of cumulative variance of which NMDS axis 1, axis 2 and axis 3 explained 14.5 %, 33.2 % and 31.2 % of total variations, respectively. Most of the variations were explained by NMDS axis 2 and axis 3 (64.4 %).

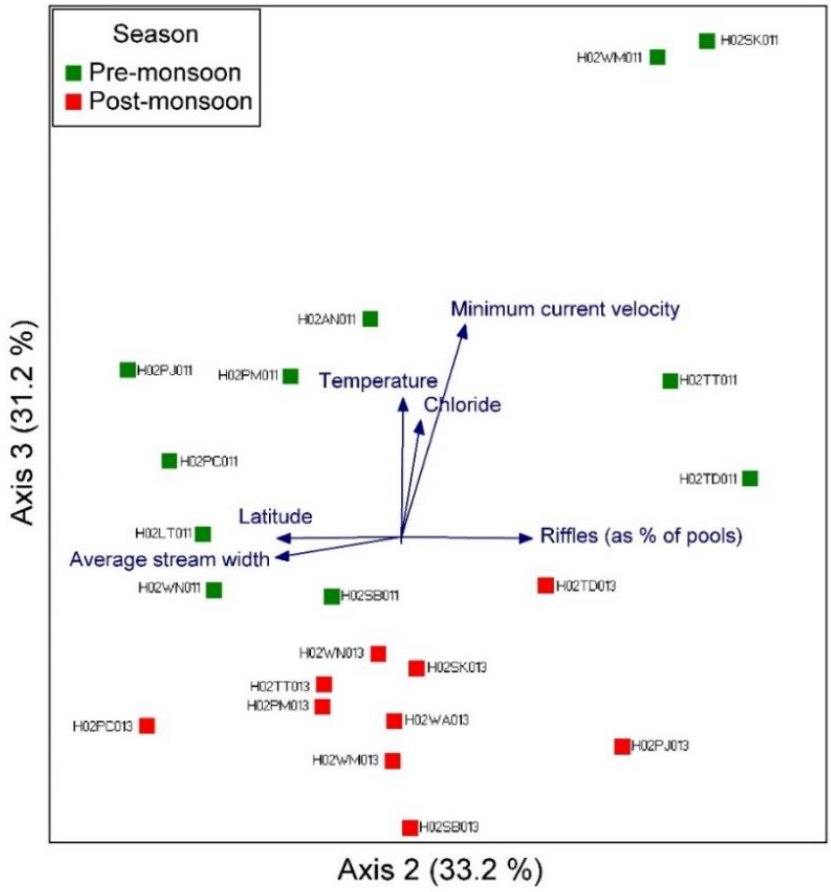


Figure 23. NMDS joint plot of benthic macroinvertebrates communities collected across the HSPF (n = 21) as function of environmental parameters with grouping based on season. Final stress for 3-dimensional solution = 16.64540, final instability = 0.00029, joint plot cut-off value: r^2 = 0.25.

Within ecoregion, the seasonal structure of macroinvertebrate communities across the HSPF was mostly determined by local-scale environmental factors. The strongly correlated environmental parameters with axis 2 were average stream width (r = – 0.565), latitude (r = – 0.560), riffle as proportion of pool (r = – 0.509) and minimum current velocity (r = 0.404). The environmental variables with strong positive correlation with axis 3 were minimum current velocity (r = 0.732), temperature (r = 0.593) and chloride (r = 0.545), whereas average stream width (r = – 0.232) and riffle as proportion of pool (r = – 0.205) were negative correlated.

Season-specific organization of macroinvertebrate communities across the HSPF as function of composition of functional feeding groups

The seasonal difference in macroinvertebrate assemblages across the HSPF in accordance with FFGs visualized as NMDS ordination provided optimal 3-dimensional solution (final stress = 14.67742, final instability = 0.000028) and explained 78.9 % of variation in community composition (axis 1 = 14.0 %, axis 2 = 29.2, and axis 3 = 35.6). The NMDS axis 2 and axis 3 explained most of cumulative variance (64.8 %) and indicated existence of distinct communities in accordance with FFGs (Figure 24). The abundance of collecting gatherers and mean depth were the most important influencing factors. The gathering collectors correlated positively with axis 2 (r = 0.107) and negatively with axis 3 (r = − 0.554). The mean depth correlated weakly with axis 2 (r = 0.091) and strongly with axis 3 (r = − 0.419).

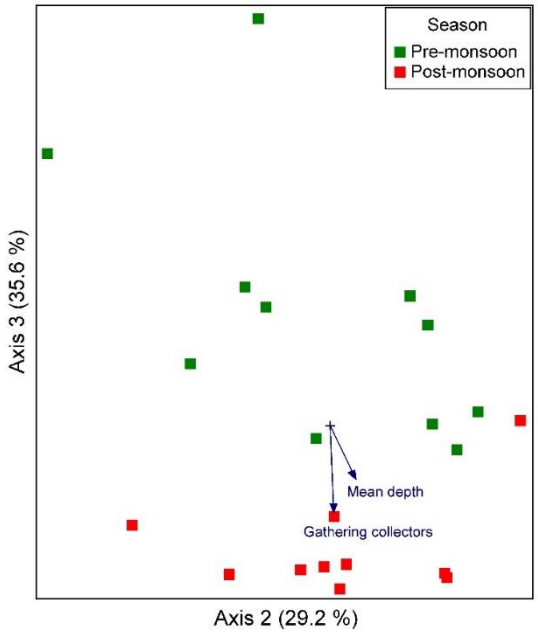


Figure 24. NMDS joint plot of macroinvertebrate communities collected from the HSPF (n = 21) as function of composition of functional feeding groups with grouping based on season. Final stress for 3-dimensional solution = 14.67742, final instability = 0.000028, joint plot cut-off value r^2 = 0.20.

4.3.1.2. Season-specific overview of abundance, composition and taxa richness across the HSPF

Of 122 taxa recorded from streams flowing through the Himalayan Subtropical Pine Forests (HSPF), 80 taxa were recorded during pre-monsoon season and 96 taxa were associated during post-monsoon season. In addition, 54 taxa were found to be common across two seasons with Jaccard's Similarity Index of 0.44 and Sørensen's Similarity Index of 0.61.

The general abundance of macroinvertebrate across the HSPF was higher during post-monsoon and was greater across all taxonomic groups with exception of Coleoptera, Oligochaeta and Plecoptera. In terms of composition, only Diptera, Ephemeroptera and others was dominant during post-monsoon season. Post-monsoon season was more diverse in terms of general diversity, and all taxonomic groups were diverse during post-monsoon with exception of Oligochaeta and Plecoptera (Figure 25, Table 24). Detailed analysis is on section 4.3.1.6 and 4.3.1.8.

Table 24. Season-specific overview of abundance, composition and taxa richness from the Himalayan Subtropical Pine Forests (HSPF).

(a) Abundance

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	448	23	2154	926	51	14	1214	54	2730
Post-monsoon	369	877	3044	1794	36	13	1237	155	4481

(b) Composition (%)

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	16.41	0.84	78.90	33.92	1.87	0.51	44.47	1.98	100.00
Post-monsoon	8.23	19.57	67.93	40.04	0.80	0.29	27.61	3.46	100.00

(c) Taxa richness

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	10	7	54	19	3	6	29	6	80
Post-monsoon	13	15	55	21	1	1	33	12	96

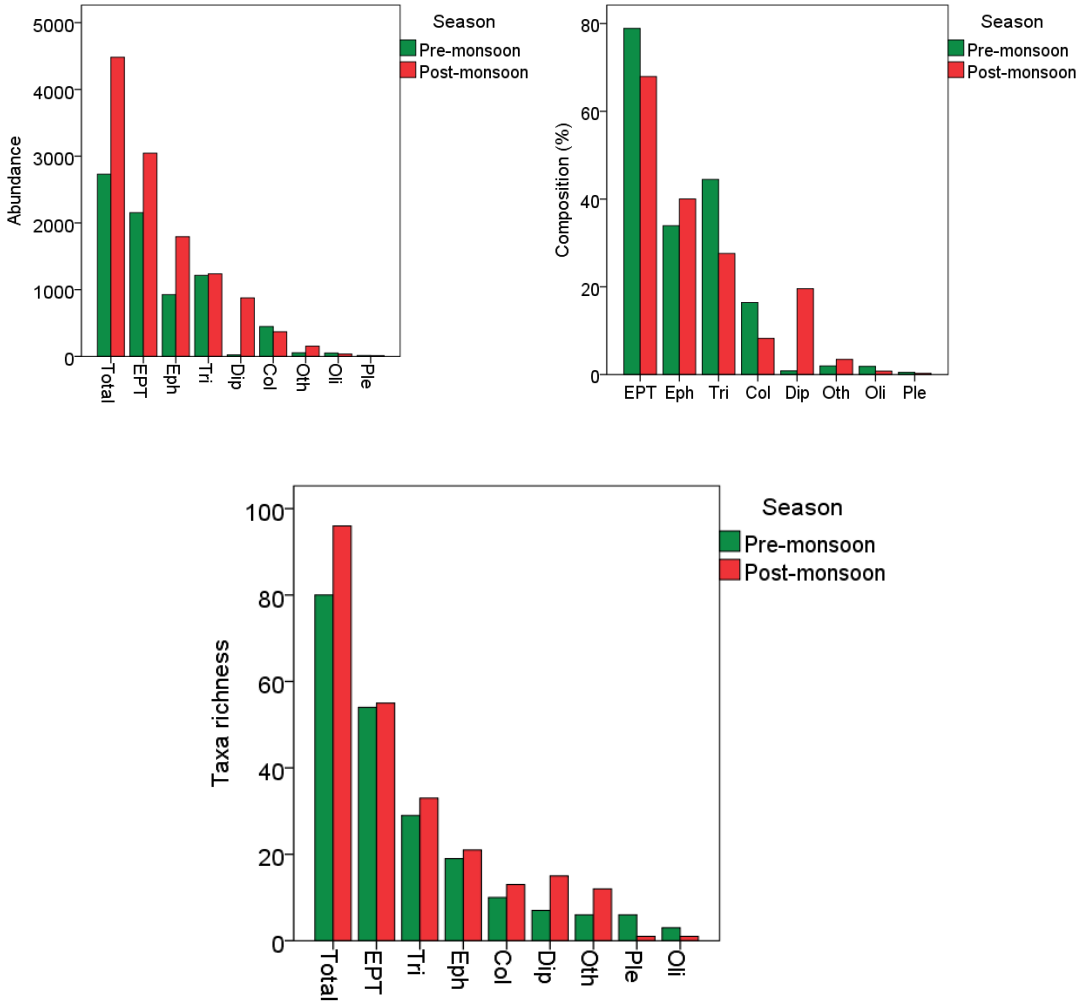


Figure 25. Season-specific overview of abundance, composition and taxa richness across the Himalayan Subtropical Pine Forests (HSPF). EPT = Ephemeroptera, Plecoptera and Trichoptera, Eph = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

4.3.1.3. Season-specific comparison of 10 dominant taxa across the HSPF

The ten most dominant pre-monsoon taxa from the HSPF were members of Trichoptera (36.52 %), Ephemeroptera (11.63 %), Coleoptera (10.31 %) and Oligochaeta (5.24 %). *Hydropsyche* sp. were the most abundant taxa followed by *Grouvellinus* sp., *Eiseniella tetraedra*, *Ecdyonurus* sp., *Chimarra* sp., *Brachycentrus* sp., *Epeorus* sp., *Cincticostella* sp., Leptoceridae *Gen*. sp. and Psephenoidinae Gen. sp. These ten dominant taxa accounted 63.44 % of pre-monsoon dominance from the HSPF (Figure 26a). The most common taxa among these were *Hydropsyche* sp. with presence over all the pre-monsoon sampling sites (*n* = 11). *Brachycentrus* sp. were least frequent and was followed by *Eiseniella tetraedra*, Psephenoidinae Gen. sp. and Leptoceridae *Gen*. sp. (Figure 26a). Among ten dominant taxa *Epeorus* sp. and *Eiseniella tetraedra* were exclusively restricted to pre-monsoon season.

The ten most dominant taxa from post-monsoon season across the HSPF were representatives of Ephemeroptera (38.99 %), Trichoptera (20.14 %), Diptera (10 %) and Coleoptera (3.84 %). *Baetis* sp. was the most dominant post-monsoon taxa across the HSPF. The other taxa among the ten most dominant one includes Chironomidae Gen. sp., *Lepidostoma* sp., *Hydropsyche* sp., *Cheumatopsyche* sp., *Ecdyonurus* sp., *Rhithrogena* sp., Psephenoidinae Gen. sp., *Cincticostella* sp. and *Brachycentrus* sp. They accounted 72.99 % of post-monsoon dominance (Figure 26b). The most frequently occurring among them were *Baetis* sp. and *Hydropsyche* sp. with occurrences in all post-monsoon sites (*n* = 11), whereas *Brachycentrus* sp. were least frequent (Figure 26b). Chironomidae Gen. sp. and *Lepidostoma* sp. were exclusive to post-monsoon season.

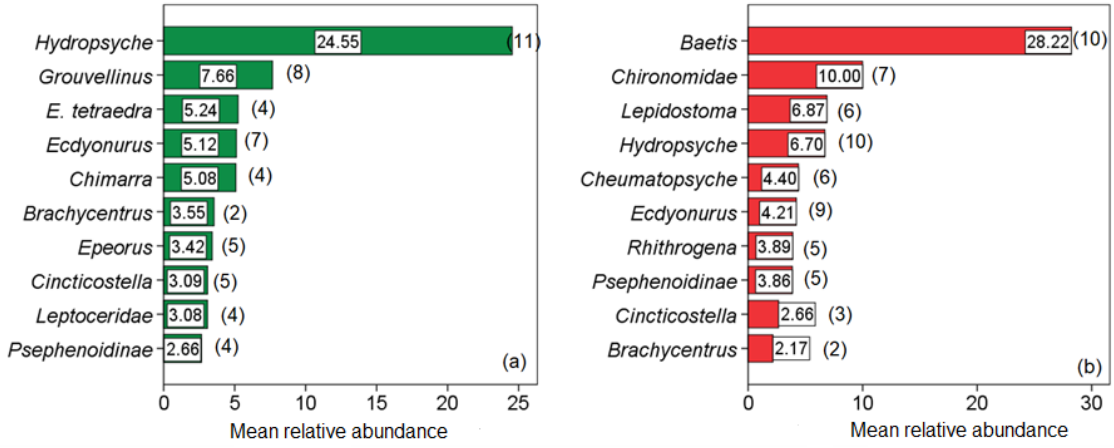


Figure 26. Ten most abundant taxa and their contribution to season-specific assemblages across the HSPF during (a) pre-monsoon season (total dominance = 63.44 %) and (b) post-monsoon season (total dominance = 72.99 %). Season-specific occurrences given in parenthesis (sites from pre-monsoon season: *n* = 11, sites from post-monsoon season: *n* = 10).

4.3.1.4. Season-specific comparison of frequently occurring taxa across the HSPF

Ten pre-monsoon taxa were observed at a minimum of 5 sites each across the HSPF (*n =11*, Figure 27a). The most frequently occurring taxa during pre-monsoon season was *Hydropsyche* sp. with presence across all pre-monsoon sampling sites. Among the ten most frequently occurring pre-monsoon taxa, five of them featured among the most dominant taxa. They are *Hydropsyche* sp., *Grouvellinus* sp., *Ecdyonurus* sp., *Epeorus* sp. and *Cincticostella* sp. However, during post-monsoon season 14 taxa were observed at minimum of 6 sites each (*n* =10; Figure 27b).

As in case of pre-monsoon season, *Hydropsyche* sp. were also most frequently occurring post-monsoon taxa along with *Baetis* sp. with presence across all post-monsoon sites.

Seven of them were among ten dominant taxa and includes *Hydropsyche* sp., *Baetis* sp., *Ecdyonurus* sp., Chironomidae Gen sp., *Cheumatopsyche* sp., Psephenoidinae Gen. sp. and *Lepidostoma* sp.

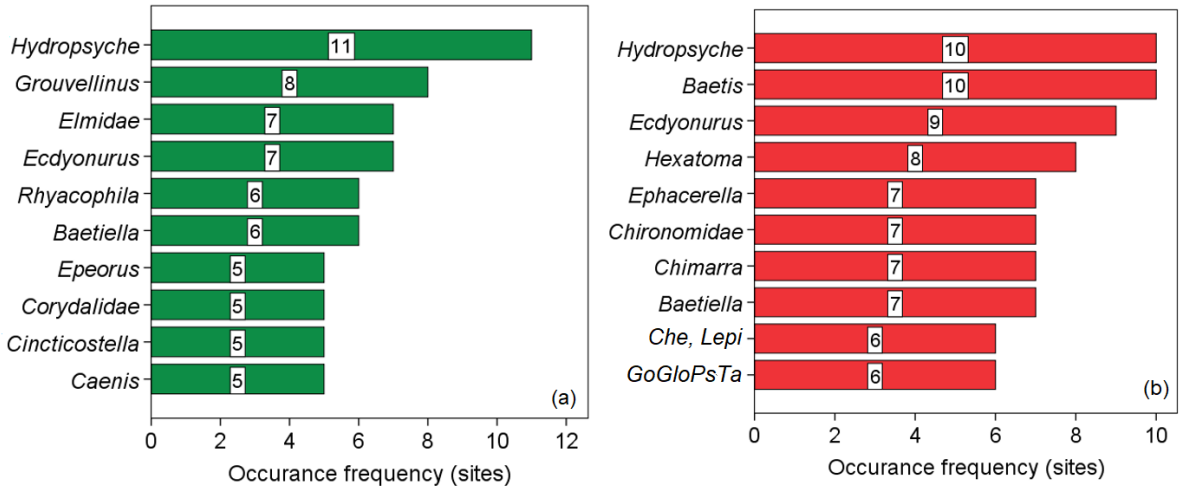


Figure 27. Most frequently occurring taxa across the HSPF during (a) pre-monsoon season (*n* = 11) and (b) post-monsoon season (*n* = 10). *Che* = *Cheumatopsyche* sp., *Lepi* = *Lepidostoma* sp. and *GoGloPsTa* = Gomphidae Gen. sp., Glossosomatinae Gen. sp., Psephenoidinae Gen. sp., and Tabanidae Gen. sp.

4.3.1.5. Season-specific comparison of exclusive taxa across the HSPF

There were 68 taxa with exclusive occurrence to particular season across the HSPF. The 26 exclusive pre-monsoon taxa from the HSPF (Table 25) contributed to 19.84 % dominance from the HSPF (Figure 28). They were dominated by *Eiseniella tetraedra* (5.24 %) and *Epeorus* sp. (3.42 %). The most commonly occurring pre-monsoon exclusive taxa from the HSPF were *Epeorus* sp. (5 sites), *Drunella* sp. and *Eiseniella tetraedra* (4 sites each), *Hydropsychidae* Gen. sp., *Wormaldia* sp., *Zephyropsyche* sp. and *Notacanthurus* sp. (3 sites each).

The 42 taxa exclusively occurring during post-monsoon season (Table 26) contributed to 23.55 % of post-monsoon dominance across the HSPF (Figure 28) and were dominated by Chironomidae Gen. sp. (10.00 %) and *Lepidostoma* sp. (6.87 %). The most frequently occurring exclusive post-monsoon taxa were *Hexatoma* sp. (8 sites), *Ephacerella* sp. and Chironomidae Gen. sp. (7 sites each), *Lepidostoma* sp. and Tabanidae Gen. sp. (6 sites each) and *Epeorus bispinosus* (5 sites). Post-monsoon season had higher number of exclusive taxa and dominance by exclusive taxa (Figure 28).

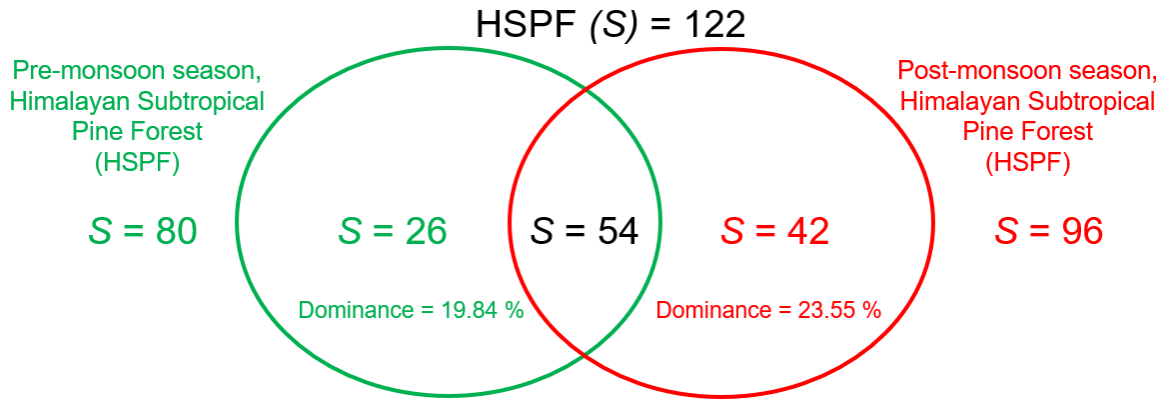


Figure 28. Season-specific comparison of total taxa, exclusive taxa and their dominance across the Himalayan Subtropical Pine Forests (HSPF).

Table 25. Taxa with exclusive occurrences during pre-monsoon season across the HSPF (*S* = 26). In order of mean dominance from highest to lowest, column wise top to down from left.

Eiseniella tetraedra	*Wormaldia* sp.	*Amphinemura* sp.
Epeorus sp.	*Diplectrona salai*	Chloroperlidae Gen. sp.
Notacanthurus sp.	*Abacaria* sp.	*Neoperla* sp.
Drunella sp.	Helodidae Gen. sp.	*Amynthas corticis*
Zephyropsyche sp.	Lepidostomatidae Gen. sp.	Peltoperlidae Gen. sp.
Cinygmula sp.	*Goera* sp.	Brachycentridae Gen. sp.
Helicopsyche sp.	Hydropsychidae Gen. sp.	Perlidae Gen. sp.
Limnocentropodidae Gen. sp.	*Plectrocnemia* sp.	*Ugandatrichia* sp.
Psephenidae Gen. sp.	*Limnodrilus* sp.	

Table 26. Taxa with exclusive occurrences during post-monsoon season across the HSPF (*S* = 42). In order of mean dominance from highest to lowest, column wise top to down from left.

Chironomidae Gen. sp.	*Graphelmis* sp.	*Hydroptila* sp.
Lepidostoma sp.	*Uenoa* sp.	*Polyplectropus* sp.
Hexatoma sp.	Sciaridae Gen. sp.	*Dugesia* sp.
Tabanidae Gen. sp.	Trichoptera Gen. sp.	*Psilotreta* sp.
Ephacerella sp.	Sericostomatidae Gen. sp.	*Anisocentropus* sp.
Nais elinguis	*Elmomorphus* sp.	*Apsilochorema* sp.
Horaia sp.	Cordulegasteridae Gen. sp.	*Himalopsyche* sp.
Limnocentropus sp.	Epiophlebiidae Gen. sp.	*Eukiefferiella* sp.
Epeorus bispinosus	Philopotamidae Gen. sp.	Hydrophilidae Gen. sp.
Stenelmis sp.	Hydroptilidae Gen. sp.	*Pseudoneureclipsis* sp.
Diptera Gen. sp.	Goeridae Gen. sp.	Mermithidae Gen. sp.
Zygoptera Gen. sp.	*Serratella* sp.	Pericomini Gen. sp.
Paraleptophlebia sp.	*Stactobia* sp.	*Pisidium* sp.
Choroterpes sp.	*Prosopistoma* sp.	*Sphaerius* sp.

4.3.1.6. Season-specific comparison of overall taxa diversity, abundance and diversity indices across the HSPF

The overall diversity and abundance of macroinvertebrate communities across the HSPF were higher during post-monsoon season (Figure 29, Table 27). The macroinvertebrate communities were more uniform during pre-monsoon with higher post-monsoon Shannon's Diversity Index and Simpson's Diversity Index (Figure 30, Table 27). Statistically, these metrics did not differ significantly across seasons.

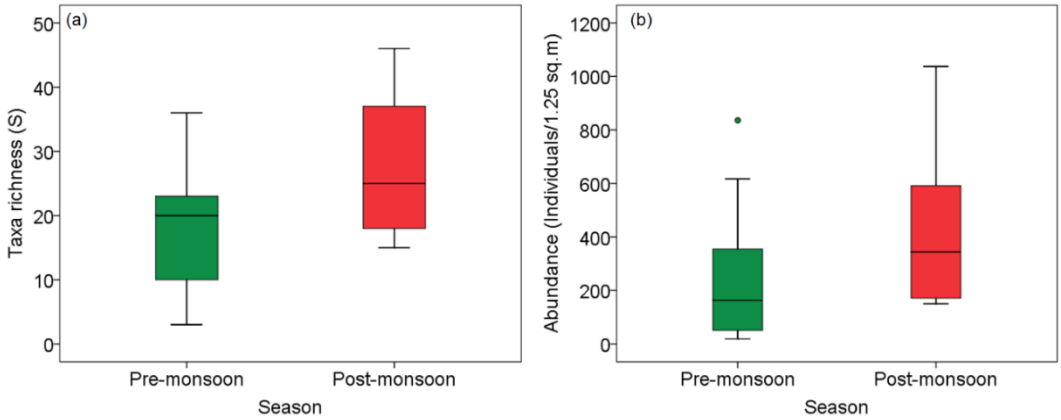


Figure 29. Season-specific distribution of (a) taxa diversity and (b) abundance across the HSPF (Sampling area:1.25 m^2).

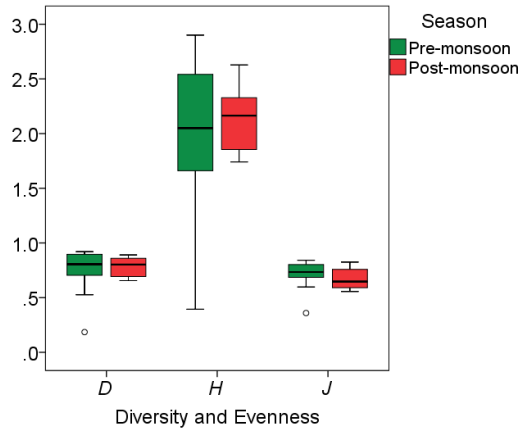


Figure 30. Season-specific distribution of Shannon's Diversity Index (*H*), Simpson's Diversity Index (*D*) and evenness (*J*) across the HSPF (Sampling area:1.25 m^2).

Table 27. Season-specific mean and standard deviation of diversity and abundance metrics across the HSPF (Sampling area:1.25 m^2).

Biological Variables	Pre-monsoon	Post-monsoon
Taxa richness (*S*)	18.45 ± 10.69	27.70 ± 11.57
Total abundance (individuals/1.25 m^2)	248.18 ± 268.99	448.10 ± 322.40
Evenness (*J*)	0.71 ± 0.14	0.66 ± 0.10
Shannon's Diversity Index (*H*)	1.97 ± 0.77	2.14 ± 0.28
Simpson's Diversity Index (*D*)	0.75 ± 0.22	0.78 ± 0.08

4.3.1.7. Season-specific comparison of dominance and taxa richness by sensitivity class across the HSPF

Within respective season, dominance and richness in terms of sensitivity class were dominated by sensitive taxa (Figure 31, Table 28, Table 29). Across season, the dominance of very sensitive, sensitive, medium tolerant taxa and extremely tolerant were higher during pre-monsoon season whereas tolerant and unscored taxa were more dominant during post-monsoon season. The post-monsoon season was diverse in terms of all categories of sensitivity class with exception of extremely tolerant, which was enumerated only during pre-monsoon season. The combined dominance of very sensitive and sensitive taxa was > 55 % across both seasons.

Pre-monsoon season was associated with significantly higher dominance of sensitive taxa (Z = – 2.310, p = 0.021), whereas during post-monsoon season unscored taxa had significantly higher dominance (Z = – 2.547, P = 0.011) and diversity (Z = – 1.982, p = 0.047).

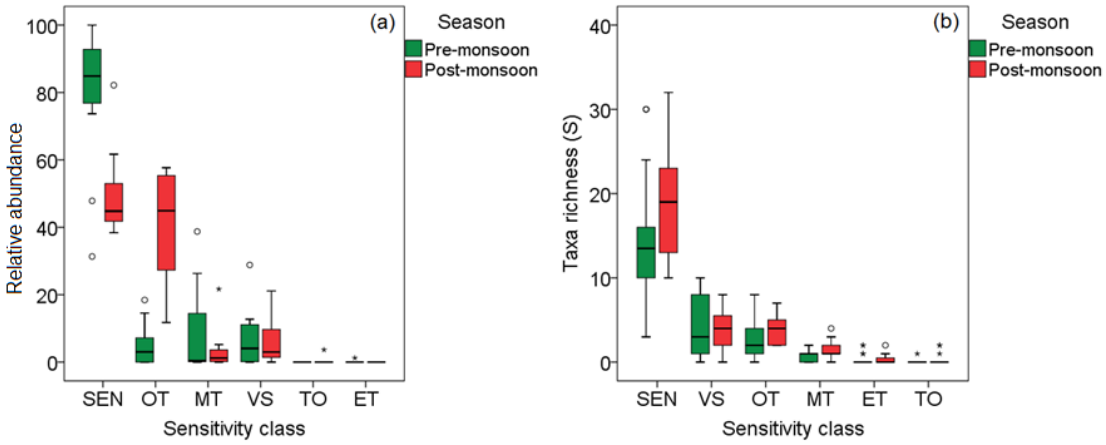


Figure 31. Season-specific distribution of (a) macroinvertebrates composition and (b) taxa richness in accordance with sensitivity class across the HSPF. SEN = sensitive, OT = Others, MT = medium tolerant, VS = very sensitive, TO = Tolerant and ET = extremely tolerant. Others in sensitivity class represents unscored taxa without clear response to organic pollution.

Table 28. Season-specific dominance and diversity of macroinvertebrates (mean ± SD) in accordance with sensitivity class across the HSPF. Significantly high values in bold (p < 0.05).

Sensitivity class	Relative abundance		Taxa diversity	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Very sensitive	6.94 ± 8.77	5.73 ± 6.56	2.00 ± 1.73	3.40 ± 2.22
Sensitive	**79.03 ± 21.31**	50.11 ± 13.41	14.00 ± 8.20	17.80 ± 7.41
Medium tolerant	8.89 ± 13.59	3.59 ± 6.57	0.82 ± 0.63	1.50 ± 1.18
Tolerant	0	0.37 ± 1.16	0	0.20 ± 0.63
Extremely tolerant	0.11 ± 0.36	0	0.09 ± 0.30	0
Others	5.02 ± 6.36	**40.20 ± 17.40**	1.55 ± 1.51	**4.00 ± 2.06**

Table 29. Season-specific of dominance of taxa in accordance with sensitivity class across the HSPF.

Sensitivity class	Pre-monsoon	Post-monsoon
Very sensitive	*Drunella* sp. (1.46 %), Agapetinae Gen. sp. (1.32 %), *Rhithrogena* sp. (1.14 %), *Cinygmula* sp. (1.12 %), *Helicopsyche* sp. (1.10 %)	*Rhithrogena* sp. (3.89 %),
Sensitive	*Hydropsyche* sp. (24.55 %), *Grouvellinus* sp. (7.66 %), *Ecdyonurus* sp. (5.12 %), *Chimarra* sp. (5.08 %), *Epeorus* sp. (3.42 %)	*Lepidostoma* sp. (6.87 %), *Hydropsyche* sp. (6.70 %), *Cheumatopsyche* sp. (4.40 %), *Ecdyonurus* sp. (4.21 %), Psephenoidinae Gen. sp. (3.86 %)
Medium tolerant	*Eiseniella tetraedra* (5.24 %), *Brachycentrus* sp. (3.55 %)	*Brachycentrus* sp. (2.17 %), Tabanidae Gen. sp. (1.06 %)
Tolerant	-	*Nais elinguis* (0.35 %)
Extremely tolerant	*Limnodrilus* sp. (0.11 %)	
Others	Leptoceridae Gen. sp. (3.08 %)	*Baetis* sp. (28.22 %), Chironomidae Gen. sp. (10.00 %), Gomphidae Gen. sp. (1.06 %)

4.3.1.8. Season-specific comparison of dominance, taxa richness and abundance by taxonomic composition across the HSPF

The dominance and diversity of macroinvertebrates were dominated Ephemeroptera, Plecoptera and Trichoptera (EPT) within particular season (Figure 32, Table 30, Table 31). The dominance of EPT was > 72 % across both seasons. Across seasons, pre-monsoon season was dominant in terms of Coleoptera, EPT, Oligochaeta and Trichoptera whereas dominance of Diptera, Ephemeroptera and Plecoptera was higher during post-monsoon season. Oligochaeta and Plecoptera had higher diversity during pre-monsoon season whereas Coleoptera, Diptera, EPT, Ephemeroptera and Trichoptera were diverse during post-monsoon season.

Statistically, post-monsoon season had significantly higher dominance of Diptera (Z = – 2.666, p = 0.008), Diptera diversity (Z = – 2.524, p = 0.012) and diversity of remaining taxonomic groups (Z = – 2.120, p = 0.034).

Table 30. Season-specific dominance of taxa across the HSPF in accordance with taxonomic composition. Highlighted in bold are 10 dominant taxa.

Major groups	Pre-monsoon	Post-monsoon
Coleoptera	***Grouvellinus* sp. (7.66 %), Psephenoidinae Gen. sp. (2.66 %),** Elmidae Gen. sp. (2.40 %), Eubriinae Gen. sp. (1.83 %), Psephenidae Gen. sp. (0.59 %)	**Psephenoidinae Gen. sp. (3.86 %),** Elmidae Gen. sp. (1.64 %), *Indosolus* sp. (0.96 %)
Diptera	Limoniidae Gen. sp. (0.17 %), Simuliidae Gen. sp. (0.09 %)	**Chironomidae Gen. sp. (10.00 %),** *Hexatoma* sp. (1.86 %), *Antocha* sp. (1.08 %), Tabanidae Gen. sp. (1.06 %)
Ephemeroptera	***Ecdyonurus* sp. (5.12 %), *Epeorus* sp. (3.42 %), *Cincticostella* sp. (3.09 %),** *Crinitella* sp. (1.96 %), *Notacanthurus* sp. (1.66 %), *Drunella* sp. (1.46 %),	***Baetis* sp. (28.22 %), *Ecdyonurus* sp. (4.21 %), *Rhithrogena* sp. (3.89 %), *Cincticostella* sp. (2.66 %),** *Acentrella* sp.

	Rhithrogena sp. (1.14 %), *Baetiella* sp. (1.12 %), *Cinygmula* sp. (1.12 %)	(1.64 %), *Baetiella* sp. (0.84 %), *Ephacerella* sp. (0.52 %)
Heteroptera	*Aphelocheirus* sp. (0.76 %)	*Aphelocheirus* sp. (0.63 %)
Lepidoptera	Pyralidae Gen. sp. (0.48 %)	Pyralidae Gen. sp. (0.51 %)
Megaloptera	Corydalidae Gen. sp. (0.69 %)	Corydalidae Gen. sp. (0.32 %)
Odonata	Euphaeidae Gen. sp. (0.24 %)	Gomphidae Gen. sp. (1.06 %)
Oligochaeta	***Eiseniella tetraedra* (5.24 %)**	*Nais elinguis* (0.35 %)
Plecoptera	*Amphinemura* sp. (0.09 %)	Perlinae Gen. sp. (0.35 %)
Trichoptera	***Hydropsyche* sp. (24.55 %), *Chimarra* sp. (5.08 %), *Brachycentrus* sp. (3.55 %), Leptoceridae Gen. sp. (3.08 %),** *Stenopsyche* sp. (2.32 %), *Cheumatopsyche* sp. (1.85 %), *Zephyropsyche* sp. (1.25 %), Agapetinae Gen. sp. (1.32 %), *Diplectrona* sp. (1.16 %), *Helicopsyche* sp. (1.10 %)	***Lepidostoma* sp. (6.87 %), *Hydropsyche* sp. (6.70 %), *Cheumatopsyche* sp. (4.40 %), *Brachycentrus* sp. (2.17 %),** Glossosomatinae Gen. sp. (1.81 %), *Stenopsyche* sp. (1.57), *Chimarra* sp. (1.48 %)

Table 31. Season-specific dominance and diversity of macroinvertebrates across the HSPF (mean ± SD) in accordance with taxonomic composition. Significantly high values in bold ($p < 0.05$).

Taxonomic groups	Relative abundance		Taxa diversity	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Coleoptera	16.29 ± 18.88	8.19 ± 11.23	2.91 ± 2.26	3.10 ± 2.64
Diptera	0.51 ± 0.96	**15.47 ± 10.30**	0.73 ± 1.01	**4.50 ± 2.99**
EPT	75.52 ± 17.62	72.65 ± 17.41	13.18 ± 7.95	16.90 ± 5.93
Ephemeroptera	23.90 ± 18.39	43.81 ± 19.96	5.55 ± 4.54	7.70 ± 3.23
Oligochaeta	5.40 ± 9.74	0.35 ± 1.09	0.55 ± 0.93	0.10 ± 0.32
Others	2.26 ± 3.23	3.34 ± 2.61	1.18 ± 0.75	**3.10 ± 1.97**
Plecoptera	0.31 ± 0.43	0.35 ± 1.11	0.72 ± 1.00	0.10 ± 0.31
Trichoptera	51.31 ± 25.06	28.48 ± 18.84	6.82 ± 3.15	9.10 ± 4.10

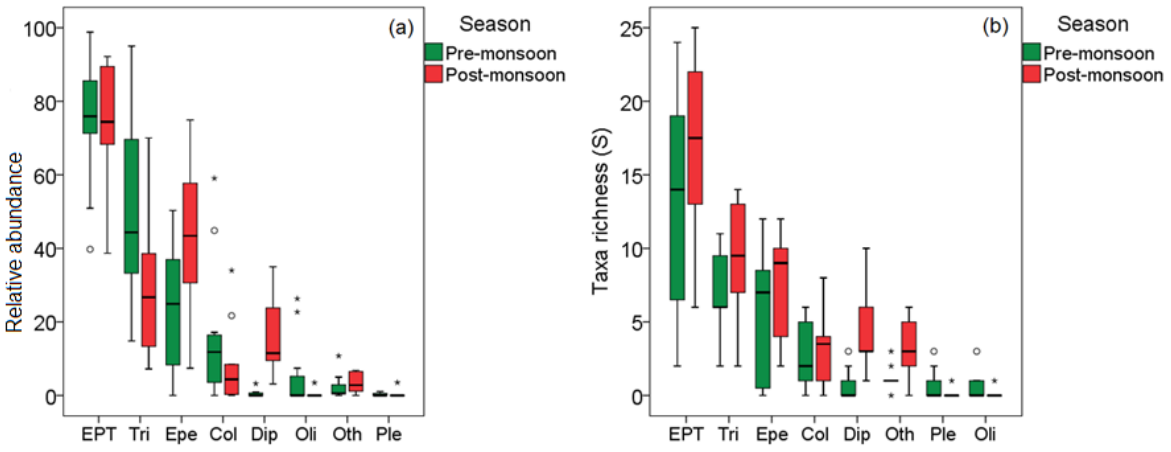


Figure 32. Season-specific distribution of (a) macroinvertebrates composition and (b) taxa richness in accordance with taxonomic groups across the HSPF. EPT = Ephemeroptera, Plecoptera and Trichoptera, Epe = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

Only the abundance of Coleoptera and Oligochaeta was higher during pre-monsoon season. Remaining taxonomic groups were abundant during post-monsoon season among which Diptera abundance was statistically significant (Table 32).

Table 32. Season-specific comparison of macroinvertebrate abundance (mean ± SD) across the Himalayan Subtropical Pine Forests in accordance with taxonomic composition ($p < 0.05$).

Taxonomic groups	Abundance (#/1.25 $m^{2)}$		Test statistics	
	Pre-monsoon	Post-monsoon	*Z*	*p*
Coleoptera	40.73 ± 62.09	36.90 ± 68.10	− 0.415	0.768
Diptera	2.09 ± 3.78	87.70 ± 112.12	− 2.666	**0.008**
EPT	195.82 ± 255.60	304.40 ± 188.78	− 1.244	0.214
Ephemeroptera	84.18 ± 105.80	179.40 ± 135.72	− 1.244	0.214
Oligochaeta	4.64 ± 10.498	3.60 ± 11.38	0	1.000
Others	4.91 ± 11.67	15.50 ± 19.21	− 2.312	**0.021**
Plecoptera	1.27 ± 2.69	1.30 ± 4.11	0	1.000
Trichoptera	110.36 ± 156.38	123.70 ± 115	− 1.125	0.260

4.3.1.9. Season-specific comparison of dominance and abundance by functional feeding groups across the HSPF

Filtering collectors were most dominant during pre-monsoon season whereas gathering collectors were most dominant during post-monsoon season (Figure 33). Across seasons, higher dominance of filtering collectors and scrapers were recorded during pre-monsoon season whereas dominance of shredders, predators and gathering collectors was higher during post-monsoon season. The functional analysis of stream macroinvertebrates indicated abundant supply of suspended fine particulate during pre-monsoon and higher FPOM storage in bed sediments during post-monsoon (Table 33). Autotropic production was comparatively higher during pre-monsoon season.

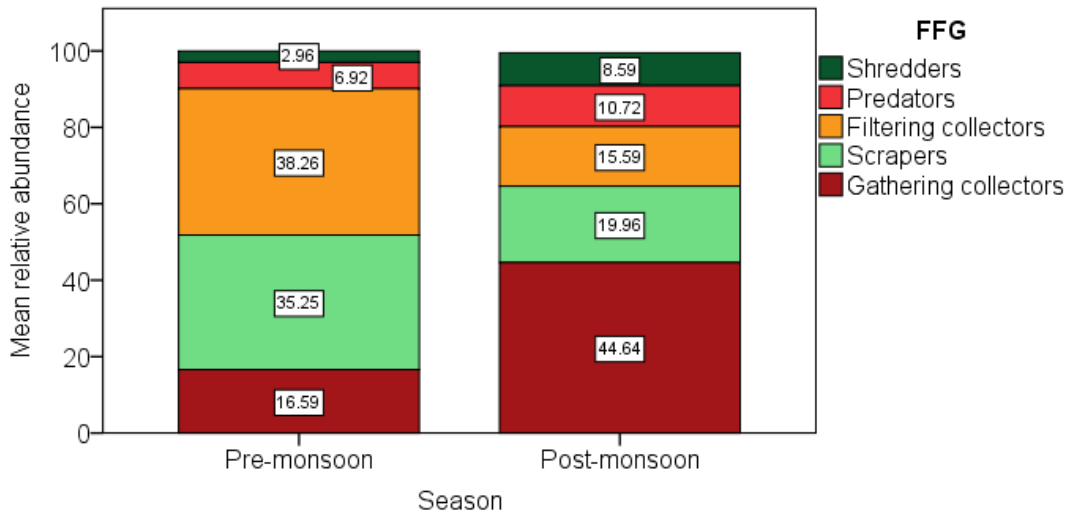


Figure 33. Season-specific dominance of functional feeding groups across the HSPF.

Table 33. Season-specific functional analysis of stream macroinvertebrates across the HSPF.

Ecosystem attributes	Pre-monsoon	Post-monsoon
Autotrophy heterotopy	0.61	0.29
Filtering collector index	02.30	0.35

The abundance of all functional feeding groups was higher during post-monsoon season. Gathering collectors and shredders were significantly abundant during post-monsoon season (Table 34).

Table 34. Season-specific comparison of macroinvertebrate abundance (mean ± SD) in accordance with functional feeding groups across the HSPF ($p < 0.05$).

Functional Feeding groups	Abundance (#/1.25 m^2)		Test statistics	
	Pre-monsoon	Post-monsoon	*Z*	*p*
Filtering collectors	50.45 ± 68.30	67.30 ± 69.54	− 1.125	0.260
Gathering collectors	51.45 ± 65.50	**209.00** ± 197	− 2.073	**0.038**
Predators	39.09 ± 102.32	46.60 ± 36.52	− 1.599	0.110
Scraper	102.55 ± 105.90	83.90 ± 78.75	− 0.415	0.678
Shredder	4.55 ± 7.37	37.50 ± 91.21	− 2.383	**0.017**

4.3.1.10. Season-specific indicator taxa for the HSPF

Based on community composition of macroinvertebrates from all sites sampled during pre-monsoon and post-monsoon seasons across the HSPF, two major cluster were obtained (0 % similarity, Figure 34), with two subclusters from first major cluster (≈ 16 % similarity). The first subcluster included one group of pre-monsoon sites (≈ 62 % similarity) and second subcluster reflected communities from all post-monsoon sampling sites (≈ 36 % similarity). The second major cluster reflected community composition from remaining pre-monsoon sites.

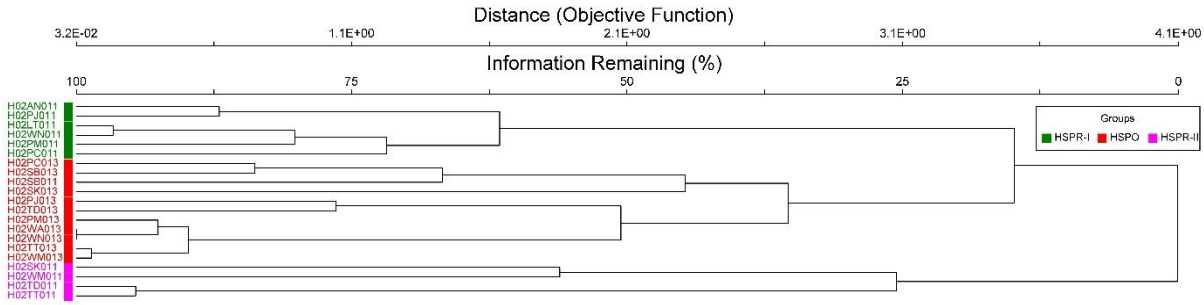


Figure 34. Hierarchical cluster analysis of macroinvertebrate communities from the HSPF (HSPR = Himalayan Subtropical Pine Forests, pre-monsoon sites; HSPO = Himalayan Subtropical Pine Forests, post-monsoon sites; I and II indicates number of clusters).

The Indicator Species Analysis (ISA) for two seasons across the HSPF identified 8 significant indicators ($p < 0.05$) with indicator value (IV) ranging from 45.50 – 80.00 and were either excellent or good indicator (Table 35). *Epeorus* sp. (IV = 45.50, p = 0.0344) were only

significant indicator taxa identified during pre-monsoon season for the HSPF and were considered as good indicator. They were exclusive to pre-monsoon season from the HSPF and were among ten dominant taxa.

Among 7 significant indicators identified for post-monsoon season, *Hexatoma* sp. (IV = 80.00, $p = 0.0008$), *Baetis* sp. (IV = 78.60, $p = 0.0020$), Chironomidae Gen. sp. (IV = 70.00, $p = 0.0004$), *Ephacerella* sp. (IV = 70.00, $p = 0.0018$), *Lepidostoma* sp. (IV = 60.00, p = 0.0034) and *Tabanidae* Gen. sp. (IV = 70.00, p = 0.0044) were regarded as an excellent indicator whereas *Epeorus bispinous* (IV = 50.00, p = 0.0138) was considered as good indicator. Chironomidae Gen. sp. and *Lepidostoma* sp. were among the exclusive and ten most dominant post-monsoon taxa from the HSPF. All indicator taxa were exclusive taxa, except for *Baetis* sp. and *Ecdyonurus* sp., which were associated across both seasons (Table 35).

Table 35. List of season-specific indicator taxa across the HSPF (excellent indicators = IV ≥ 60, good indicators = IV ≥ 40 – < 60, $p < 0.05$ are in bold, * exclusive taxa to season, ** exclusive and among 10 dominant taxa for particular season).

Season	Taxa	Indicator Value (IV)	Mean	SD	*p*
Pre-monsoon	*Hydropsyche* sp.	50.00	50.00	0.71	1.0000
Pre-monsoon	*Grouvellinus* sp.	46.90	38.70	7.95	0.2034
Pre-monsoon	*Epeorus* sp. **	45.50	21.80	7.76	**0.0344**
Pre-monsoon	Elmidae Gen. sp.	39.10	36.30	8.30	0.3807
Pre-monsoon	*Drunella* sp.	36.40	18.30	8.14	0.0912
Pre-monsoon	*Eiseniella tetraedra*	36.40	18.40	8.09	0.0914
Post-monsoon	*Hexatoma* sp. *	80.00	29.20	8.65	**0.0008**
Post-monsoon	*Baetis* sp.	78.60	40.50	7.93	**0.0020**
Post-monsoon	Chironomidae Gen. sp. **	70.00	27.10	8.32	**0.0004**
Post-monsoon	*Ephacerella* sp. *	70.00	27.20	8.46	**0.0018**
Post-monsoon	*Lepidostoma* sp. **	60.00	23.90	8.51	**0.0034**
Post-monsoon	Tabanidae Gen. sp. *	60.00	23.90	8.59	**0.0044**
Post-monsoon	*Ecdyonurus* sp.	52.70	46.80	6.23	0.3149
Post-monsoon	*Epeorus bispinosus* *	50.00	21.70	7.69	**0.0138**

4.3.2. Season-specific comparison of macroinvertebrate communities across the Eastern Himalayan Broadleaf Forests (EHBF)

4.3.2.1 Season-specific organization of macroinvertebrate communities across the EHBF

The comparison of macroinvertebrate communities across the EHBF through multi-response permutation procedure (MRPP) indicated significant differences in assemblages between pre-monsoon and post-monsoon seasons (A = 0.3523, p = 0.0000). The value of A > 0.30 indicates very high within-group similarity (McCune and Grace, 2002).

Season-specific organization of macroinvertebrate communities as function of environmental parameters across the EHBF

The NMDS ordination provided optimal 2-dimensional solution (final stress = 18.11194, final instability = 0.00134). The ordination showed clear differences in assemblage pattern of macroinvertebrates across pre-monsoon and post-monsoon season and were influenced by local-scale environmental factors (Figure 35). The ordination accounted for 80.9 % of cumulative variance (axis 1 = 37.7 %, axis 2 = 43.2 %).

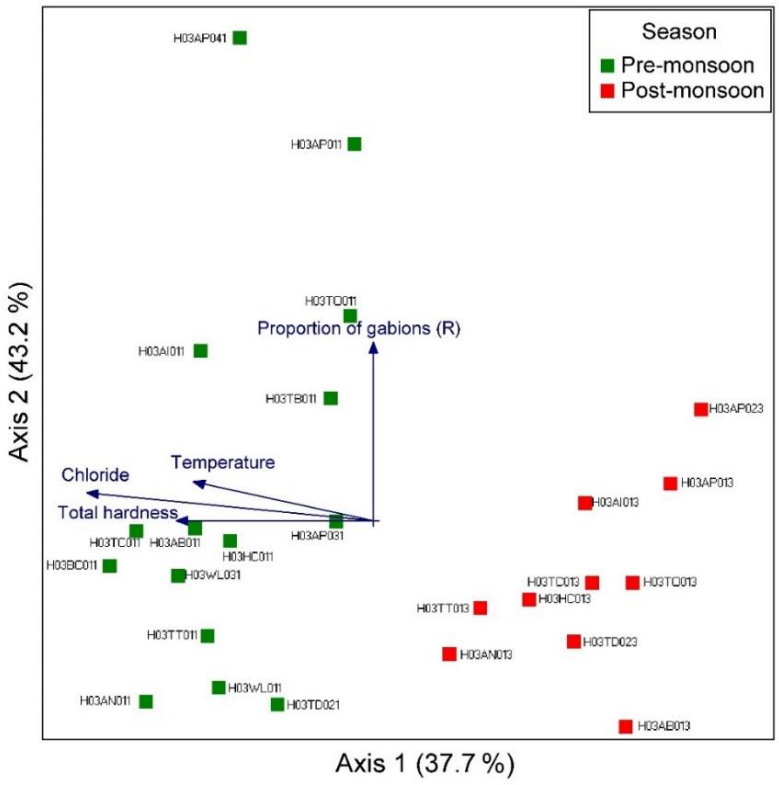


Figure 35. NMDS joint plot of benthic macroinvertebrates communities collected from the EHBF (n = 25) as function of environmental variables with grouping based on season. Final stress for 3-dimensional solution = 18.11194, final instability = 0.00134, joint plot cut-off value: r^2 = 0.50. R in parenthesis indicates right bank, proportion of gabion reflects absence of gabions.

The most strongly correlated environmental parameters with axis 1 were chloride (r = 0.913), hardness (r = 0.756) and temperature (r = 0.725) whereas proportion of gabions in right bank (r = 0.722) were strongly correlated with axis 2. Temperature (r = 0.337) and chloride (r = 0.285) were positively correlated with axis 2.

Season-specific organization of macroinvertebrate communities as function of composition of functional feeding groups across the EHBF

The difference in seasonal macroinvertebrate communities across the EHBF in accordance with FFGs visualized through NMDS ordination provided optimal 2-dimensional solution (final stress = 18.24818, final instability = 0.00101) and explained 80.7 % of variation in community assemblages (axis 1 = 37.8 %, axis 2 = 42.9 %) and indicated distinct communities in accordance with FFGs (Figure 36). The most important influencing variables were abundance of collecting gatherers and floodplain forest. The gathering collectors correlated negatively with both axes, axis 1 (r = − 0.315) and axis 2 (r = − 0.601). The floodplain forest exhibited strong positive correlation with axis 1 (r = 0.613) and very weak positive correlation with axis 2 (r = − 0.017).

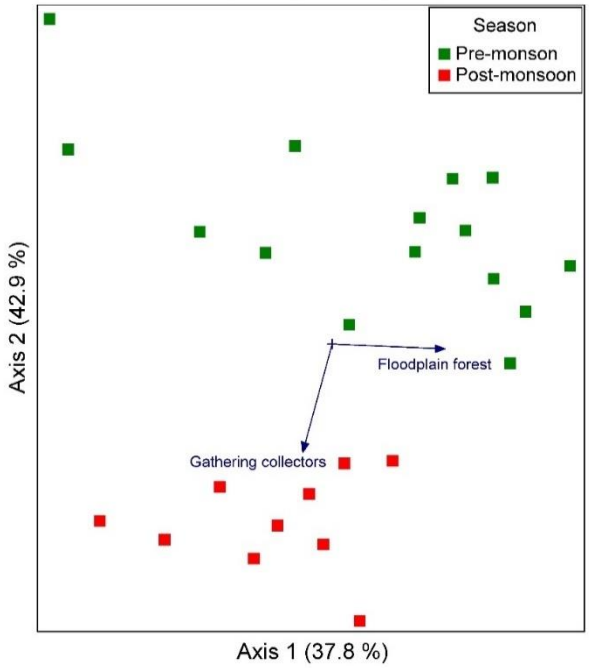


Figure 36. NMDS joint plot of macroinvertebrate communities collected from the EHBF (n = 25) as function of composition of functional feeding groups with grouping based on season. Final stress for 2-dimensional solution = 18.24818, final instability = 0.00101, joint plot cut-off value r^2 = 0.25.

4.3.2.2. Season-specific overview of abundance, composition and taxa richness across the EHBF

In total, 130 taxa were recorded from streams flowing through the Eastern Himalayan Broadleaf Forests (EHBF) of which 88 taxa were enumerated during pre-monsoon season and 89 taxa during post-monsoon season. A total of 47 taxa were found to be common across seasons with Jaccard's Similarity Index of 0.36 and Sørensen's Similarity Index of 0.53.

The general abundance of macroinvertebrate across the Eastern Himalayan Broadleaf Forests was higher during post-monsoon and was higher across all taxonomic groups with exception of Coleoptera, Ephemeroptera and Plecoptera. However, only Diptera and Trichoptera had higher dominance during post-monsoon season. The general diversity was comparable, and post-monsoon season was more diverse in Coleoptera, Oligochaeta and Trichoptera (Figure 37, Table 36). Detailed analysis is presented on section 4.3.2.6. and 4.3.2.8.

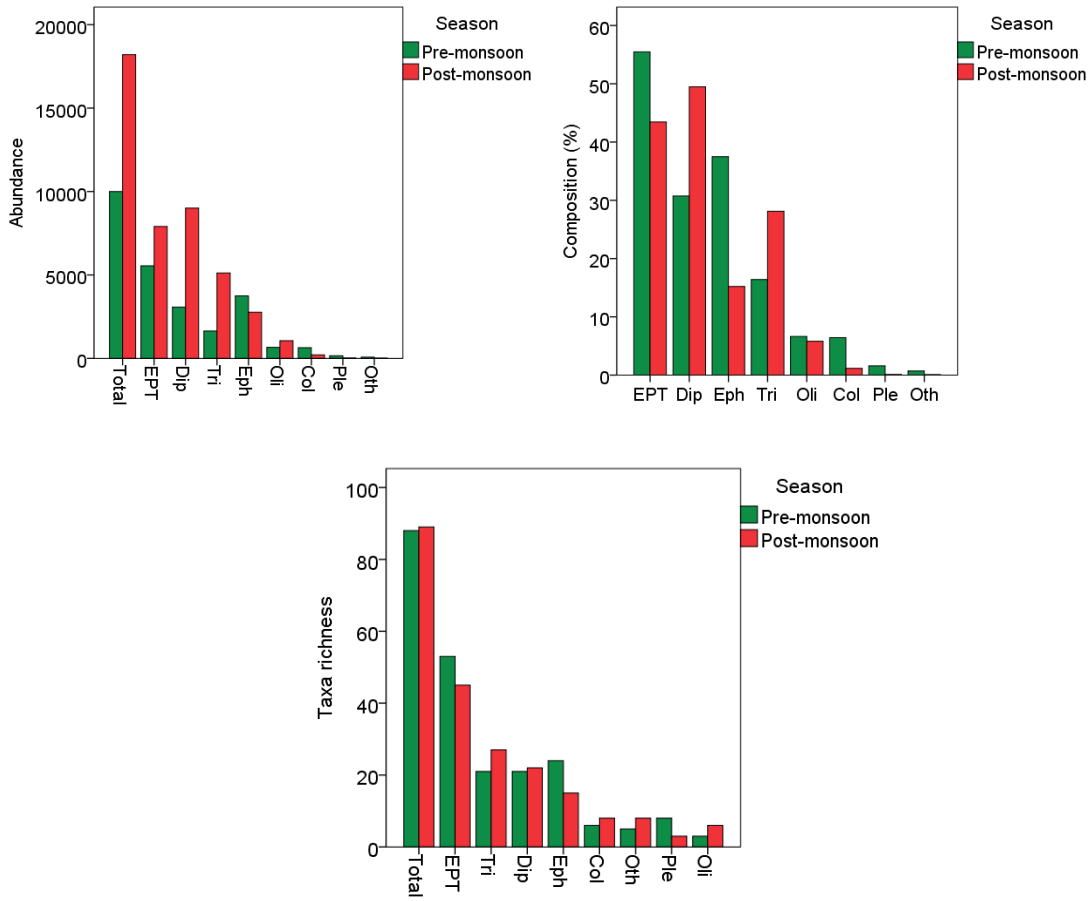


Figure 37. Season-specific overview of abundance, composition and taxa richness across the Eastern Himalayan Broadleaf Forests. (EPT = Ephemeroptera, Plecoptera and Trichoptera, Epe = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

Table 36. Season-specific overview of abundance, composition and taxa richness across the Eastern Himalayan Broadleaf Forests.

Abundance

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	643	3075	5548	3748	663	159	1641	72	10001
Post-monsoon	211	9009	7908	2769	1059	21	5118	17	18204

Composition (%)

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	6.43	30.75	55.47	37.48	6.63	1.59	16.41	0.72	100
Post-monsoon	1.16	49.49	43.44	15.21	5.82	0.12	28.11	0.09	100

Taxa richness

Season	Coleoptera	Diptera	EPT	Ephmeroptera	Oligochaeta	Plecoptera	Trichoptera	Others	Total
Pre-monsoon	6	21	53	24	3	8	21	5	88
Post-monsoon	8	22	45	15	6	3	27	8	89

4.3.2.3. Season-specific comparison of 10 dominant taxa across the EHBF

The ten most dominant pre-monsoon taxa from the EHBF were members of Ephemeroptera (33.74 %), Diptera (17.76 %), Trichoptera (9.12 % %), Coleoptera (4.44 %) and Oligochaeta (3.83 %). The members of *Baetis* sp. were most dominant among all taxa. They were followed by Simuliidae Gen. sp., *Baetiella* sp., *Brachycentrus* sp., *Cincticostella* sp., Scirtidae Gen. sp., *Ecdyonurus* sp., Tubificidae Gen. sp., *Micrasema* sp. and Chironomidae Gen. sp. These ten most dominant taxa accounted for 68.89 % of pre-monsoon dominance of macroinvertebrates across the EHBF (Figure 38a). Simuliidae Gen. sp., *Baetis* sp. and *Baetiella* sp. were most frequently occurring whereas *Micrasema* sp. were least frequent in occurrences (Figure 38a). Scirtidae Gen. sp. and Tubificidae Gen. sp. were strictly restricted to pre-monsoon season.

The ten dominant post-monsoon taxa from the EHBF were mainly dominated by Diptera (44.77 %), followed by Trichoptera (15.83%) and Ephemeroptera (11.73 %). The members of Chironomidae Gen. sp., were the most dominant, followed by *Baetis* sp., *Brachycentrus* sp., *Psychomyia* sp., *Lepidostoma* sp., Simuliidae Gen. sp., *Acentrella* sp., *Antocha* sp., *Apatania* sp. and *Epeorus bispinosus*. They accounted 72.33 % of post-monsoon dominance across the EHBF (Figure 38b). *Lepidostoma* sp., *Apatania* sp. and *Epeorus bispinosus* were the dominant taxa exclusively restricted to post-monsoon season. Among them, most frequently occurring was Chironomidae Gen. sp. whereas *Apatania* sp. was the least common (Figure 38b).

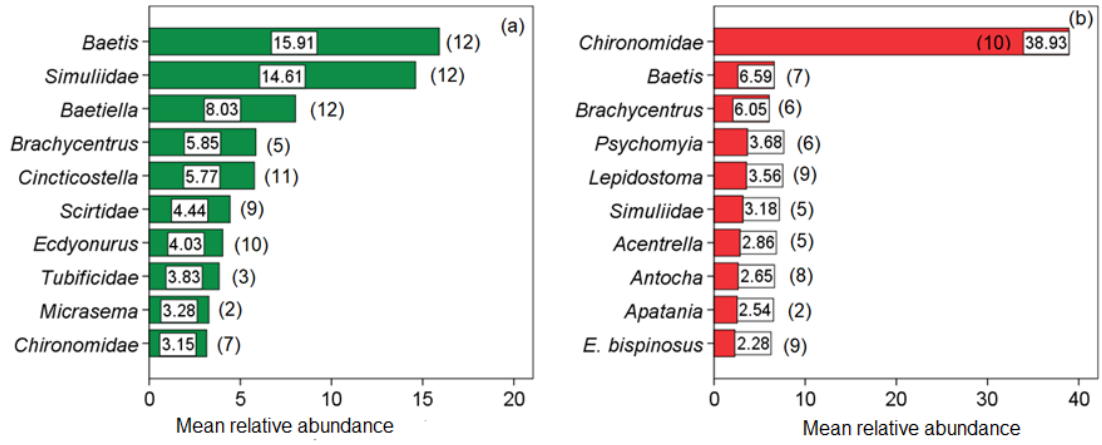


Figure 38. Ten most abundant taxa and their contribution to season-specific assemblages across the EHBF during (a) pre-monsoon season (total dominance = 68.89 %) and (b) post-monsoon season (total dominance = 72.33 %). Seasonal occurrences are given in parenthesis (sites from pre-monsoon season: *n* = 15, sites from post-monsoon season: *n* = 10).

4.3.2.4. Season-specific comparison of frequently occurring taxa across the EHBF

Ten pre-monsoon taxa were recorded from 9 sites each from the EHBF (*n* = 15, Figure 39a). The most frequently occurring pre-monsoon taxa were Simuliidae Gen. sp., *Baetis* sp., *Baetiella* sp. and *Acentrella* sp. with presence across 12 sites. Among these, *Baetis* sp. *Baetiella* sp. Simuliidae Gen. sp., *Cincticostella* sp., Scirtidae Gen. sp. and *Ecdyonurus* sp. were also among the ten most abundant pre-monsoon taxa. During post-monsoon season, 13 taxa were found from 7 sites each (*n* = 10, Figure 39b) among which Chironomidae Gen. sp. were recorded from all sites. Among these, Chironomidae Gen. sp., *Lepidostoma* sp., *Antocha* sp., *Baetis* sp. and *Epeorus bispinous* were also listed among ten dominant post-monsoon taxa across the EHBF.

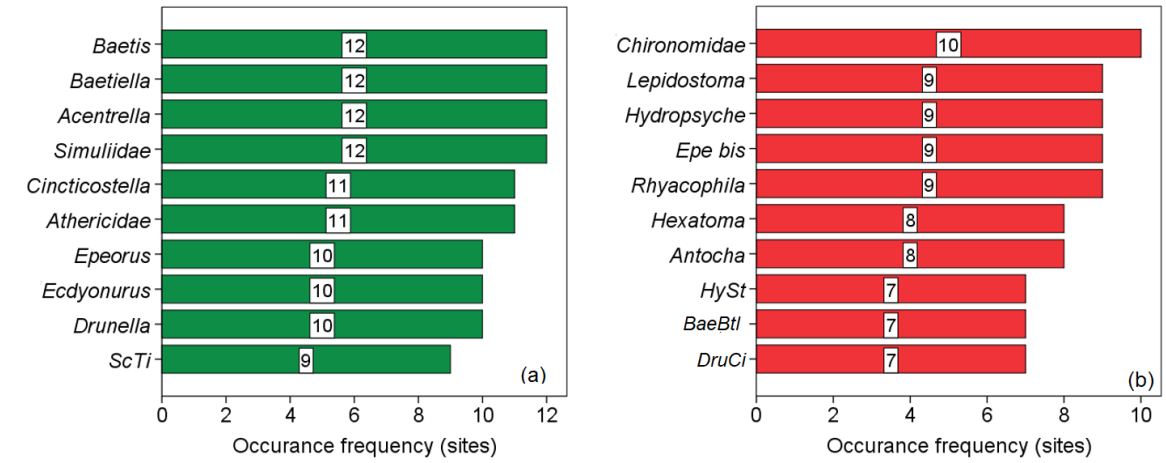


Figure 39. Most frequently occurring taxa across the EHBF during (a) pre-monsoon season (*n* = 15) and (b) post monsoon season (*n* = 10). *ScTi* = Scirtidae Gen. sp. and Tipulidae Gen. sp., *Epe bis* = *Epeorus bispinosus*, *HySt* = *Hydrocyphon* sp. and *Stenopsyche* sp., *BaeBtl* = *Baetis* sp. and *Baetiella* sp., and *DruCi*= *Drunella* sp. and *Cincticostella* sp.

4.3.2.5. Season-specific comparison of exclusive taxa across the EHBF

The total number of taxa with exclusive occurrences in particular season from the EHBF were 83. There were 41 taxa exclusively associated with pre-monsoon season (Table 37) and contributed to 20.21 % of pre-monsoon dominance (Figure 40). Exclusive taxa were dominated by Scirtidae Gen. sp. (4.47 %), Tubificidae Gen. sp. (3.83 %), *Epeorus* sp. (2.23 %) and Orthocladiinae Gen. sp. (1.53 %). The most frequently occurring among exclusive pre-monsoon taxa were *Epeorus* sp. (10 sites), Scirtidae Gen. sp. (9 sites), Paraleptophlebia sp. (8 sites), *Amphinemura* sp. (7 sites) and Chloroperlidae Gen. sp. (6 sites).

There were 42 taxa exclusive post-monsoon taxa from the EHBF (Table 38), and they contributed 16.17 % of post-monsoon dominance (Figure 40). They were dominated by *Lepidostoma* sp. (3.56 %), *Apatania* sp. (2.53 %), *Epeorus bispinosus* (2.28 %) and *Nais elinguis* (1.55 %). The most frequently occurring exclusive post monsoon taxa were *Lepidostoma* sp. and *Epeorus bispinosus* (9 sites each) followed by *Hexatoma* sp. (8 sites), *Hydrocyphon* sp. (7 sites), *Parapsyche* sp., Psephenoidinae Gen. sp., *Himalopsyche* sp. and *Dicranota* sp. (6 sites each), and *Atherix* sp. and *Hyporhyacophila* sp. (5 sites each).

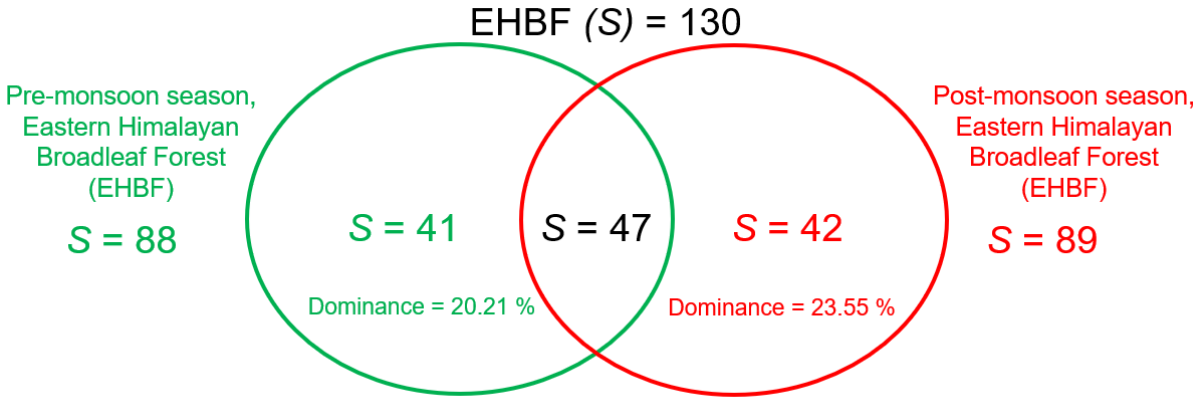


Figure 40. Season-specific comparison of total taxa, exclusive taxa and their dominance across the EHBF.

Table 37. Taxa with exclusive occurrences during pre-monsoon seasons across the EHBF (*S* = 41). In order of mean dominance from highest to lowest, column wise top to down from left.

Scirtidae Gen. sp.	*Serratella* sp.	*Isonychia* sp.
Tubificidae Gen. sp.	Diamesini Gen. sp.	*Agapetus* sp.
Epeorus sp.	*Arctopsyche* sp.	*Dolophilodes* sp.
Orthocladiinae Gen. sp.	Heptageniidae Gen. sp.	*Nemoura* sp.
Eiseniella sp.	*Potamanthellus* sp.	Ephydridae Gen. sp.
Paraleptophlebia sp.	Pediciinae Gen. sp.	*Haploperla* sp.
Chironomini Gen. sp.	Empididae Gen. sp.	*Glossosoma* sp.

Amphinemura sp.	Ephemerellidae Gen. sp.	Hydraenidae Gen. sp.
Cinygmula sp.	*Indosorius* sp.	*Chimarra* sp.
Zephyropsyche sp.	*Epiophlebia* sp.	*Neophylax* sp.
Tanypodinae Gen. sp.	Potamanthidae Gen. sp.	Philopotamidae Gen. sp.
Chloroperlidae Gen. sp.	Baetidae Gen. sp.	Tabanidae Gen. sp.
Leptocerinae Gen. sp.	Nemouridae Gen. sp.	*Ranatra* sp.
Tanytarsini Gen. sp.	Ameletidae Gen. sp.	

Table 38. Taxa with exclusive occurrences during post-monsoon season across the EHBF (S = 42). In order of mean dominance from highest to lowest, column wise top to down from left.

Lepidostoma sp.	*Himalopsyche* sp.	*Bazarella* sp.
Apatania sp.	*Dicranota* sp.	Bidessini Gen. sp.
Epeorus bispinosus	Stactobiini Gen. sp.	Sciaridae Gen. sp.
Nais elinguis	Eubriinae Gen. sp.	*Blepharicera* sp.
Epeorus unispinosus	*Pseudostenophylax* sp.	Hydroptilidae Gen. sp.
Hexatoma sp.	*Limnodrilus hoffmeisteri*	Corixidae Gen. sp.
Parapsyche sp.	Clinocerinae Gen. sp.	*Eukiefferiella* sp.
Psephenoidinae Gen. sp.	*Epiophlebiidae* Gen. sp.	Rhyacophilidae Gen. sp.
Atherix sp.	*Hydropsychidae* Gen. sp.	*Eiseniella tetraedra*
Hydrocyphon sp.	*Polycelis* sp.	*Cheumatopsyche* sp.
Nais variabilis	*Eloeophila* sp.	*Potamia* sp.
Hyporhyacophila sp.	Polycentropodidae Gen. sp.	Corydalidae Gen. sp.
Kisaura sp.	Psephenidae Gen. sp.	*Enchytraeus indicus*
Glossosomatidae Gen. sp.	Psychomyiidae Gen. sp.	*Heteroptera* Gen. sp.

4.3.2.6. Season-specific comparison of overall taxa diversity, abundance and diversity indices across the EHBF

Post-monsoon season were associated with higher diversity and abundance of macroinvertebrate communities (Figure 141, Table 39). However, diversity indices indicated, pre-monsoon season to be more diverse in terms of macroinvertebrates composition (H, D) with higher pre-monsoon evenness (Figure 42, Table 39). Statistically, significant increase in taxa richness (Z = – 2.194, p = 0.028) and abundance (Z = – 2.293, p = 0.022) was observed during post-monsoon season.

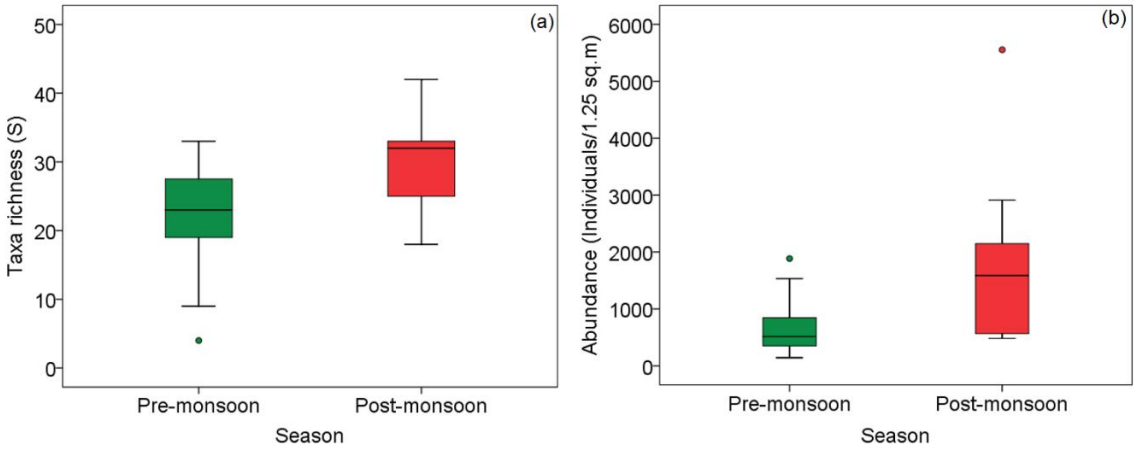


Figure 41. Season-specific distribution of (a) taxa diversity and (b) abundance across the EHBF (Sampling area:1.25 m^2).

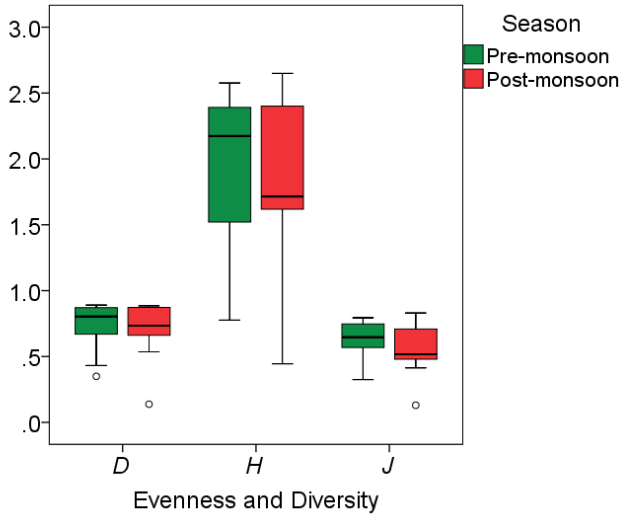


Figure 42. Season-specific distribution of Shannon's Diversity Index (*H*), Simpson's Diversity Index (*D*) and evenness (*J*) across the EHBF (Sampling area:1.25 m^2).

Table 39. Season-specific mean and standard deviation of diversity and abundance metrics across the HSPF (Sampling area:1.25 m^2). Significantly high values in bold ($p < 0.05$).

Biological variables	Pre-monsoon	Post-monsoon
Taxa richness (*S*)	22.27 ± 7.95	**30.50 ± 6.65**
Evenness (*J*)	0.63 ± 0.14	0.55 ± 0.20
Shannon's Diversity Index (*H*)	1.92 ± 0.611	1.84 ± 0.65
Simpson's Diversity Index (*D*)	0.73 ± 0.18	0.70 ± 0.23
Total abundance (individuals/1.25 m^2)	666.73 ± 494.54	**1820 ± 1526.44**

4.3.2.7. Season-specific comparison of dominance and taxa richness by sensitivity class across the EHBF

Within season, dominance and richness in terms of sensitivity class were dominated by sensitive taxa during pre-monsoon season whereas post-monsoon had higher dominance of unscored taxa and higher diversity of sensitive taxa (Figure 43, Table 40, Table 41). Across

season, pre-monsoon had higher dominance of very sensitive, sensitive, medium tolerant and extremely tolerant taxa whereas post-monsoon had higher dominance of unscored and tolerant taxa. In terms of diversity, only very sensitive taxa were higher during pre-monsoon season whereas those categorized as others were more diverse during post-monsoon season. The combined dominance of very sensitive and sensitive taxa was > 65 % during pre-monsoon and was 44.25 % during post-monsoon. However, seasonal differences of dominance and diversity of taxa in accordance with sensitivity class were not significantly different.

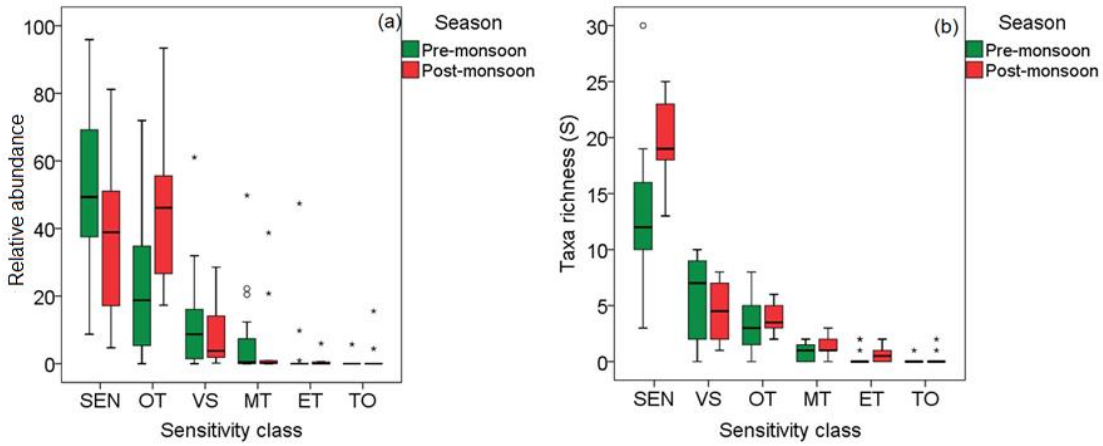


Figure 43. Season-specific distribution of (a) macroinvertebrates composition and (b) taxa richness in accordance with sensitivity class across the EHBF. SEN = sensitive, OT = Others, MT = medium tolerant, VS = very sensitive, TO = Tolerant and ET = extremely tolerant. Others in sensitivity class represents unscored taxa without clear response to organic pollution.

Table 40. Season-specific dominance and diversity of macroinvertebrates (mean ± SD) in accordance with sensitivity class across the EHBF.

Sensitivity class	Relative abundance		Taxa diversity	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Very sensitive	13.52 ± 16.18	7.65 ± 9.15	5.73 ± 3.69	4.60 ± 2.50
Sensitive	51.99 ± 25.38	36.60 ± 23.29	13 ± 6.50	19.80 ± 3.68
Medium tolerant	7.33 ± 14.00	6.12 ± 13.15	0.80 ± 0.86	1.40 ± 1.08
Tolerant	0.38 ± 1.47	1.99 ± 4.96	0.07 ± 0.26	0.30 ± 0.68
Extremely tolerant	3.87 ± 12.29	0.73 ± 1.85	0.33 ± 0.72	0.60 ± 0.70
Others	22.89 ± 20.56	46.89 ± 23.41	3.47 ± 2.39	3.70 ± 1.34

Table 41. Season-specific dominance of taxa in accordance with sensitivity class across the EHBF.

Major Groups	Pre-monsoon	Post-monsoon
Very sensitive	*Micrasema* sp. (3.28 %), *Drunella* sp. (3.01 %), Athericidae Gen. sp. (1.69 %), *Iron* sp. (1.56 %), *Amphinemura* sp. (0.78 %)	*Apatania* sp. (2.54 %), *Drunella* sp. (1.47 %), *Micrasema* sp. (1.35 %), Agapetinae Gen. sp. (1.11 %)
Sensitive	Simuliidae Gen. sp. (14.61 %), *Baetiella* sp. (8.03 %), *Cincticostella*	*Psychomyia* sp. (3.68 %), *Lepidostoma* sp. (3.56 %), Simuliidae Gen. sp. (3.18 %),

	sp. (5.77 %), Scirtidae Gen. sp. (4.44 %), *Ecdyonurus* sp. (4.03 %)	*Acentrella* sp. (2.86 %), *Antocha* sp. (2.65 %)
Medium tolerant	*Brachycentrus* sp. (5.85 %), *Eiseniella* sp. (1.45 %),	*Brachycentrus* sp. (6.05 %)
Tolerant	*Dugesia* sp. (0.38 %)	*Nais elinguis* (1.56 %)
Extremely tolerant	Tubificidae Gen. sp. (3.83 %)	Oligochaeta Gen. sp. (0.67 %)
Others	*Baetis* sp. (15.91 %), Chironomidae Gen. sp. (3.15 %), Orthocladiinae Gen. sp. (1.53 %)	Chironomidae Gen. sp. (38.93 %), *Baetis* sp. (6.59 %), Leptoceridae Gen. sp. (1.01 %)

4.3.2.8. Season-specific comparison of dominance, taxa richness and abundance by taxonomic composition across the EHBF

In accordance with taxonomic groups, Ephemeroptera, Plecoptera and Trichoptera (EPT) had highest dominance and diversity across both seasons across the EHBF (Figure 44, Table 42, Table 43). The dominance of EPT during pre-monsoon was 61.42 % whereas it was 47.03 % during post-monsoon. The sites with < 50 % EPT composition were dominate by Diptera across both seasons. Across season, Coleoptera, EPT, Ephemeroptera, Oligochaeta and Plecoptera was dominant during pre-monsoon season whereas post-monsoon was associated with higher dominance of Diptera and Trichoptera. Pre-monsoon season was diverse in terms of Ephemeroptera and Trichoptera whereas Coleoptera, Diptera, EPT, Oligochaeta and Trichoptera was diverse during post-monsoon season.

Pre-monsoon season was associated with significantly higher dominance of Ephemeroptera ($Z = -2.090$, $p = 0.037$) and Plecoptera ($Z = -2.666$, $p = 0.008$). Plecoptera richness were significantly higher during pre-monsoon season ($Z = -2.555$, $p = 0.011$). The orders which were significantly diverse during post-monsoon were Trichoptera ($Z = -2.818$, $p = 0.005$) and Coleoptera ($Z = -2.448$, $p = 0.014$).

Table 42. Season-specific dominance and diversity of macroinvertebrates (mean ± SD) across the EHBF in accordance with taxonomic composition. Significantly high values in bold ($p < 0.05$).

Taxonomic groups	Relative abundance		Taxa diversity	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Coleoptera	7.60 ± 9.06	1.91 ± 1.60	1.47 ± 1.36	**2.80 ± 1.55**
Diptera	25.48 ± 24.42	48.21 ± 25.47	5.47 ± 2.94	7.90 ± 2.18
EPT	61.42 ± 27.62	47.03 ± 24.01	14.13 ± 5.80	17.60 ± 3.47
Ephemeroptera	**46.80 ± 22.78**	20.58 ± 18.12	8.67 ± 3.48	6.80 ± 1.93
Oligochaeta	5.30 ± 12.92	2.71 ± 5.04	0.47 ± 0.73	0.90 ± 1.29
Others	0.57 ± 1.43	0.11 ± 0.15	0.80 ± 0.67	1.20 ± 1.40
Plecoptera	**2.32 ± 3.26**	0.18 ± 0.39	**2.27 ± 2.81**	0.30 ± 68
Trichoptera	11.92 ± 18.35	26.27 ± 15.88	3.60 ± 2.87	**10.50 ± 2.41**

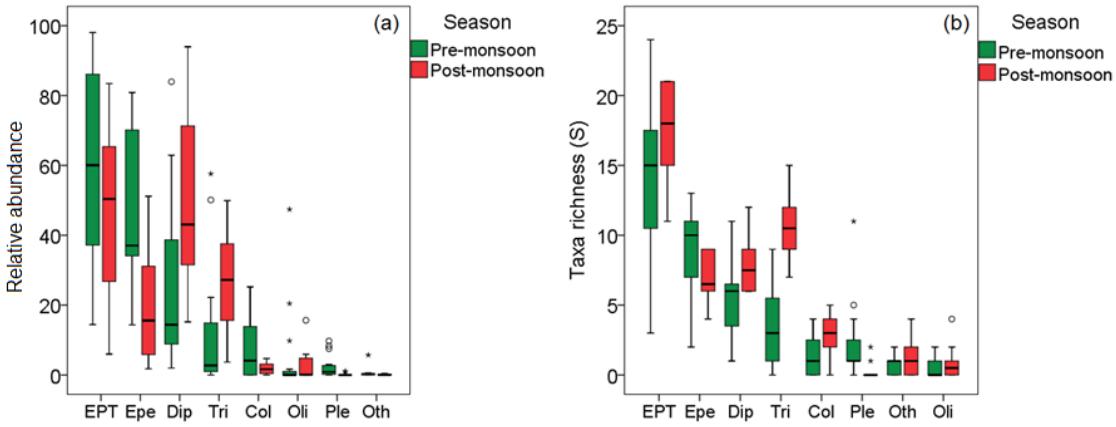


Figure 44. Season-specific distribution of (a) macroinvertebrates abundance and (b) taxa richness in accordance with taxonomic groups across the EHBF. EPT = Ephemeroptera, Plecoptera and Trichoptera, Epe = Ephemeroptera, Tri = Trichoptera, Dip = Diptera, Col = Coleoptera, Oli = Oligochaeta, Ple = Plecoptera, Oth = remaining taxonomic groups.

The abundance of Coleoptera and Plecoptera was higher during pre-monsoon season and remaining taxonomic groups were more abundant during post-monsoon season. However, Plecoptera was significantly higher during pre-monsoon season whereas Diptera was significantly higher during post-monsoon season (Table 44).

Table 43. Season-specific relative abundance of dominant taxa across the EHBF in accordance with taxonomic composition. Highlighted in bold are 10 dominant taxa.

Major Groups	Pre-monsoon	Post-monsoon
Coleoptera	**Scirtidae Gen. sp. (4.44 %),** Elmidae Gen. sp. (2.62 %)	Elmidae Gen. sp. (0.70 %), Psephenoidinae Gen. sp. (0.52 %)
Diptera	**Simuliidae Gen. sp. (14.61 %), Chironomidae Gen. sp. (3.15 %),** Athericidae Gen. sp. (1.69 %), Orthocladiinae Gen. sp. (1.53 %)	**Chironomidae Gen. sp. (38.93 %), Simuliidae Gen. sp. (3.18 %), *Antocha* sp. (2.65 %),** Deuterophlebiidae Gen. sp. (1.18 %),
Ephemeroptera	***Baetis* sp. (15.91 %), *Baetiella* sp. (8.03 %), *Cincticostella* sp. (5.77 %), *Ecdyonurus* sp. (4.03 %),** *Drunella* sp. (3.01 %), *Acentrella* sp. (2.88 %), *Epeorus* sp. (2.23 %), *Iron* sp. (1.56 %), Paraleptophlebia sp. (1.17 %)	***Baetis* sp. (6.59 %), *Acentrella* sp. (2.86 %), *Epeorus bispinosus* (2.28 %),** Leptophlebiidae Gen. sp. (1.84 %), *Ephacerella* sp. (1.76 %), *Drunella* sp. (1.47 %), *Baetiella* sp. (1.44 %), *Epeorus unispinosus* (1.01 %)
Heteroptera	*Ranatra* sp. (< 0.001 %)	Corixidae Gen. sp. (0.01 %)
Odonata	Gomphidae Gen. sp. (0.11 %)	Gomphidae Gen. sp. (0.04 %)
Oligochaeta	**Tubificidae Gen. sp. (3.83 %)** *Eiseniella* sp. (1.45 %)	*Nais elinguis* (1.56 %)
Plecoptera	*Amphinemura* sp. (0.78 %), *Paraleuctra* sp. (0.74 %)	*Indonemoura* sp. (0.09 %)
Trichoptera	***Brachycentrus* sp. (5.85 %), *Micrasema* sp. (3.28 %),**	***Brachycentrus* sp. (6.05 %), *Psychomyia* sp. (3.68 %), *Lepidostoma* sp. (3.56 %), *Apatania* sp. (2.54 %),** *Hydropsyche* sp. (2.03 %), *Rhyacophila* sp. (1.56 %), *Micrasema* sp. (1.35 %), Glossosomatinae Gen. sp. (1.16 %), Agapetinae Gen. sp. (1.11 %), Leptoceridae Gen. sp. (1.01 %)

Table 44. Season-specific comparison of abundance (mean ± SD) across the EHBF in accordance with taxonomic composition ($p < 0.05$).

Taxonomic groups	Abundance (#/1.25 $m^{2)}$		Test statistics	
	Pre-monsoon	Post-monsoon	*Z*	*p*
Coleoptera	42.87 ± 54.65	21.10 ± 17.82	− 0.119	0.906
Diptera	205.00 ± 319.97	900.90 ± 750.46	− 2.310	**0.021**
EPT	369.87 ± 382.12	790.80 ± 809.21	− 1.955	0.051
Ephemeroptera	249.87 ± 159.88	276.90 ± 247.03	− 178.00	0.859
Oligochaeta	44.20 ± 122.06	105.90 ± 271.12	− 0.734	0.463
Others	4.80 ± 14.47	1.70 ± 1.947	− 0.965	0.335
Plecoptera	10.60 ± 17.618	2.10 ± 5.384	− 2.366	**0.018**
Trichoptera	109.40 ± 257.113	511.80 ± 681.287	− 1.955	0.510

4.3.2.9. Season-specific comparison of dominance and abundance by functional feeding groups across the EHBF

The gathering collectors were more dominant functional feeding group within respective season (Figure 45). Across seasons, pre-monsoon had higher dominance of filtering collectors and scraper whereas shredders, predators and gathering collectors had higher post-monsoon dominance. The functional analysis of stream macroinvertebrates higher storage FPOM in bed sediments across both seasons (Table 45).

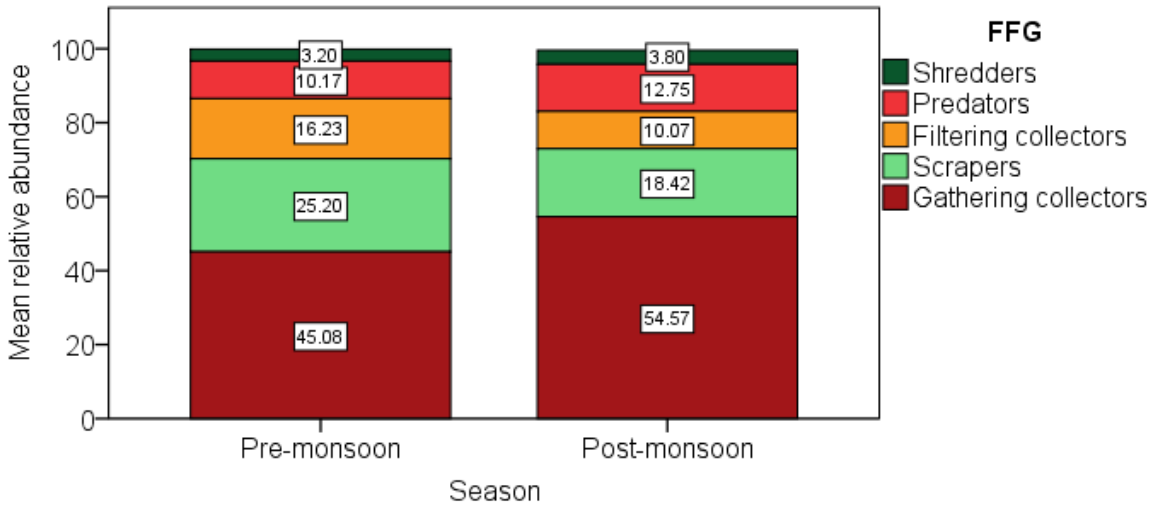


Figure 45. Season-specific dominance of functional feeding groups across the EHBF.

Table 45. Season-specific functional analysis of stream macroinvertebrates across the EHBF.

Ecosystem attributes	Pre-monsoon	Post-monsoon
Autotrophy heterotopy	0.39	0.29
Filtering collector index	0.38	0.18

The abundance of filtering collectors was higher during pre-monsoon season whereas others were less during post-monsoon season. However, gathering collectors were significantly higher during post-monsoon season (Table 46).

Table 46. Season-specific comparison of abundance (mean SD) in accordance with functional feeding groups across the EHBF ($p < 0.05$).

Functional Feeding groups	Abundance (#/1.25 $m^{2)}$		Test statistics	
	Pre-monsoon	Post-monsoon	*Z*	*p*
Filtering collectors	138.47 ± 309.72	109.20 ± 90.87	− 1.376	0.169
Gathering collectors	266.30 ± 214.27	1053.50 ± 870.28	− 2.845	**0.004**
Predators	98.47 ± 242.34	308.80 ± 740.09	− 1.735	0.083
Scrapers	147.60 ± 143.42	276.20 ± 289.16	− 0.800	0.424
Shredders	15.60 ± 21.05	64.60 ± 149.77	− 0.044	0.965

4.3.2.10. Season-specific indicator taxa for the EHBF

The cluster analysis of community composition from the EHBF resulted in two distinct cluster (0 % similarity, Figure 46). The first cluster reflected all pre-monsoon community composition (≈ 15 % similarity), and second cluster reflected all post-monsoon sampling sites (≈ 38 % similarity).

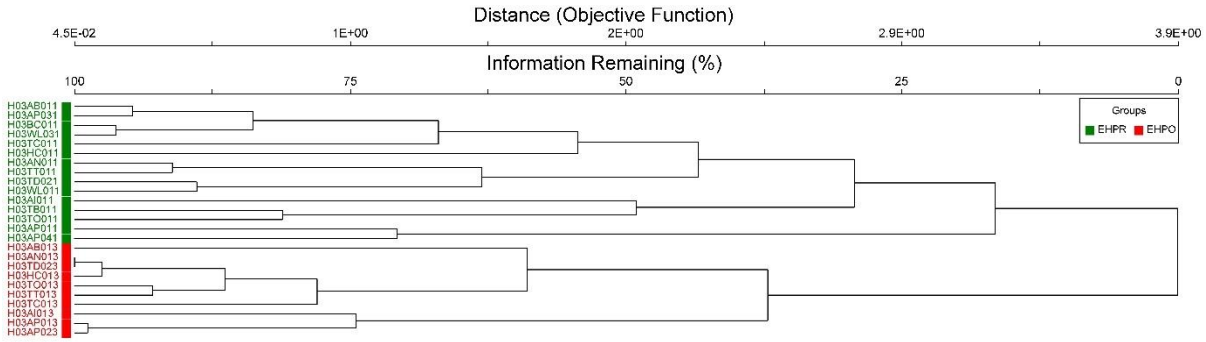


Figure 46. Hierarchical cluster analysis of macroinvertebrate communities across the EHBF (EHPR = Eastern Himalayan Broadleaf Forests, pre-monsoon sites, EHPO = Eastern Himalayan Broadleaf Forests, post-monsoon sites).

The output of Indicator Species Analysis (ISA) identified 25 significant indicators across pre-monsoon and post-monsoon season for the EHBF with indicator value (IV) ranging from 40.00 – 90.00 and all were considered either as excellent or good indicators (Table 47).

Table 47. List of season-specific indicator taxa across the EHBF (excellent indicators = IV ≥ 60, good indicators = IV ≥ 40 – < 60, $p < 0.05$ are in bold, * exclusive taxa to season, ** exclusive and among 10 dominant taxa for particular season).

Season	Taxa	Indicator value (IV)	Mean	SD	*p*
Pre-monsoon	*Epeorus* sp. *	66.70	29.10	8.32	**0.0010**
Pre-monsoon	Scirtidae Gen. sp. **	60.00	27.70	7.61	**0.0020**
Pre-monsoon	Athericidae Gen. sp.	57.60	35.30	7.57	**0.0152**
Pre-monsoon	*Paraleptophlebia* sp. *	53.30	25.10	7.67	**0.0068**
Pre-monsoon	Simuliidae Gen. sp.	49.20	42.40	6.83	0.1890
Pre-monsoon	*Acentrella* sp.	49.20	42.50	6.66	0.2014
Pre-monsoon	*Amphinemura* sp. *	46.70	23.10	7.68	**0.0218**
Post-monsoon	*Epeorus bispinosus* *	90.00	27.60	7.62	**0.0002**
Post-monsoon	*Lepidostoma* sp. **	90.00	27.50	7.57	**0.0002**
Post-monsoon	*Hexatoma* sp. *	80.00	25.30	7.85	**0.0002**
Post-monsoon	*Hydropsyche* sp.	78.40	31.90	7.58	**0.0002**
Post-monsoon	*Hydrocyphon* sp.	70.00	23.10	7.70	**0.0004**
Post-monsoon	Chironomidae Gen. sp.	68.20	42.70	6.85	**0.0096**
Post-monsoon	*Rhyacophila* sp.	65.70	37.30	7.15	**0.0060**
Post-monsoon	*Dicranota* sp. *	60.00	21.20	7.20	**0.0006**
Post-monsoon	*Parapsyche* sp. *	60.00	21.10	7.17	**0.0010**
Post-monsoon	Psephenoidinae Gen. sp. *	60.00	21.00	7.13	**0.0016**
Post-monsoon	*Himalopsyche* sp. *	60.00	21.00	7.17	**0.0018**
Post-monsoon	*Glossosomatinae* Gen. sp.	54.00	22.90	7.68	**0.0064**
Post-monsoon	*Deuterophlebiidae* Gen. sp.	54.00	23.20	7.86	**0.0076**
Post-monsoon	*Atherix* sp. *	50.00	18.00	7.88	**0.0042**
Post-monsoon	*Hyporhyacophila* sp. *	50.00	18.10	7.84	**0.0054**
Post-monsoon	*Psychomyia* sp.	49.10	25.30	7.81	**0.0288**
Post-monsoon	*Antocha* sp.	48.00	40.90	6.73	0.2268
Post-monsoon	*Stenopsyche* sp.	44.50	35.50	7.98	0.2350
Post-monsoon	Diptera Gen. sp.	44.10	21.00	7.06	**0.0214**
Post-monsoon	*Ephacerella* sp.	44.10	21.00	7.28	**0.0240**
Post-monsoon	*Agapetinae* Gen. sp.	44.10	21.10	7.36	**0.0280**
Post-monsoon	*Kisaura* sp. *	40.00	16.30	6.42	**0.0186**

Among the 5 significant pre-monsoon indicators, *Epeorus* sp. (IV = 66.70, $p = 0.0010$) and Scirtidae Gen. sp. (IV = 60.00, $p = 0.0020$) were the excellent indicators whereas Athericidae Gen. sp. (IV = 57.60, $p = 0.0152$), *Paraleptophlebia* sp. (IV = 53.30, p = 0.0068) and *Amphinemura* sp. (IV = 46.70, p = 0.0218) were the good indicators.

Out of 20 significant post-monsoon indicators from the EHBF, 11 taxa were excellent indicators whereas 9 were good indicators. Excellent indicators include *Epeorus bispinosus* (IV = 90.00, $p = 0.0002$), *Lepidostoma* sp. (IV = 90.00, $p = 0.0002$), *Hexatoma* sp. (IV = 80.00, $p = 0.0002$), *Hydropsyche* sp. (IV = 78.40, $p = 0.0002$), *Hydrocyphon* sp. (IV = 70.00, $p = 0.0004$), Chironomidae Gen. sp. (IV = 68.20, $p = 0.0096$), *Rhyacophila* sp. (IV = 65.70, $p = 0.0060$), *Dicranota* sp. (IV = 60.00, $p = 0.0006$), *Parapsyche* sp. (IV = 60.00, $p = 0.0010$), Psephenoidinae Gen. sp. (IV = 60.00, $p = 0.0016$) and *Himalopsyche* sp. (IV = 60.00, p = 0.0018).

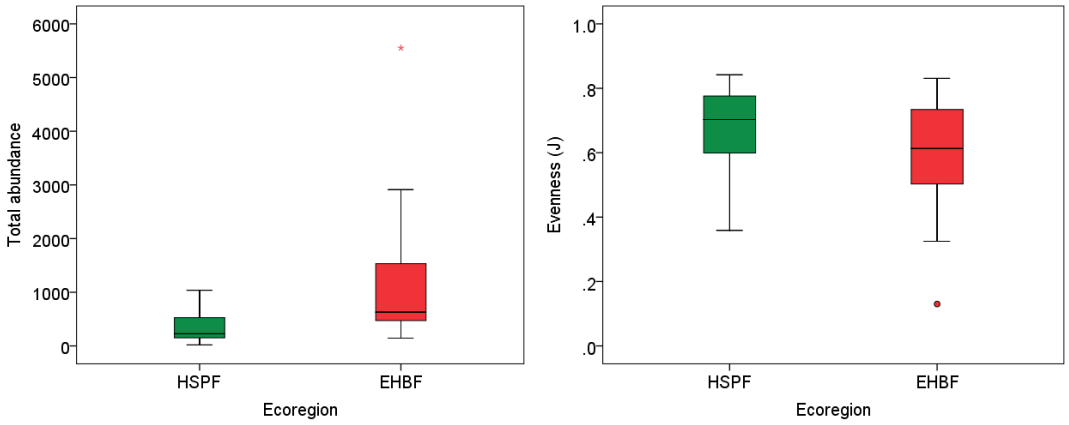
Good indicators for post-monsoon season across the EHBF were *Glossosomatinae* Gen. sp. (IV = 54.00, *p* = 0.0064), *Deuterophlebiidae* Gen. sp. (IV = 54.00, *p* = 0.0076), *Atherix* sp. (IV = 50.00, *p* = 0.0042), *Hyporhyacophila* sp. (IV = 54.00, *p* = 0.0054), *Psychomyia* sp. (IV = 49.00, *p* = 0.0288), Diptera Gen. sp. (IV = 44.10, *p* = 0.0214), *Ephacerella* sp. (IV = 44.10, *p* = 0.0064), *Agapetinae* Gen. sp. (IV = 44.10, *p* = 0.0280) and *Kisaura* sp. (IV = 40.00, *p* = 0.0186). Most of the significant indicators across both seasons were exclusive taxa (Table 47).

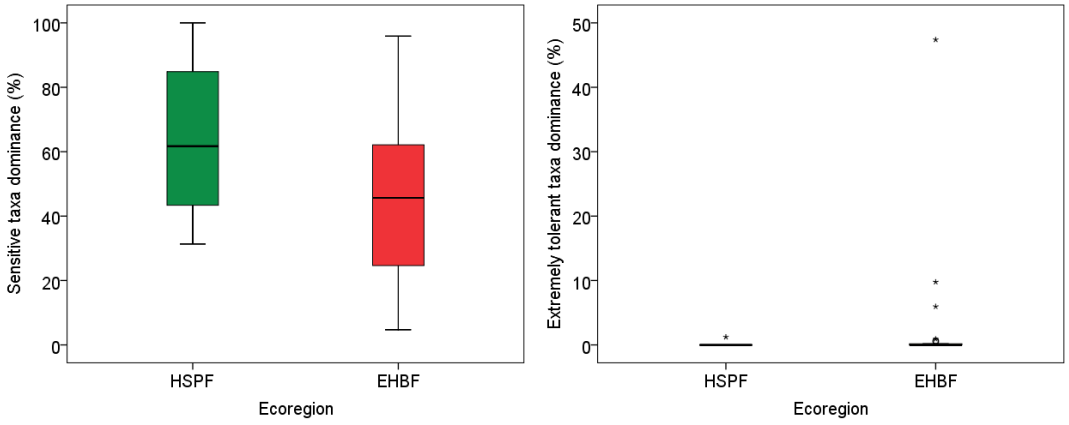
4.4. Summary table and figures for significant metrics
4.4.1. Ecoregion-specific significant metrics

Here, summary of ecoregion-specific (the Himalayan Subtropical Pine Forests, HSPF *vs* the Eastern Himalayan Broadleaf Forests, EHBF) significant metrics ($p < 0.05$) are reflected (Figure 47, Table 48). All dominance metrics are based on relative abundance data. Abundance based on abundance data.

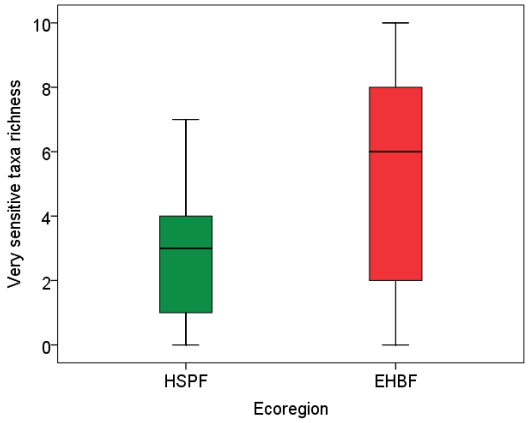
Table 48. Ecoregion-specific summary table of significant metrics across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF).

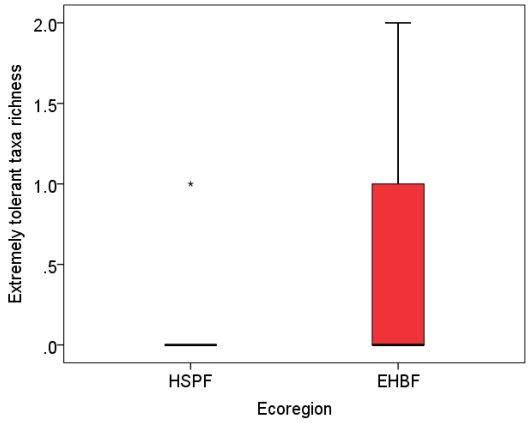
Biological metrics	**HSPF**	**EHBF**	***U***	***p***
Total abundance (individuals/1.25 m^2)	343.38 ± 305.645	1128.20 ± 1161.54	108.00	0.001
Evenness (*J*)	0.67 ± 0.14	0.60 ± 0.17	170.50	0.042
Sensitive taxa dominance (%)	65.26 ± 22.96	45.83 ± 25.27	159.00	0.022
Extremely tolerant dominance (%)	0.06 ± 0.27	2.61 ± 9.59	192.00	0.025
Very sensitive taxa richness	2.67 ± 2.058	5.28 ± 3.26	139.50	0.006
Extremely tolerant taxa richness	0.05 ± 0.218	0.44 ± 0.77	189.50	0.020
Coleoptera dominance (%)	12.44 ± 15.89	5.32 ± 7.55	188	0.099
Diptera dominance (%)	7.63 ± 10.34	34.57 ± 26.84	74	0.000
EPT dominance (%)	74.17 ± 17.14	55.67 ± 26.74	152.00	0.015
Other taxonomic group dominance (%)	2.78 ± 2.93	0.39 ± 1.12	70	0.000
Plecoptera dominance (%)	0.35 ± 0.81	1.47 ± 2.80	181.50	0.048
Trichoptera dominance (%)	40.44 ± 24.71	17.66 ± 18.50	115.00	0.001
Diptera taxa richness	2.52 ± 2.87	6.44 ± 2.88	84.50	0.000
Other taxonomic group taxa richness	2.10 ± 1.73	0.96 ± 1.020	152	0.010
Plecoptera taxa richness	0.43 ± 0.81	1.48 ± 2.40	179	0.041
Diptera abundance	42.86 ± 87.08	483.36 ± 626.09	62.00	0.000
EPT abundance	247.52 ± 227.58	538.24 ± 612.398	153.50	0.016
Ephemeroptera abundance	129.52 ± 127.52	260.68 ± 194.93	144.50	0.009
Other taxonomic group abundance	9.95 ± 16.23	3.56 ± 11.29	151.50	0.013
Plecoptera abundance	1.29 ± 3.33	7.20 ± 14.49	174.00	0.031
Gathering collector's abundance	126.48 ± 161.68	581.12 ± 682.47	80.00	0.000
Predators' abundance	42.67 ± 76.49	182.60 ± 500.72	149.00	0.012

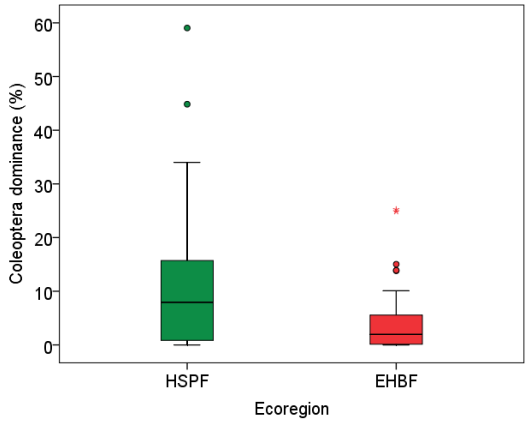


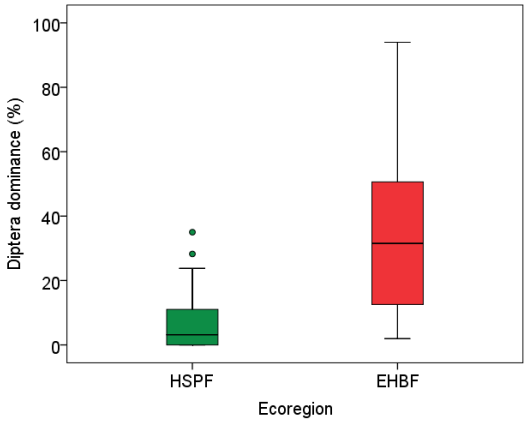

Sensitive taxa dominance (%)
100
80
60
40
20
0
HSPF
EHBF
Ecoregion

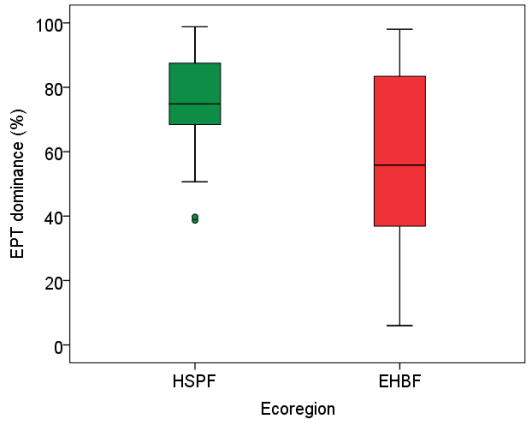
Extremely tolerant taxa dominance (%)
50
40
30
20
10
0
HSPF
EHBF
Ecoregion

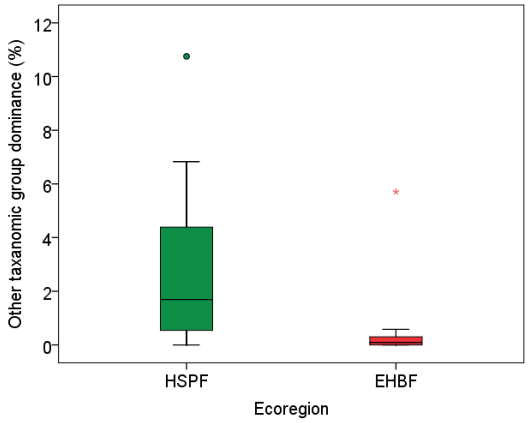

Very sensitive taxa richness
10
8
6
4
2
0
HSPF
EHBF
Ecoregion

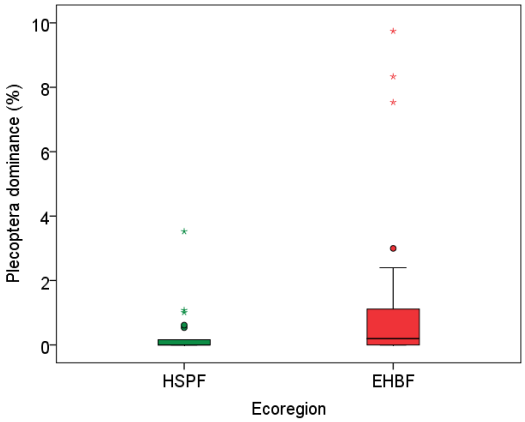

Extremely tolerant taxa richness
2.0
1.5
1.0
.5
.0
HSPF
EHBF
Ecoregion

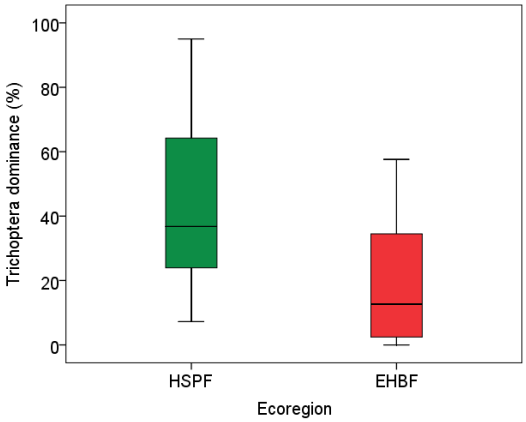

Coleoptera dominance (%)
60
50
40
30
20
10
0
HSPF
EHBF
Ecoregion

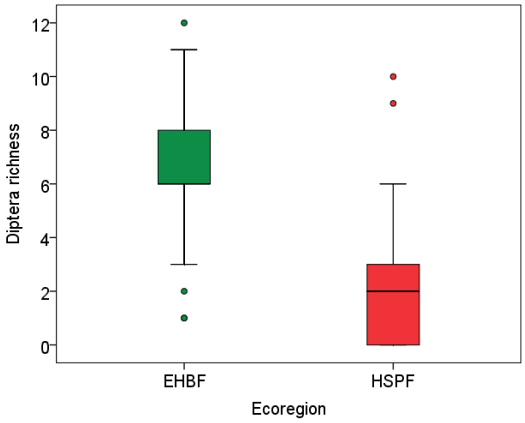

Diptera dominance (%)
100
80
60
40
20
0
HSPF
EHBF
Ecoregion

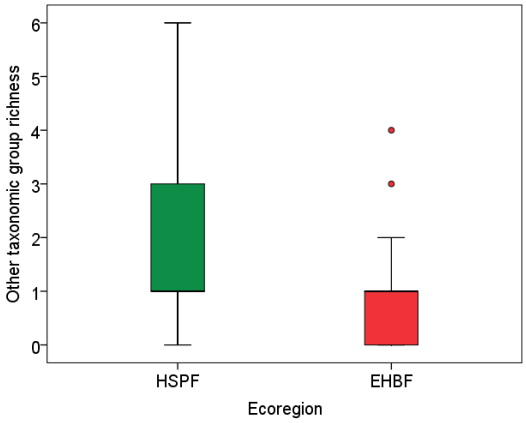

EPT dominance (%)
100
80
60
40
20
0
HSPF
EHBF
Ecoregion

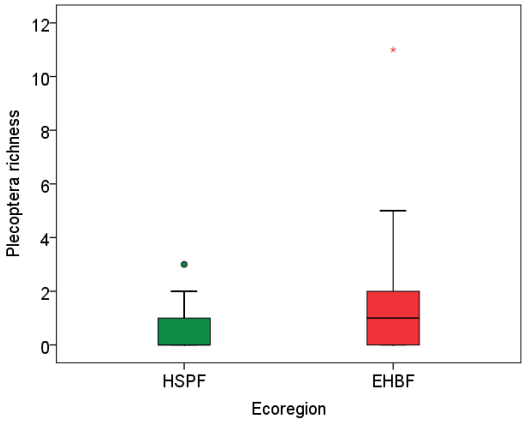

Other taxanomic group dominance (%)
12
10
8
6
4
2
0
HSPF
EHBF
Ecoregion

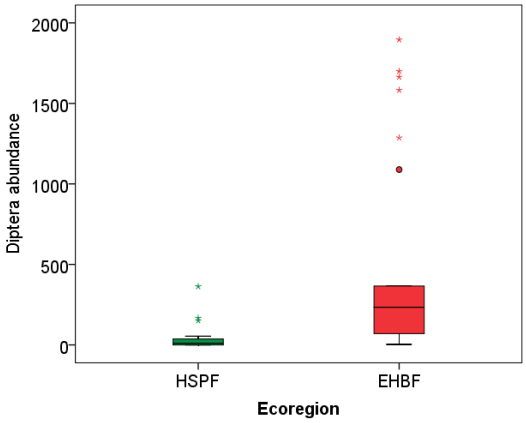

Plecoptera dominance (%)
10
8
6
4
2
0
HSPF
EHBF
Ecoregion

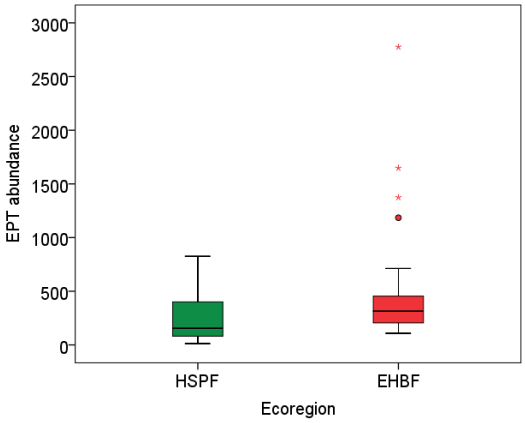

Trichoptera dominance (%)
100
80
60
40
20
0
HSPF
EHBF
Ecoregion

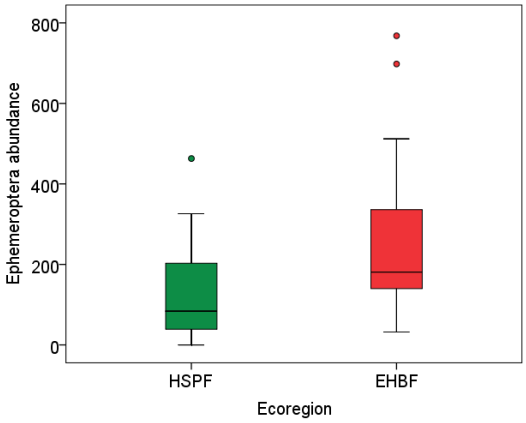

Diptera richness
12
10
8
6
4
2
0
EHBF
HSPF
Ecoregion


Other taxonomic group richness
6
5
4
3
2
1
0
HSPF
EHBF
Ecoregion


Plecoptera richness
12
10
8
6
4
2
0
HSPF
EHBF
Ecoregion


Diptera abundance
2000
1500
1000
500
0
HSPF
EHBF
Ecoregion


EPT abundance
3000
2500
2000
1500
1000
500
0
HSPF
EHBF
Ecoregion


Ephemeroptera abundance
800
600
400
200
0
HSPF
EHBF
Ecoregion

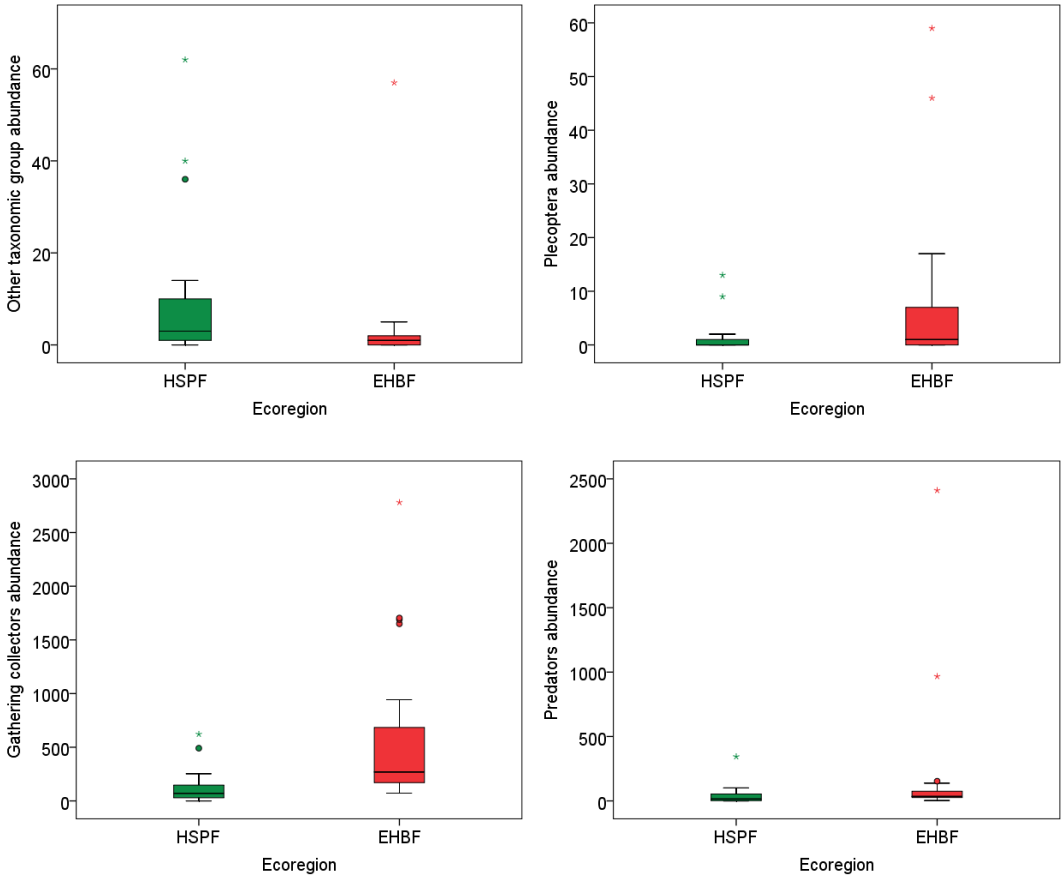


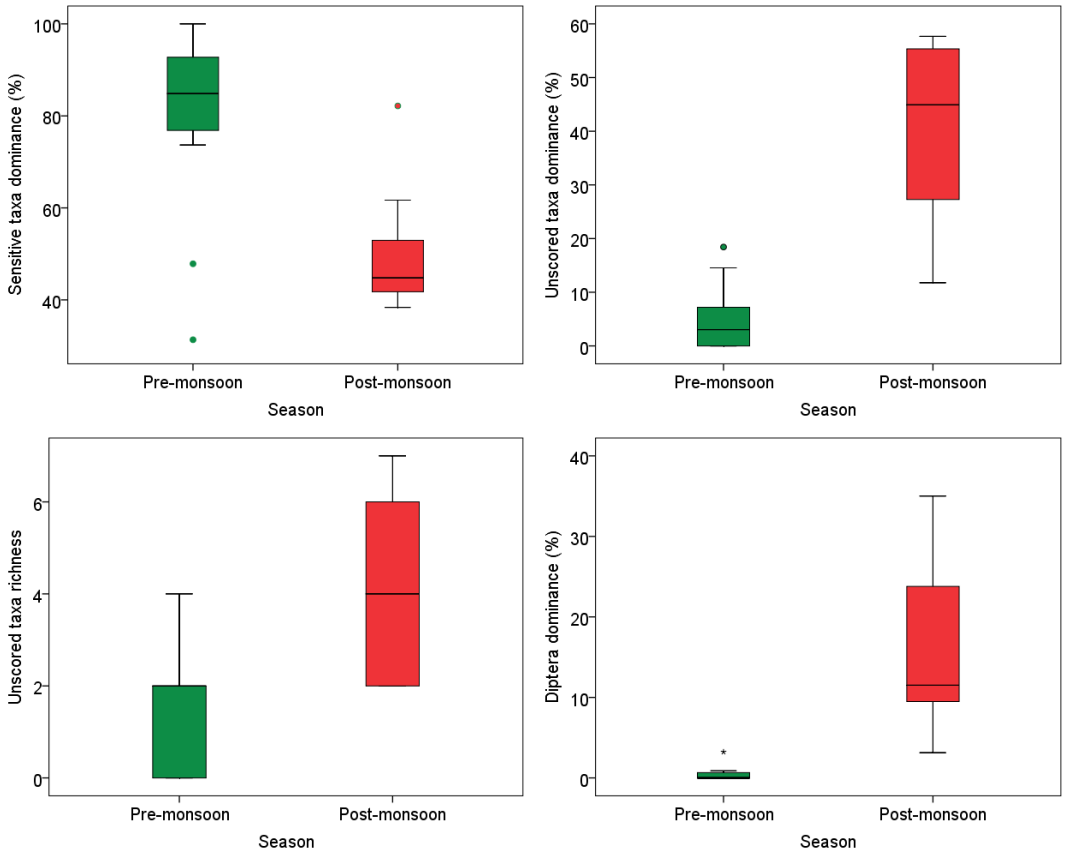
Figure 47. Ecoregion-specific comparison and distribution of significant metrics across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF).

4.4.2. Season-specific significant metrics from the HSPF

The summary of season-specific significant metrics ($p < 0.05$) across the Himalayan Subtropical Pine Forests (pre-monsoon *vs* post-monsoon) are reflected (Figure 48, Table 49). All dominance metrics are based on relative abundance data. Abundance based on abundance data.

Table 49. Season-specific summary table of significant metrics across the Himalayan Subtropical Pine Forests (HSPF).

Biological metrics	**Pre-monsoon**	**Post-monsoon**	***Z***	***p***
Sensitive taxa dominance (%)	79.03 ± 21.31	50.11 ± 13.41	– 2.310	0.021
Unscored taxa dominance (%)	5.02 ± 6.36	40.20 ± 17.40	– 2.547	0.011
Unscored taxa richness	1.55 ± 1.51	4.00 ± 2.06	– 1.982	0.047
Diptera dominance (%)	0.51 ± 0.96	15.47 ± 10.30	– 2.666	0.008
Diptera taxa richness	0.73 ± 1.01	4.50 ± 2.99	– 2.524	0.012
Other taxonomic group richness	1.18 ± 0.75	3.10 ± 1.97	– 2.120	0.034
Diptera abundance	2.09 ± 3.78	87.70 ± 112.12	− 2.666	0.008
Other taxonomic group abundance	4.91 ± 11.67	15.50 ± 19.21	− 2.312	0.021
Gathering collectors	51.45 ± 65.50	209.00 ± 197	− 2.073	0.038
Shredder	4.55 ± 7.37	37.50 ± 91.21	− 2.383	0.017



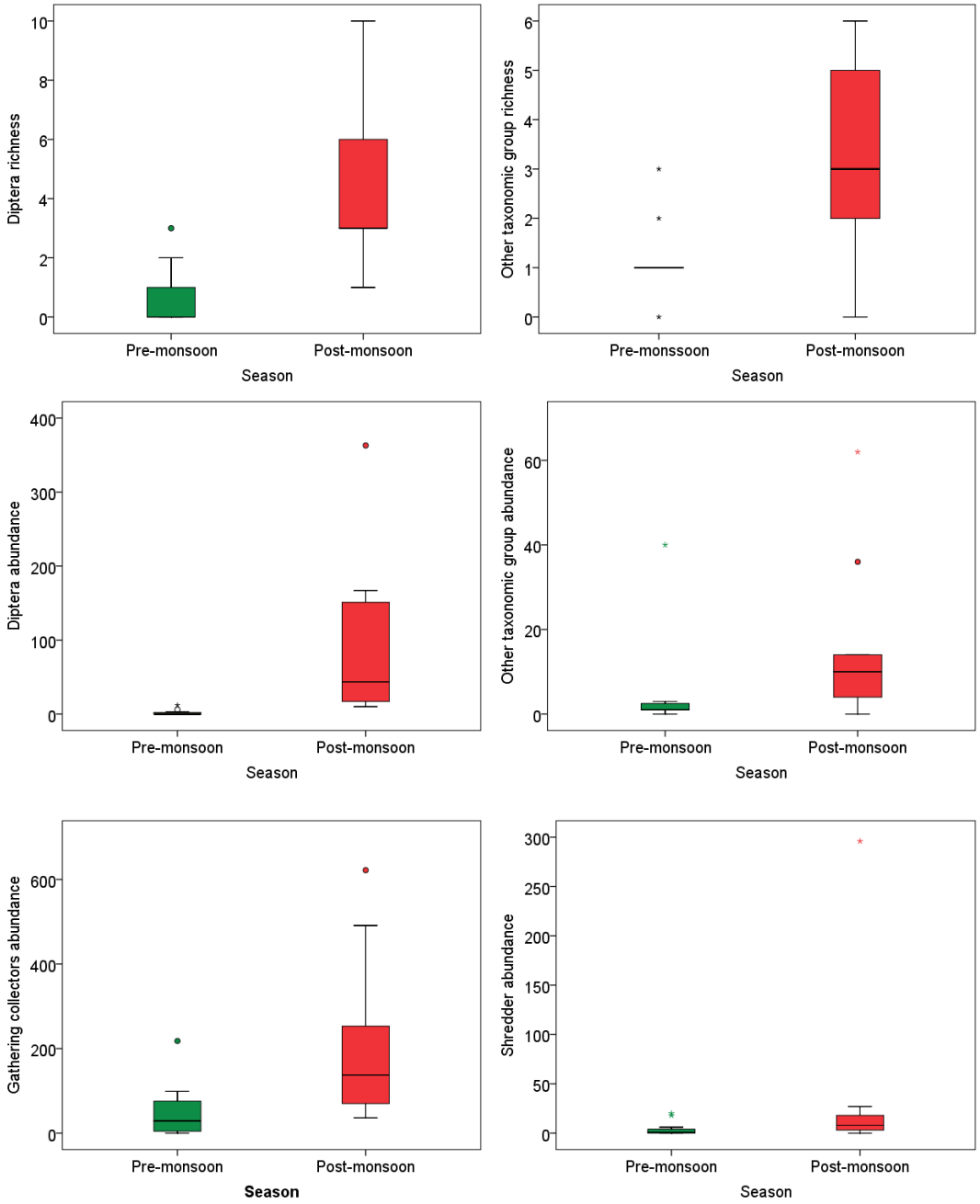


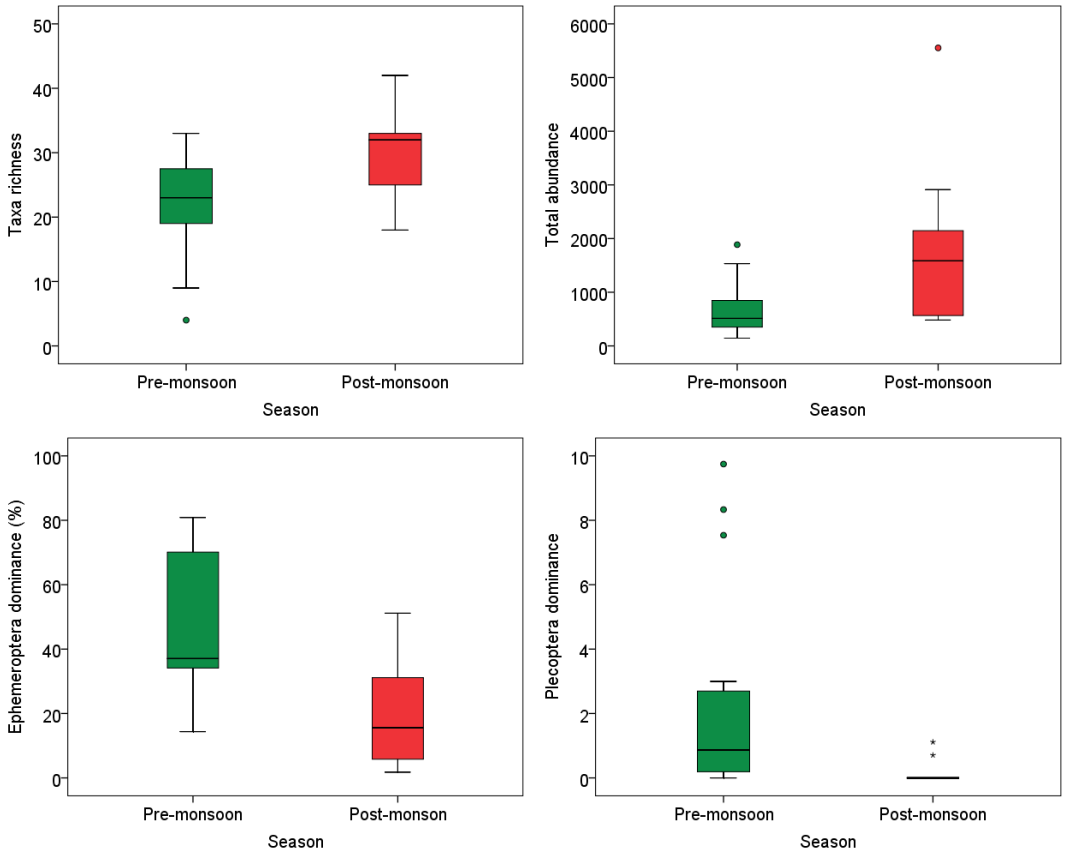
Figure 48. Season-specific comparison and distribution of significant metrics across the HSPF.

4.4.3. Season-specific significant metrics from the EHBF

The summary of season-specific significant metrics ($p < 0.05$) across the Eastern Himalayan Broadleaf Forests (pre-monsoon *vs* post-monsoon) are reflected (Figure 49, Table 50). All dominance metrics are based on relative abundance data. Abundance based on abundance data.

Table 50. Season-specific summary table of significant metrics from the Eastern Himalayan Broadleaf Forests (EHBF).

Biological metrics	**Pre-monsoon**	**Post-monsoon**	***Z***	***p***
Taxa richness (*S*)	22.27 ± 7.95	30.50 ± 6.65	– 2.194	0.028
Total abundance (individuals/1.25 m^2)	666.73 ± 494.54	1820 ± 1526.44	– 2.293	0.022
Ephemeroptera dominance (%)	46.80 ± 22.78	20.58 ± 18.12	– 2.090	0.037
Plecoptera dominance (%)	2.32 ± 3.26	0.18 ± 0.39	– 2.666	0.008
Coleoptera richness	1.47 ± 1.36	2.80 ± 1.55	– 2.448	0.014
Plecoptera richness	2.27 ± 2.81	0.30 ± 68	– 2.555	0.011
Trichoptera richness	3.60 ± 2.87	10.50 ± 2.41	– 2.818	0.005
Diptera abundance	205.00 ± 319.97	900.90 ± 750.46	− 2.310	0.021
Plecoptera abundance	10.60 ± 17.618	2.10 ± 5.384	− 2.366	0.018
Gathering collector's abundance	266.30 ± 214.27	1053.50 ± 870.28	− 2.845	0.004



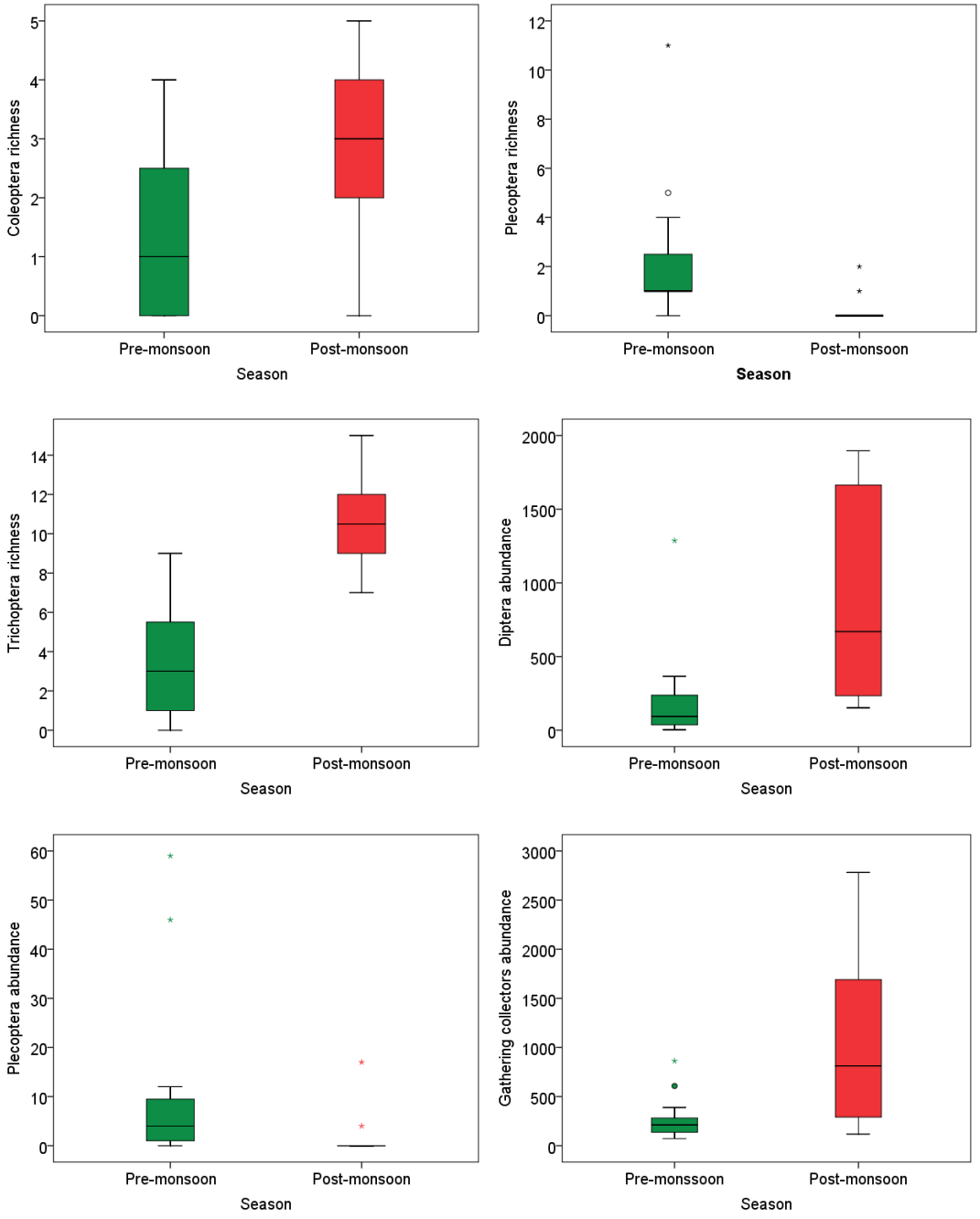


Figure 49. Season-specific comparison and distribution of significant metrics across the EHBF.

CHAPTER 5. DISCUSSION

5.1. Spatial variation of macroinvertebrate communities

5.1.1. Ecoregion (ER) approach and management of freshwater ecosystems

The ecoregion (ER) approach of delineating freshwater water bodies into homogenous entity is an important step in management, conservation and biological assessment of aquatic ecosystems (Gerritsen et al. 2000; Abell et al. 2008). The ecoregion approach considers area that are relatively homogenous in terms of environmental conditions (geology, soil, vegetations and climatic conditions) and therefore they are expected to harbour similar biological communities, then the adjacent regions. The concordance of macroinvertebrate communities in accordance with ecoregion approach (terrestrial-based systems) are reported from North America (Feminella 2000; Rabeni and Doisy 2000), Europe (Johnson 2000; Mykra et al. 2004; Heino et al. 2007) and South America (Pero et al. 2019). As consequences, the European Water Framework Directive (WFD) requires usage of ecoregion approach facilitated by typologies (Sandin and Verdonschot 2006) to remove natural variability for meaningful assessment, management and conservation of aquatic ecosystem as whole (Borja et al. 2004; Solheim et al. 2019). The distinct taxonomic and functional composition of macroinvertebrates across the Himalayan Subtropical Pine Forests (HSPF) and the Eastern Himalayan Broadleaf Forests (EHBF) of Bhutan through multi-scale regularly factors confirm concordance of aquatic communities in accordance with ecoregion approach (Figure 9, Figure 10).

The knowledge on multi-scale regulation of macroinvertebrate community structure are poorly studied (Heino et al. 2007) and is true for Bhutan. The interaction of multiple factors acting at different scales offers an extremely heterogeneous stream environment, which governs the spatiotemporal assemblage structure of local biocoenosis through environmental filtering (Poff 1997; Mykra et al. 2004; Heino et al. 2007). The distinct communities are as function of among-ecoregion heterogeneity and within-ecoregion homogeneity in climatic conditions (proxies: altitude, longitude, latitude), geology (proxy: total hardness) and catchment vegetation (proxy: forest cover in catchment, Figure 9). In accordance with this study, organization of macroinvertebrate communities across near-natural Bhutanese streams were mostly characterized by spatial-scale environmental factors such as altitude, latitude, longitude and catchment forest type (Figure 9). Spatial-scale environmental factors are considered to be more influential across the ecoregions (Heino et al. 2007) and most often, altitude is an important factor for determining the composition of stream biocoenosis.

Similarly, across Bhutan, altitude was most important among spatial environmental variable and present finding corroborates with previous studies from Himalayan region of Nepal (Ormerod et al. 1994; Suren 1994; Thapa et al. 2020) and Tibet (Xu et al. 2014). The altitudinal difference influences the amount of solar radiation and rainfall, which subsequently determines the terrestrial vegetation and also influences instream temperature, discharge, habitat conditions and biotic composition (Kong et al. 2013; He et al. 2020). The steep elevational differences between the Himalayan Subtropical Pine Forests (324 – 1467 m a.s.l.) and the Eastern Himalayan Broadleaf Forests (2175 – 2874 m. a.s.l.) can be attributed to significant differences in temperature across two ecoregions, cascading the influence on stream biocoenosis. The siliceous pre-dominated catchment geology of the Himalayan Subtropical Pine Forests and calcareous pre-dominated catchment geology of the Eastern Himalayan Broadleaf Forests is also evident in form of significant differences in spatial variation of total hardness (Figure 8, Table 9). Concordance among taxonomic and functional composition of macroinvertebrates indicate ecosystem (ER) approach as useful tool in delineation of aquatic ecosystems in Bhutan, and probably for neighbouring Hindu-Kush Himalaya (HKH) countries for implementation of biomonitoring, management and conservation actions at broader scale.

5.1.2. Ecoregional pattern of macroinvertebrate communities

The Himalayan Subtropical Pine Forests (< 1800 m a.s.l.) were characterized by dominance of representatives of the order Trichoptera (Figure 18, Table 18) especially the family Hydropsychidae, like for example the genera *Hydropsyche* sp. and *Cheumatopsyche* sp. (Figure 12a). Altogether the warmer low altitude Himalayan Subtropical Pine Forest harboured a large number of exclusive Trichoptera taxa (S = 24) in comparison to cooler Eastern Himalayan Broadleaf Forest (S = 15, Table 13, Table 14). Most of the dominant taxa from the Himalayan Subtropical Pine Forests also belonged to Trichoptera (*Hydropsyche* sp., *Chimarra* sp., *Lepidostoma* sp., *Cheumatopsyche* sp. and *Brachycentrus* sp., Figure 12a). This corroborates the dominance of Trichoptera from comparable altitudes (< 1700 m a.s.l.) across Thailand (Malicky and Chantaramongkol 1993). Trichoptera are considered sensitive to temperature variation along altitudinal gradients which influence their development, growth and survival (Cogo et al. 2020).

The dominance of Diptera and Ephemeroptera (Figure 18, Table 18) across the Eastern Himalayan Broadleaf Forests is consistent with their dominance across temperate regions over their subtropical counterparts (Pearson and Boyero 2009). The majority of dominant taxa from

the broadleaf forests were either members of Diptera (Chironomidae Gen. sp. and Simuliidae Gen. sp.) or Ephemeroptera (*Baetis* sp., Baetiella sp., *Cincticostella* sp., *Acentrella* sp., *Ecdyonurus* sp. and *Drunella* sp., Figure 12b). Although, exclusive Ephemeroptera were comparable, broadleaf forests was associated with highest diversity of exclusive Diptera (S = 19) as compared with coniferous forests (S = 3, Table 13, Table 14). The dominance of Diptera in temperate regions may be from characteristics of broadleaf forests, such as herb diversity and plant-specific litter quality (Scherber et al. 2014). Ephemeroptera and Diptera were also dominant groups across streams of Temperate Phobjikha catchment (Wangchuk and Dorji 2018). Presence of more than 55 taxa exclusive to each ecoregion and > 9.5 % % dominance across each (Figure 14, Figure 21) also supports the ecoregion-specific heterogenicity.

Lower abundances of macroinvertebrates (Figure 15b, Table 15), and shredders (Table 22) are reported from pine forests, as their leaf litter are poor quality food because of higher toughness, low nitrogen level and higher concentration of phenolic compounds (Martínez et al. 2013). The monotypic pine forests harbours low microflora and as a consequence, their resistant leaf-litter decompose slower in comparison to litter from diverse broadleaf trees, which are rich in bacteria decomposers and invertebrate detritivore (Usman et al. 2000). The poor physicochemical properties of soil from pine forest properties (higher bulk density, lower pH and moisture) slows down rate of mineralization (Usman et al. 2000). The quality and quantity of resources availability probably resulted in significant differences in macroinvertebrate abundances across ecoregion. Subtropical forests were also found to be poor in terms of macroinvertebrate abundance in comparison with temperate forests (Heino et al. 2018).

As expected in case of near-natural streams, the foodweb is primarily driven by autochthonous food resources (Figure 19, Table 21). However, dominance of collectors, and least dominance by shredders (Figure 19) partly corroborates the River Continuum Concept (Vannote et al. 1980). As evident from filtering collector index (Table 21), yearly resource supply in case of Himalayan Subtropical Pine Forests could be driven by increased loading of suspended particulate organic matter from catchment, resulting from higher surface runoff. The dominance by filtering collectors, e.g., *Hydropsyche* sp. across the Himalayan Subtropical Pine Forests (Figure 12a, Figure 19) and dominance by gathering collector, e.g., representatives of the Chironomidae Gen. sp. from the Eastern Himalayan Broadleaf Forest (Figure 12b, Figure 19) also signifies ecoregion-specific differences in abundance of food resource.

Higher overall taxa diversity, overall abundances, EPT abundances and higher shredder abundance was associated across the Eastern Himalayan Broadleaf Forests (Figure 15a, Figure 15b, Table 15, Table 20, Table 22) owing to resource availability (Martínez et al. 2013). The broadleaf forests with abundant litter, higher litter quality (Liu et al. 2004) and abundant shredders, probably could have enhanced instream processing of coarse particulate organic matter, increasing supply of deposited fine particulate organic matter for the gathering collectors.

On contrary, dominance of shredders (Figure 19) was higher across the Himalayan Subtropical Pine Forests, including the dominance of *Lepidostoma* sp. (Figure 12a, Figure 12b). Shredders from the Himalayan Subtropical Pine Forests were represented by exclusive Trichoptera (*Anisocentropus* sp., Lepidostomatidae Gen. sp., *Marilia* sp., *Psilotreta* sp., Sericostomatidae Gen. sp. and *Zephyropsyche* sp., Figure 21, Table 12) whereas from the Eastern Himalayan Broadleaf Forests were represented by exclusive Plecoptera (*Indonemoura* sp., *Mesonemoura* sp., *Nemoura* sp., *Nemouridae* Gen. sp., and *Paraleuctra* sp. Figure 21, Table 13). In absence of alternative food resources, Trichoptera shredders are efficient in processing pine needle and are diverse in streams flowing through pine forests than deciduous streams (Whiles and Wallace 1997). The dominance of *Lepidostoma* sp. across both ecoregions (Figure 12a, Figure 12b) emphasizes their importance in instream litter processing in Bhutanese streams, probably indicating existence of different species. This is evident from different taxa adapted to resource type (Trichoptera in coniferous forests vs Plecoptera in broadleaf forests).

The taxonomic and functional differences in assemblage patterns of macroinvertebrates are further supported by distinct indicator taxa (Table 23). As indicated earlier, *Hydropsyche* sp. (Trichoptera: Hydropsychidae) was the best taxa indicative of the Himalayan Subtropical Pine Forests, whereas Simuliidae Gen. sp. (Diptera) and *Drunella* sp. (Ephemeroptera: Ephemerellidae) was best indicator taxa for the Eastern Himalayan Broadleaf Forests. Hydropsychidae are considered to be dominant families across subtropical and tropical regions worldwide (Morse 2016) and are characteristics fauna for lowland streams in Nepal (Suren 1994).

5.2. Temporal patterns of macroinvertebrate communities within ecoregions (ER)

Understanding on temporal variability of macroinvertebrate communities is important aspect in biomonitoring program (Chi et al. 2017). The temporal changes in assemblage of macroinvertebrates are mainly attributed to seasonal changes in discharge, temperature regime,

and concentration of nutrients (Dorji 2016; Chi et al. 2017; Shah, Sharma, and Bharati 2020; Thapa et al. 2020). Within particular ecoregion, current velocity and habitat characteristics, i.e., riffles expressed as proportion of pools were most important local variables determining the seasonal composition of taxa across the Himalayan Subtropical Pine Forests (Figure 23), whereas the proportion of gabions across bank indicating naturalness of instream habitat was the most important deterministic variable across the Eastern Himalayan Broadleaf Forests (Figure 35). The velocity of water is an important factor in influencing the distribution of macroinvertebrate and elsewhere are reported to influence food supply (Habdija et al. 2004), dissolved oxygen concentration and substrate composition (Thapa et al. 2020).

The riffle-pool sequence is an important instream feature and changes in such habitat characteristics are known to affect community composition by influencing the flow velocity, oxygen concentration, coarse substrate and drifting food particles (Herbst et al. 2018). All the sites across the EHBF were without bank stabilization structures, except for Pachhu (< 20 %) and absence of such structures across other sites, indicates natural ecosystem dynamics to be vital for shaping the macroinvertebrate community composition. One important hydrological factor discriminating season and subsequently influencing the assemblage pattern is flow regime (Shah et al. 2020). Although, the data contained information on multitude of environmental variables, information on site-specific discharge were relatively poor and their influence should not be ignored in future assessments.

5.2.1. Seasonal patterns of macroinvertebrate communities across the HSPF

The present result reflected distinct macroinvertebrate communities in accordance with season across the Himalayan Subtropical Pine Forests, indicating strong temporal variations in taxonomic structure of macroinvertebrate assemblage as function of season (Figure 23). The composition of ten most dominant taxa over season showed high degree of temporal instability. The pre-monsoon season were pre-dominated by *Hydropsyche* sp. both in terms of composition and occurrences whereas the post-monsoon was dominated by *Baetis* sp. both in terms of composition and occurrences (Figure 26a, Figure 26b). This is in consistent with earlier findings from subtropical Bhutanese streams, where the Hydropsychidae and Baetidae were found to be more abundant across comparable pre-monsoon post-monsoon sampling periods, respectively (Dorji 2016). The post-monsoon increases in overall abundance and diversity of macroinvertebrates (Figure 29, Table 27) are consistent with earlier findings, especially pertaining to set of minimally disturbed sites considered, among others in subtropical region

of Bhutan (Dorji 2016) and Nepal (Brewin et al. 2000). The gradual changes in macroinvertebrate assembles in terms of diversity, abundance and composition over time was attributed to hydrological changes, consequently driving the seasonal assemblage pattern of macroinvertebrate. Similar observations were recorded from subtropical Chinese streams (Chi et al. 2017). The changes in hydrological characteristics as function of season during present study were evident in form of hydrological surrogates, i.e., of changes in current velocity, pool-riffle sequence and stream width (Figure 23). In addition, corresponding to present sampling months, the occurrences of spates are relatively higher during pre-monsoon season and consequently may have resulted in rapid post-monsoon colonization of macroinvertebrates taking advantage of stable hydromorphological conditions (Dorji 2016). The post-monsoon increase in abundance and diversity was mainly driven by increase in Ephemeroptera and Diptera (Table 31, Table 32). Representatives of these orders are adapted to rapidly fluctuating environment and their dominance during low flow seasons across subtropical monsoonal streams are attributed to their small size, fast growth and near-continuous reproduction strategies which makes them rapid colonizers (Mesa 2012; Dorji 2016).

The changes in pre-monsoon dominance of filtering collectors (*Hydropsyche* sp.) to post-monsoon dominance of gathering collectors (*Baetis* sp. and some Chironomidae Gen. sp.) explains post-monsoon decrease in dominance of Trichoptera and post-monsoon increase in dominance of Ephemeroptera and Diptera (Figure 26, Figure 32, Table 31). Moreover, ten most dominant taxa in accordance with their respective feeding groups constitute greatest share of functional feeding groups across respective season. This clearly reflects to changes in macroinvertebrate assemblage pattern as season is also driven by changes in food supply and resource acquisition. This is supported by distinct taxonomic assemblage pattern of macroinvertebrates as function of functional feeding groups (Figure 24).

The pre-monsoon macroinvertebrate composition was driven by suspended fine particulate organic matter as evident from comparable composition of filtering collectors and scrapers, and to some extend by autotropic algal production (Figure 33, Table 33). The significance of pre-monsoon autotropic production can be attributed to combined influence of temperature and bottom-up control of foodweb, subsequently supporting scrapers which are among most dominant taxa (*Grouvellinus* sp., *Ecdyonurus* sp., *Epeorus* sp. and Psephenoidinae Gen. sp., Figure 26a). The general rainfall pattern across Bhutan corresponding to present pre-monsoon sampling months are higher as compared to the post-monsoon season (National Centre for Hydrology and Meterology 2019). This may be major factor in enhancing input of

fine particulate organic matter through wash off of decomposed forest litter (Rowland et al. 2017) as resources for dominant gathering collectors (*Baeti*s sp., Chironomidae Gen. sp. and *Cincticostella* sp., Figure 26b, Figure 33).

Post-monsoon season supported significantly higher shredder abundance and dominance, in comparison with pre-monsoon season, indicating abundance of leaf litter (Figure 33, Table 34). The increased instream processing of detritus increases storage of fine particulate organic matter in stream bed as food resources to gathering collectors, which are dominant during post-monsoon season. *Lepidostoma* sp. were exclusive to post-monsoon and represented more than three quarter of shredder dominance (Figure 26b & 33). Elsewhere, they are found to be rapid colonizers (Whiles et al. 1993) providing important role in leaf litter decomposition across coniferous catchments (Whiles and Wallace 1997). This indicates they are likely the most important shredders across the Himalayan Subtropical Pine Forests. The predator-ratio of $0.01 - 0.20$ indicates balanced predator-prey ratio (Cummins 2019) which was evident only during post-monsoon season (Figure 33). The higher post-monsoon abundance of macroinvertebrates (Figure 45b, Table 42) and higher post-monsoon composition of predators (Figure 33) signifies pre-dominance of predator as function of increased resource supply. However, considering the lowest dominance by shredder dominance, the seasonal assemblage pattern of functional feeding groups across investigated first to third order streams partly corroborates with the River Continuum Concept (Vannote et al. 1980).

The best season specific indicator taxa were exclusive to particular season, reflecting shift in community composition in response seasonal changes in resources supply, in addition to other stream characteristics. *Epeorus* sp. was best indicator for pre-monsoon season (Table 35) and signifies the importance of autochthonous mobilization of food resources (Figure 33). In addition, they are reported to prefer habitats with fast current across the riffles (Wellnitz et al. 2001), which is in consistent with local-scale factors (i.e. current velocity and riffles) driving the community structure across the Himalayan Subtropical Pine Forests (Figure 23). The predator *Hexatoma* sp. was best indicator for post-monsoon (Table 35) season, probably due to higher predator-prey balance as compared to pre-monsoon season (Figure 33).

5.2.2. Seasonal patterns of macroinvertebrate communities across the EHBF

As in case of the Himalayan Subtropical Pine Forests, there was distinct seasonal composition of macroinvertebrates across the Eastern Himalayan Broadleaf Forests (Figure 35, Figure 36.). However, seasonal food web for macroinvertebrates across streams of the Eastern

Himalayan Broadleaf Forests are predominantly dependent on allochthonous resource supply, particularly storage fine particulate matter (Figure 45, Table 45). The importance of storage fine particulate matter increases with increase in abundance of shredders because of enhanced resource availability and increased processing of leaf litter. As consequences, there is post-monsoon increase in gathering collectors and post-monsoon decrease in filtering collectors (Figure 45, Table 46). This is also evident from post-monsoon dominance and abundance of shredders, e.g., *Lepidostoma* sp. (Figure 38, Table 45) following increased supply of coarse particulate organic matter. Lepidostomatidae is considered to be most dominant shredders following increased inputs of leaf litter during fall and some species are reported take benefit of abundant resource supply (Muto et al. 2011). Consequently, increased post-monsoon abundance and diversity (Figure 41, Table 39), which is in line with findings from temperate Bhutanese streams (Wangchuk and Dorji 2018) can be attributed to increased availability of coarse particulate organic matter highlighting importance of shredders in regulation of macroinvertebrate communities (Mbaka et al. 2014). However, considering the lower dominance of shredders (Figure 45) the functional composition of macroinvertebrates across season partly corroborates assemblage pattern expected across first to third order streams (Vannote et al. 1980).

The pre-monsoon dominance of representatives of EPT, Ephemeroptera (Figure 44a) and considerable post-monsoon increase in Trichoptera (Figure 44a) is consistent with catchment-level findings from temperate Bhutanese streams (Wangchuk and Dorji 2018). The dominance of Baetidae observed from temperate grasslands and forested streams of Nepal (Suren 1994) during comparable sampling season supports dominance of *Baetis* sp. observed during pre-monsoon season (Figure 39a). However, considerable post-monsoon dominance of Diptera (Chironomidae) observed during present study (Figure 39b, Figure 43a) contrast with earlier findings (Wangchuk and Dorji 2018). The members of Chironomidae are diverse and have varying level of tolerance, and as a consequence, some members are reported to occur in high abundances across near-natural sites (Beneberu et al. 2014; Mezgebu et al. 2019). It can be further justified from high diversity of very sensitive, sensitive and EPT taxa despite dominance of site by Chironomidae (e.g., post-monsoon Dreychhu). The best indicator taxa for particular season across the Eastern Himalayan Broadleaf Forests (Table 47) also signifies the seasonal availability of resources. As in case of the Himalayan Subtropical Fine Forests, the best pre-monsoon indicator taxa were *Epeorus* sp. (scraper) whereas *Epeorus bispinous*

(scraper) and *Lepidostoma* sp. (shredder) were best indicator for post-monsoon season of the Eastern Himalayan Broadleaf Forests (EHBF).

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion and recommendations

The overall macroinvertebrate community assemblages in Bhutan are distinct in accordance with ecoregions (ER), i.e., the Himalayan Subtropical Pine Forests and the Eastern Himalayan Broadleaf Forests. Altitudinal difference among ecoregions was major factor influencing the macroinvertebrate community composition. In addition, distinct communities were observed in accordance with seasons (pre-monsoon and post-monsoon) within respective ecoregion.

Of 186 taxa, only 66 taxa were common, and 120 taxa were exclusive, of which 56 taxa were exclusive to the ER Himalayan Subtropical Pine Forests and 64 were exclusive to the ER Eastern Himalayan Broadleaf Forests. The ER Himalayan Subtropical Pine Forests was characterized by Hydropsychidae (Trichoptera) whereas the ER Eastern Himalayan Broadleaf Forests was characterized mainly by Simuliidae (Diptera) and Ephemerellidae (Ephemeroptera). The diversity, exclusive taxa and dominance of Trichoptera was higher across the ER Himalayan Subtropical Pine Forests, whereas diversity, exclusive taxa and dominance of Diptera was higher across the ER Eastern Himalayan Broadleaf Forests. The dominance and diversity of Ephmeroptera were comparable across ecoregions.

The post-monsoon season were associated with higher diversity, abundance and EPT abundance. Across season, the dominance of Diptera became significant during post-monsoon season across the ER Himalayan Subtropical Pine Forests, whereas Ephemeroptera and Plecoptera was significantly dominant during pre-monsoon season across the ER Eastern Himalayan Broadleaf Forests. *Hexatoma* sp. (Diptera: Limoniidae) was indicative taxa for post-monsoon season across the ER Himalayan Subtropical Pine Forests whereas *Epeorus bispinous* (Ephemeroptera: Heptagenidae) was indicative taxa for post-monsoon season across the ER Eastern Himalayan Broadleaf Forests. *Epeorus* sp. (Ephemeroptera: Heptagenidae) was the best pre-monsoon season indicative taxa for both the ecoregions. The difference in macroinvertebrate composition among ecoregions and seasons within a particular ecoregion also changed as function of resource availability. Although collectors (gathering and filtering) were dominant, shredders were least dominant among functional feeding groups across ecoregion and season.

In conclusion, the tested hypotheses are shortly repeated:

1) The community structure of macroinvertebrates in the ER Eastern Himalayan Broadleaf Forests of Bhutan will show higher overall diversity, abundance, EPT abundance, EPT dominance and EPT taxa diversity as compared with the ER Himalayan Subtropical Pine Forests (**H1**). Higher overall diversity, abundance and EPT abundance from the ER Eastern Himalayan Broadleaf Forests was verified, and on contrary, higher EPT dominance and EPT diversity was falsified.

2) Due to higher elevation and resource availability, the functional feeding groups (FFGs) across the ER Eastern Himalayan Broadleaf Forests will show pre-dominance (dominance and abundance) of shredders and gathering collectors over the ER Himalayan Subtropical Pine Forests (**H2**). Higher abundance of shredders and higher abundance and dominance of gathering collectors across the ER Eastern Himalayan Broadleaf Forests was verified, whereas higher dominance by shredders was falsified.

3) Pre-monsoon ecoregion-specific assemblage pattern of macroinvertebrates will show higher total abundance, taxa diversity, EPT abundance, EPT dominance and EPT diversity. Diptera abundance, dominance, and taxa diversity will increase during post-monsoon season (**H3**). Higher pre-monsoon total abundance, taxa diversity, EPT abundance, EPT dominance and EPT diversity across both ecoregions were falsified with exception of pre-monsoon dominance of EPT from the ER Eastern Himalayan Broadleaf Forests. Post-monsoon increases in abundance, dominance and diversity of Diptera was verified across both ecoregions.

4) The dominance and abundance of shredders and gathering collectors will increases during post-monsoon season, because of increased resource availability (**H4**). These expectations were verified across both ecoregions.

5) The assemblage pattern of macroinvertebrates across season corroborates with the expectations for first to third order streams in accordance with the River Continuum Concept (**H5**). However, from present findings, composition of functional feeding groups does not agree with River Continuum Concept.

First, it must be noted that this thesis deals with biodiversity in a broader sense, as it is not concerned with species-level analyses. Nevertheless, in accordance with the present results,

the following recommendations can be proposed to improve the understanding and management of aquatic ecosystems in Bhutan:

1) Considering distinct assemblage of macroinvertebrate across two ecoregions (ER), and inadequate information on aquatic biodiversity in Bhutan, existing research in aquatic ecology, especially with regards to zoobenthos should be enhanced. Government and academic institutions are recommended to undertake collaborative exploratory survey in partnership with international institutions to strengthen taxa inventory knowledge.

2) The regional biomonitoring tools developed for HKH countries are rarely used in Bhutan. Considering this, institutions mandated with assessment of waterbodies within their jurisdictions are recommended adopt regional biomonitoring tools. The application of monitoring tool should be ecoregion-specific and season-specific within a particular ecoregion. Long-term application, understanding on regional biomonitoring tool and enhanced knowledge taxa diversity will be useful basis for improvement of existing tool or development of new bioassessment tool (if required).

3) In consideration of distinct taxonomic and functional structures of macroinvertebrates (especially high diversity of exclusive taxa) the application of the ecoregion approach is required in future aquatic biodiversity management and conservation plans. The seasonal aspect should be considered in all future assessment approaches and their further developments.

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ANNEXURES

Annexure 1. Taxa list and assignment of functional feeding groups and HKH taxa score.

Taxonomic Group	Family	Species	Functional feeding groups (FFGs)	FFGs reference	HKHBios	HKHBios reference
Coleoptera	Dryopidae	*Elmomorphus* sp.	Shredder	Merritt et al. (2008)	5	Ofenböck et al. (2010)
Coleoptera	Dytiscidae	Bidessini Gen. sp.	Predator	Merritt et al. (2008)	5	Ofenböck et al. (2010)
Coleoptera	Elmidae	*Elmidae* Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Elmidae	*Graphelmis* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Elmidae	*Grouvellinus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Elmidae	*Indosolus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Elmidae	*Stenelmis* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Eulichadidae	Eulichadidae Gen. sp.	Shredder	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Coleoptera	Gyrinidae	Gyrinidae Gen. sp.	Predator	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Coleoptera	Helodidae	Helodidae Gen. sp.	Scraper	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Coleoptera	Hydraenidae	Hydraenidae Gen. sp.	Predator	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Coleoptera	Hydrophilidae	Hydrophilidae Gen. sp.	Gathering collector	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Coleoptera	Psephenidae	Eubriinae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Psephenidae	Psephenidae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Psephenidae	Psephenoidinae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Scirtidae	*Hydrocyphon* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Scirtidae	Scirtidae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Coleoptera	Sphaeriusidae	*Sphaerius* sp.	Scraper	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Coleoptera	Staphylinidae	*Indosorius* sp.	Predator	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Diptera	Athericidae	Athericidae Gen. sp.	Predator	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Diptera	Athericidae	*Atherix* sp.	Predator	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Diptera	Blephariceridae	*Blepharicera* sp.	Scraper	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Diptera	Blephariceridae	Blephariceridae Gen. sp.	Scraper	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Diptera	Blephariceridae	*Horaia* sp.	Scraper	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Diptera	Ceratopogonidae	Ceratopogonidae Gen. sp.	Predator	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)

Diptera	Chironomidae	Chironomidae Gen. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Diptera	Chironomidae	Chironomini Gen. sp.	Gathering collector	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Diptera	Chironomidae	*Diamesa* sp.	Gathering collector	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Diptera	Chironomidae	Diamesini Gen. sp.	Gathering collector	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Diptera	Chironomidae	*Eukiefferiella* sp.	Gathering collector	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Diptera	Chironomidae	Orthocladiinae Gen. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Diptera	Chironomidae	Tanypodinae Gen. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Diptera	Chironomidae	Tanytarsini Gen. sp.	Filtering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Diptera	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Diptera	Empididae	Clinocerinae Gen. sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Diptera	Empididae	Empididae Gen. sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Diptera	Ephydridae	Ephydridae Gen. sp.	Gathering collector	Merritt et al. (2008)	1	Ofenböck et al. (2010)
Diptera	Limoniidae	*Antocha* sp.	Predator	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Diptera	Limoniidae	*Eloeophila* sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Diptera	Limoniidae	*Hexatoma* sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Diptera	Limoniidae	Limoniidae Gen. sp.	Predator	Moog (2017)	8	Ofenböck et al. (2010)
Diptera	Muscidae	*Potamia* sp.	Predator	Merritt et al. (2008)	1	Ofenböck et al. (2010)
Diptera	Order: Diptera	Diptera Gen. sp.	Unknown		Unscored	Ofenböck et al. (2010)
Diptera	Pediciidae	*Dicranota* sp.	Predator	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Diptera	Pediciidae	Pediciidae Gen. sp.	Predator	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Diptera	Pediciidae	Pediciinae Gen. sp.	Predator	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Diptera	Psychodidae	*Bazarella* sp.	Gathering collector	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Diptera	Psychodidae	Pericomini Gen. sp.	Gathering collector	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Diptera	Psychodidae	Psychodidae Gen. sp.	Gathering collector	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Diptera	Sciaridae	Sciaridae Gen. sp.	Unknown		6	Ofenböck et al. (2010)
Diptera	Simuliidae	Simuliidae Gen. sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Diptera	Tabanidae	Tabanidae Gen. sp.	Predator	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Diptera	Tipulidae	Tipulidae Gen. sp.	Shredder	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ameletidae	Ameletidae Gen. sp.	Scraper	Hudson et al. (2012)	10	Ofenböck et al. (2010)
Ephemeroptera	Baetidae	*Acentrella* sp.	Gathering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)

Ephemeroptera	Baetidae	Baetidae Gen. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Ephemeroptera	Baetidae	*Baetiella* sp.	Gathering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Baetidae	*Baetis* sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Ephemeroptera	Caenidae	*Caenis* sp.	Gathering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Cincticostella* sp.	Gathering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Crinitella* sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Drunella* sp.	Scraper	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Ephacerella* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	Ephemerellidae Gen. sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Serratella* sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Torleya* sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemerellidae	*Uracanthella* sp.	Gathering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Ephemeridae	*Ephemera* sp.	Gathering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Cinygmula* sp.	Scraper	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Ecdyonurus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Epeorus bispinosus*	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Epeorus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Epeorus unispinosus*	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	Heptageniidae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Iron* sp.	Scraper	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Notacanthurus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Heptageniidae	*Rhithrogena* sp.	Scraper	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Ephemeroptera	Isonychiidae	*Isonychia* sp.	Filtering collector	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Ephemeroptera	Leptophlebiidae	*Choroterpes* sp.	Gathering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Leptophlebiidae	*Choroterpides* sp.	Gathering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Leptophlebiidae	*Euthraulus* sp.	Gathering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Ephemeroptera	Leptophlebiidae	Leptophlebiidae Gen. sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.	Scraper	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Ephemeroptera	Neoephemeridae	*Potamanthellus* sp.	Gathering collector	Sarvar (2005)	10	Ofenböck et al. (2010)
Ephemeroptera	Potamanthidae	Potamanthidae Gen. sp.	Shredder	Merritt et al. (2008)	10	Ofenböck et al. (2010)

Ephemeroptera	Prosopistomatidae	P*rosopistoma* sp.	Scraper	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Heteroptera	Aphelocheiridae	*Aphelocheirus* sp.	Predator	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Heteroptera	Corixidae	Corixidae Gen. sp.	Scraper	Domínguez & Fernández (2009)	6	Ofenböck et al. (2010)
Heteroptera	Nepidae	*Ranatra* sp.	Predator	Merritt et al. (2019)	6	Ofenböck et al. (2010)
Heteroptera	Order: Heteroptera	Heteroptera Gen. sp.	Predator	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Hydrachnidia	Phylum: Hydrachnidia	Hydrachnidia Gen. sp.	Predator	Merritt and Cummins (1996)	Unscored	Ofenböck et al. (2010)
Lepidoptera	Pyralidae	Pyralidae Gen. sp.	Shredder	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Megaloptera	Corydalidae	Corydalidae Gen. sp.	Predator	Domínguez & Fernández (2009)	7	Ofenböck et al. (2010)
Mollusca	Pisidiidae (Shpaeriidae)	*Pisidium* sp.	Predator	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Nematoda	Mermithidae	Mermithidae Gen. sp.	Predator		Unscored	Ofenböck et al. (2010)
Odonata	Cordulegasteridae	Cordulegasteridae Gen. sp.	Predator	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Odonata	Epiophlebiidae	*Epiophlebia* sp.	Predator	Moog (2017)	10	Ofenböck et al. (2010)
Odonata	Epiophlebiidae	Epiophlebiidae Gen. sp.	Predator	Moog (2017)	Unscored	Ofenböck et al. (2010)
Odonata	Euphaeidae	Euphaeidae Gen. sp.	Predator	Moog (2017)	9	Ofenböck et al. (2010)
Odonata	Gomphidae	Gomphidae Gen. sp.	Predator	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Odonata	Suborder: Zygoptera	Zygoptera Gen. sp.	Predator	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Oligochaeta	Enchytraeidae	*Enchytraeus indicus*	Gathering collector	Merritt et al. (2019)	Unscored	Ofenböck et al. (2010)
Oligochaeta	Kingdom: Oligochaeta	Oligochaeta Gen. sp.	Gathering collector	Merritt et al. (2019)	2	Ofenböck et al. (2010)
Oligochaeta	Lumbricidae	*Eiseniella* sp.	Gathering collector	Merritt et al. (2019)	5	Ofenböck et al. (2010)
Oligochaeta	Lumbricidae	*Eiseniella tetraedra*	Gathering collector	Merritt et al. (2019)	5	Ofenböck et al. (2010)
Oligochaeta	Megascolecidae	*Amynthas corticis*	Gathering collector	Merritt et al. (2019)	6	Ofenböck et al. (2010)
Oligochaeta	Naididae	*Nais elinguis*	Gathering collector	Merritt et al. (2019)	3	Ofenböck et al. (2010)
Oligochaeta	Naididae	*Nais variabilis*	Gathering collector	Merritt et al. (2019)	3	Ofenböck et al. (2010)
Oligochaeta	Tubificidae	*Limnodrilus hoffmeisteri*	Gathering collector	Merritt et al. (2019)	1	Ofenböck et al. (2010)
Oligochaeta	Tubificidae	*Limnodrilus* sp.	Gathering collector	Merritt et al. (2019)	1	Ofenböck et al. (2010)
Oligochaeta	Tubificidae	Tubificidae Gen. sp.	Gathering collector	Merritt et al. (2019)	1	Ofenböck et al. (2010)
Plecoptera	Chloroperlidae	Chloroperlidae Gen. sp.	Predator	Moog (2017)	9	Ofenböck et al. (2010)
Plecoptera	Chloroperlidae	*Haploperla* sp.	Predator	Moog (2017)	9	Ofenböck et al. (2010)

Plecoptera	Leuctridae	*Paraleuctra* sp.	Shredder	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Plecoptera	Nemouridae	*Amphinemura* sp.	Shredder	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Plecoptera	Nemouridae	*Indonemoura* sp.	Shredder	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Plecoptera	Nemouridae	*Mesonemoura* sp.	Shredder	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Plecoptera	Nemouridae	*Nemoura* sp.	Shredder	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Plecoptera	Nemouridae	Nemouridae Gen. sp.	Shredder	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Plecoptera	Peltoperlidae	Peltoperlidae Gen. sp.	Shredder	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Plecoptera	Perlidae	*Neoperla* sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Plecoptera	Perlidae	Perlidae Gen. sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Plecoptera	Perlidae	Perlinae Gen. sp.	Predator	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Apataniidae	*Apatania* sp.	Scraper	Moog (2017)	9	Ofenböck et al. (2010)
Trichoptera	Brachycentridae	Brachycentridae Gen. sp.	Predator	Moog (2017)	8	Ofenböck et al. (2010)
Trichoptera	Brachycentridae	*Brachycentrus* sp.	Predator	Moog (2017)	6	Ofenböck et al. (2010)
Trichoptera	Brachycentridae	*Micrasema* sp.	Scraper	Moog (2017)	10	Ofenböck et al. (2010)
Trichoptera	Calamoceratidae	*Anisocentropus* sp.	Shredder	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Trichoptera	Ecnomidae	*Ecnomus* sp.	Predator	Merritt et al. (2008)	6	Ofenböck et al. (2010)
Trichoptera	Glossosomatidae	Agapetinae *Gen. sp.*	Scraper	Merritt et al. (2008)	9	Ofenböck et al. (2010)
Trichoptera	Glossosomatidae	*Agapetus* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Glossosomatidae	*Glossosoma* sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Glossosomatidae	Glossosomatidae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Glossosomatidae	Glossosomatinae Gen. sp.	Scraper	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Goeridae	*Goera* sp.	Scraper	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Trichoptera	Goeridae	Goeridae Gen. sp.	Scraper	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Trichoptera	Helicopsychidae	*Helicopsyche* sp.	Scraper	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Trichoptera	Hydrobiosidae	*Apsilochorema* sp.	Predator	Merritt et al. (2008)	10	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	*Abacaria* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	*Arctopsyche* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	*Diplectrona salai*	Filtering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	Diplectrona sp.	Filtering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)

Trichoptera	Hydropsychidae	*Hydropsyche* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	Hydropsychidae Gen. sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydropsychidae	*Parapsyche* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydroptilidae	*Hydroptila* sp.	Filamentous algae piercer	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Trichoptera	Hydroptilidae	Hydroptilidae Gen. sp.	Filamentous algae piercer	Moog (2017)	7	Ofenböck et al. (2010)
Trichoptera	Hydroptilidae	*Stactobia* sp.	Filamentous algae piercer	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydroptilidae	Stactobiini Gen. sp.	Filamentous algae piercer	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Hydroptilidae	*Ugandatrichia* sp.	Filamentous algae piercer	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Lepidostomatidae	*Lepidostoma* sp.	Shredder	Moog (2017)	8	Ofenböck et al. (2010)
Trichoptera	Lepidostomatidae	Lepidostomatidae Gen. sp.	Shredder	Moog (2017)	8	Ofenböck et al. (2010)
Trichoptera	Lepidostomatidae	*Zephyropsyche* sp.	Shredder	Merritt et al. (2008)	8	Ofenböck et al. (2010)
Trichoptera	Leptoceridae	Leptoceridae *Gen*. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Trichoptera	Leptoceridae	Leptocerinae Gen. sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Trichoptera	Leptoceridae	*Oecetis* sp.	Gathering collector	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Trichoptera	Limnephilidae	Limnephilidae Gen. sp.	Scraper	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Trichoptera	Limnephilidae	*Pseudostenophylax* sp.	Scraper	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Trichoptera	Limnocentropodidae	Limnocentropodidae Gen. sp.	Filtering collector	Tanida (2000)	Unscored	Ofenböck et al. (2010)
Trichoptera	Limnocentropodidae	*Limnocentropus* sp.	Filtering collector	Tanida (2000)	9	Ofenböck et al. (2010)
Trichoptera	Odontoceridae	*Marilia* sp.	Shredder	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Odontoceridae	*Psilotreta* sp.	Shredder	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Order: trichoptera	Trichoptera Gen. sp.	Unknown		Unscored	Ofenböck et al. (2010)
Trichoptera	Philopotamidae	*Chimarra* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Philopotamidae	Dolophilodes sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Philopotamidae	*Kisaura* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Philopotamidae	Philopotamidae Gen. sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Philopotamidae	*Wormaldia* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Polycentropodidae	*Plectrocnemia* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Polycentropodidae	Polycentropodidae Gen. sp.	Predator	Moog (2017)	7	Ofenböck et al. (2010)
Trichoptera	Polycentropodidae	*Polyplectropus* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Polycentropodidae	*Pseudoneureclipsis* sp.	Filtering collector	Merritt et al. (2008)	8	Ofenböck et al. (2010)

Trichoptera	Psychomyiidae	*Psychomyia* sp.	Filtering collector	Merritt et al. (2008)	7	Ofenböck et al. (2010)
Trichoptera	Psychomyiidae	Psychomyiidae Gen. sp.	Filtering collector	Merritt et al. (2019)	7	Ofenböck et al. (2010)
Trichoptera	Rhyacophilidae	*Himalopsyche* sp.	Predator	Merritt et al. (2019)	9	Ofenböck et al. (2010)
Trichoptera	Rhyacophilidae	*Hyporhyacophila* sp.	Predator	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Trichoptera	Rhyacophilidae	*Rhyacophila* sp.	Predator	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Trichoptera	Rhyacophilidae	Rhyacophilidae Gen. sp.	Predator	Merritt et al. (2019)	8	Ofenböck et al. (2010)
Trichoptera	Sericostomatidae	Sericostomatidae Gen. sp.	Shredder	Merritt et al. (2008)	Unscored	Ofenböck et al. (2010)
Trichoptera	Stenopsychidae	*Stenopsyche* sp.	Filtering collector	Jiang et al. (2010)	8	Ofenböck et al. (2010)
Trichoptera	Uenoidae	*Neophylax* sp.	Scraper	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Trichoptera	Uenoidae	*Uenoa* sp.	Scraper	Merritt et al. (2019)	10	Ofenböck et al. (2010)
Turbellaria	Dugesiidae	*Dugesia* sp.	Predator	Merritt and Cummins (1996)	4	Ofenböck et al. (2010)
Turbellaria	Kingdom: Turbellaria	Turbellaria Gen. sp.	Predator	Merritt and Cummins (1996)	Unscored	Ofenböck et al. (2010)
Turbellaria	Planariidae	*Polycelis* sp.	Predator	Merritt and Cummins (1996)	Unscored	Ofenböck et al. (2010)

Annexure 2. Site-wise distribution of taxa from different sampling sites across Himalayan Subtropical Pine Forests of Bhutan.

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Ngakhuchhu	24.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella tetraedra*	34
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	22
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Notacanthurus*	*Notacanthurus* sp.	21
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	20
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	19
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	15
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona* sp.	8
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	4
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	3
Ngakhuchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Elmidae*	*Elmidae* Gen. sp.	2
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	2
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	Hydropsychidae	Hydropsychidae Gen. sp.	2
Ngakhuchhu	24.04.2006	Pre-monsoon	Oligochaeta	Tubificidae	*Limnodrilus*	*Limnodrilus* sp.	2
Ngakhuchhu	24.04.2006	Pre-monsoon	Oligochaeta	Megascolecidae	*Amynthas*	*Amynthas corticis*	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Ngakhuchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	1
TOTAL (*n*)							**163**
TOTAL TAXA (*S*)							**22**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	61
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	54
Toebirongchhu	24.04.2006	Pre-monsoon	Heteroptera	Aphelocheiridae	*Aphelocheirus*	*Aphelocheirus* sp.	31
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	31
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	21
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	19
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Limnocentropodidae	Limnocentropodidae	Limnocentropodidae Gen. sp.	19
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	16
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	14
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	Lepidostomatidae	Lepidostomatidae Gen. sp.	13
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	11
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	10
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	10
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	8
Toebirongchhu	24.04.2006	Pre-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	8
Toebirongchhu	24.04.2006	Pre-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	7
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	5
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	4
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Eulichadidae	Eulichadidae	Eulichadidae Gen. sp.	4
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Indosolus*	*Indosolus* sp.	4
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	Hydropsychidae	Hydropsychidae Gen. sp.	3
Toebirongchhu	24.04.2006	Pre-monsoon	Diptera	Simuliidae	*Simuliidae*	*Simuliidae* Gen. sp.	3
Toebirongchhu	24.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	2
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	2
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	Brachycentridae	Brachycentridae Gen. sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	1

Toebirongchhu	24.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Elmidae*	*Elmidae* Gen. sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Goeridae	*Goera*	*Goera* sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Plecoptera	Perlidae	Perlidae	Perlidae Gen. sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Lepidoptera	Pyralidae	Pyralidae	Pyralidae Gen. sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
Toebirongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Torleya*	*Torleya* sp.	1
TOTAL (*n*)							**372**
TOTAL TAXA (*S*)							**36**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	324
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	150
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	146
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	65
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	59
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Goeridae	*Goera*	*Goera* sp.	25
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	13
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	12
Mochhu	25.04.2006	Pre-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	6
Mochhu	25.04.2006	Pre-monsoon	Plecoptera	Perlidae	*Neoperla*	*Neoperla* sp.	6
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	5
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	4
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	*Oecetis*	*Oecetis* sp.	4
Mochhu	25.04.2006	Pre-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	3
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	3
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	3
Mochhu	25.04.2006	Pre-monsoon	Plecoptera	Perlidae	*Perlinae*	*Perlinae* Gen. sp.	2

Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	1
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	1
Mochhu	25.04.2006	Pre-monsoon	Plecoptera	Peltoperlidae	Peltoperlidae	Peltoperlidae Gen. sp.	1
Mochhu	25.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	1
Mochhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	1
Mochhu	25.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	1
TOTAL (*n*)							**836**
TOTAL TAXA (*S*)							**23**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	95
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	80
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	77
Mochhu	28.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	37
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	21
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	15
Mochhu	28.11.2005	Post-monsoon	Plecoptera	Perlidae	Perlinae	Perlinae Gen. sp.	13
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	10
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	6
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	3
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	2
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	2
Mochhu	28.11.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	2
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	2
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	Ephemerellidae	Ephemerellidae Gen. sp.	1
Mochhu	28.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	1
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Sericostomatidae	Sericostomatidae	Sericostomatidae Gen. sp.	1
Mochhu	28.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
TOTAL (*n*)							**369**

TOTAL TAXA (*S*)	18

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	20
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	18
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	10
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	9
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Elmidae*	*Elmidae* Gen. sp.	8
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	5
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Wormaldia*	*Wormaldia* sp.	5
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	5
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Notacanthurus*	*Notacanthurus* sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	*Oecetis*	*Oecetis* sp.	2
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	1
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	1
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	1
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	1
Jichulum Rongchhu	25.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Torleya*	*Torleya* sp.	1
TOTAL (*n*)							**99**
TOTAL TAXA (*S*)							**20**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	39
Jichulum Rongchhu	24.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	34
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	17
Jichulum Rongchhu	24.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	10
Jichulum Rongchhu	24.11.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	8
Jichulum Rongchhu	24.11.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	7
Jichulum Rongchhu	24.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	6
Jichulum Rongchhu	24.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	6
Jichulum Rongchhu	24.11.2005	Post-monsoon	Diptera	Blephariceridae	*Horaia*	*Horaia* sp.	5
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	4
Jichulum Rongchhu	24.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	3
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	2
Jichulum Rongchhu	24.11.2005	Post-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	2
Jichulum Rongchhu	24.11.2005	Post-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	2
Jichulum Rongchhu	24.11.2005	Post-monsoon	Coleoptera	Elmidae	*Stenelmis*	*Stenelmis* sp.	2
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona* sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Ecnomidae	*Ecnomus*	*Ecnomus* sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Coleoptera	Dryopidae	*Elmomorphus*	*Elmomorphus* sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Torleya*	*Torleya* sp.	1
Jichulum Rongchhu	24.11.2005	Post-monsoon	Trichoptera	Uenoidae	*Uenoa*	*Uenoa* sp.	1
TOTAL (*n*)							**154**
TOTAL TAXA (*S*)							**22**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	26
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	23
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Helicopsychidae	*Helicopsyche*	*Helicopsyche* sp.	20
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Elmidae*	*Elmidae* Gen. sp.	19
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	16
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	13
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	13
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	6
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella tetraedra*	5
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	5
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	3
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Eulichadidae	Eulichadidae	Eulichadidae Gen. sp.	3
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	2
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	2
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	Ephemerellidae	Ephemerellidae Gen. sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	*Oecetis*	*Oecetis* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
Dungkhar Rongchhu	24.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	1
TOTAL (*n*)							**165**
TOTAL TAXA (*S*)							**23**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	291
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	27
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	25
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	20
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Heteroptera	Aphelocheiridae	*Aphelocheirus*	*Aphelocheirus* sp.	19
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	18
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	16
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	16
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	15
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	10
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	9
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	8
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	6
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	5
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	4
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Ecnomidae	*Ecnomus*	*Ecnomus* sp.	3
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Goeridae	*Goeridae*	*Goeridae* Gen. sp.	3
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	3
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Leptoceridae	*Oecetis*	*Oecetis* sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Sericostomatidae	Sericostomatidae	Sericostomatidae Gen. sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Tipulidae	*Tipulidae*	*Tipulidae* Gen. sp.	2
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Calamoceratidae	*Anisocentropus*	*Anisocentropus* sp.	1

Dungkhar Rongchhu	28.11.2005	Post-monsoon	Trichoptera	Hydrobiosidae	*Apsilochorema*	*Apsilochorema* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Coleoptera	Elmidae	*Graphelmis*	*Graphelmis* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Diptera	Blephariceridae	*Horaia*	*Horaia* sp.	1
Dungkhar Rongchhu	28.11.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	1
TOTAL (*n*)							**527**
TOTAL TAXA (*S*)							**37**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Bhurchhu	20.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	113
Bhurchhu	20.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	81
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	38
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	21
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	20
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	15
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Euthraulus*	*Euthraulus* sp.	10
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	8
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	7
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	6
Bhurchhu	20.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenidae	Psephenidae Gen. sp.	4
Bhurchhu	20.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	3
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Wormaldia*	*Wormaldia* sp.	3
Bhurchhu	20.04.2006	Pre-monsoon	Diptera	Ceratopogonidae	Ceratopogonidae	Ceratopogonidae Gen. sp.	2
Bhurchhu	20.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	1
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Ecnomidae	*Ecnomus*	*Ecnomus* sp.	1

Bhurchhu	20.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Elmidae*	*Elmidae* Gen. sp.	1
Bhurchhu	20.04.2006	Pre-monsoon	Hydrachnidia	Ph:hydrachnidia	Hydrachnidia	Hydrachnidia Gen. sp.	1
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	1
Bhurchhu	20.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	Hydropsychidae	Hydropsychidae Gen. sp.	1
TOTAL (*n*)							**337**
TOTAL TAXA (*S*)							**20**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	62
Bhurchhu	27.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	36
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	22
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	21
Bhurchhu	27.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	18
Bhurchhu	27.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	16
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	12
Bhurchhu	27.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	10
Bhurchhu	27.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	9
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Euthraulus*	*Euthraulus* sp.	6
Bhurchhu	27.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	5
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	3
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Choroterpes*	*Choroterpes* sp.	2
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	2
Bhurchhu	27.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	2
Bhurchhu	27.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
TOTAL (*n*)							**227**
TOTAL TAXA (*S*)							**16**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Kamikhola	19.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	12
Kamikhola	19.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella tetraedra*	5
Kamikhola	19.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona salai*	1
Kamikhola	19.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenidae	Psephenidae Gen. sp.	1
TOTAL (*n*)							**19**
TOTAL TAXA (*S*)							**4**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Kamikhola	26.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	50
Kamikhola	26.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	42
Kamikhola	26.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	19
Kamikhola	26.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	16
Kamikhola	26.11.2005	Post-monsoon	Coleoptera	Eulichadidae	Eulichadidae	Eulichadidae Gen. sp.	7
Kamikhola	26.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	3
Kamikhola	26.11.2005	Post-monsoon	Odonata	Uord:Zygoptera	Zygoptera	Zygoptera Gen. sp.	3
Kamikhola	26.11.2005	Post-monsoon	Lepidoptera	Pyralidae	Pyralidae	Pyralidae Gen. sp.	2
Kamikhola	26.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Torleya*	*Torleya* sp.	2
Kamikhola	26.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
Kamikhola	26.11.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	1
Kamikhola	26.11.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	1
Kamikhola	26.11.2005	Post-monsoon	Coleoptera	Gyrinidae	Gyrinidae	Gyrinidae Gen. sp.	1
Kamikhola	26.11.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	1
Kamikhola	26.11.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
TOTAL (*n*)							**150**
TOTAL TAXA (*S*)							**15**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	24
Darachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	8
Darachhu	18.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	5
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	3
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Abacaria*	*Abacaria* sp.	2
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona* sp.	2
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Odontoceridae	*Marilia*	*Marilia* sp.	2
Darachhu	18.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	1
Darachhu	18.04.2006	Pre-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	1
TOTAL (*n*)							**16**
TOTAL TAXA (*S*)							**9**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Darachhu	27.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	89
Darachhu	27.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	20
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	20
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	10
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Odontoceridae	*Marilia*	*Marilia* sp.	9
Darachhu	27.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	8
Darachhu	27.11.2005	Post-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	2
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Limnocentropodidae	*Limnocentropus*	*Limnocentropus* sp.	2
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Odonata	Cordulegasteridae	Cordulegasteridae	Cordulegasteridae Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona* sp.	1
Darachhu	27.11.2005	Post-monsoon	Odonata	Epiophlebiidae	Epiophlebiidae	Epiophlebiidae Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	1

Darachhu	27.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	1
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Philopotamidae	Philopotamidae	Philopotamidae Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Lepidoptera	Pyralidae	*Pyralidae*	*Pyralidae* Gen. sp.	1
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
Darachhu	27.11.2005	Post-monsoon	Trichoptera	Ord:trichoptera	Trichoptera	Trichoptera Gen. sp.	1
TOTAL (*n*)							**171**
TOTAL TAXA (*S*)							**19**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	27
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	9
Ragchhu	19.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella tetraedra*	4
Ragchhu	19.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	3
Ragchhu	19.04.2006	Pre-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	2
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Diplectrona*	*Diplectrona* sp.	2
Ragchhu	19.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	2
Ragchhu	19.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	2
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	1
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Polycentropodidae	*Plectrocnemia*	*Plectrocnemia* sp.	1
Ragchhu	19.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
TOTAL (*n*)							**54**
TOTAL TAXA (*S*)							**11**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Ragchhu	25.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	304
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	271
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Indosolus*	*Indosolus* sp.	100
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	90

Ragchhu	25.11.2005	Post-monsoon	Oligochaeta	Naididae	*Nais*	*Nais elinguis*	36
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	33
Ragchhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	25
Ragchhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	17
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	15
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	14
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	11
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	10
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Stenelmis*	*Stenelmis* sp.	9
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	8
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	7
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	7
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Graphelmis*	*Graphelmis* sp.	7
Ragchhu	25.11.2005	Post-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	6
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Hydroptilidae	Hydroptilidae	Hydroptilidae Gen. sp.	6
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	6
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	5
Ragchhu	25.11.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	5
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	4
Ragchhu	25.11.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	4
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	4
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	3
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	3
Ragchhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	3
Ragchhu	25.11.2005	Post-monsoon	Hydrachnidia	Ph:hydrachnidia	Hydrachnidia	Hydrachnidia Gen. sp.	3
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Prosopistomatidae	*Prosopistoma*	*Prosopistoma* sp.	3
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	3
Ragchhu	25.11.2005	Post-monsoon	Turbellaria	Dugesiidae	*Dugesia*	*Dugesia* sp.	2
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Odontoceridae	*Psilotreta*	*Psilotreta* sp.	2
Ragchhu	25.11.2005	Post-monsoon	Diptera	Ceratopogonidae	Ceratopogonidae	Ceratopogonidae Gen. sp.	1

Ragchhu	25.11.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	1
Ragchhu	25.11.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Nematoda	Mermithidae	Mermithidae	Mermithidae Gen. sp.	1
Ragchhu	25.11.2005	Post-monsoon	Diptera	Psychodidae	Pericomini	Pericomini Gen. sp.	1
Ragchhu	25.11.2005	Post-monsoon	Mollusca	Pisidiidae (Shpaeriidae)	*Pisidium*	*Pisidium* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	1
Ragchhu	25.11.2005	Post-monsoon	Coleoptera	Sphaeriusidae	*Sphaerius*	*Sphaerius* sp.	1
TOTAL (*n*)							**1037**
TOTAL TAXA (*S*)							**44**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	182
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	28
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	26
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	13
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	9
Nahichhu	29.11.2005	Post-monsoon	Heteroptera	Aphelocheiridae	*Aphelocheirus*	*Aphelocheirus* sp.	6
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	5
Nahichhu	29.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	5
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	4
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	4
Nahichhu	29.11.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	4
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	4
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Limnocentropodidae	*Limnocentropus*	*Limnocentropus* sp.	4
Nahichhu	29.11.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	3
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	3

Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	2
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	2
Nahichhu	29.11.2005	Post-monsoon	Odonata	Gomphidae	*Gomphidae*	*Gomphidae* Gen. sp.	2
Nahichhu	29.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	2
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	2
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	2
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	1
Nahichhu	29.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Choroterpides*	*Choroterpides* sp.	1
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	1
Nahichhu	29.11.2005	Post-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	1
Nahichhu	29.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	1
Nahichhu	29.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	1
Nahichhu	29.11.2005	Post-monsoon	Lepidoptera	Pyralidae	*Pyralidae*	*Pyralidae* Gen. sp.	1
TOTAL (*n*)							**319**
TOTAL TAXA (*S*)							**28**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Neychhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	18
Neychhu	18.04.2006	Pre-monsoon	Lepidoptera	Pyralidae	Pyralidae	Pyralidae Gen. sp.	1
Neychhu	18.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
TOTAL (*n*)							**20**
TOTAL TAXA (*S*)							**3**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	424
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	102
Neychhu	25.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	54
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	51

Neychhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	43
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	43
Neychhu	25.11.2005	Post-monsoon	Lepidoptera	Pyralidae	Pyralidae	Pyralidae Gen. sp.	27
Neychhu	25.11.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	18
Neychhu	25.11.2005	Post-monsoon	Diptera	Order:Diptera	Diptera	Diptera Gen. sp.	17
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	17
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	15
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	12
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	11
Neychhu	25.11.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	10
Neychhu	25.11.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	10
Neychhu	25.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	10
Neychhu	25.11.2005	Post-monsoon	Diptera	Sciaridae	Sciaridae	Sciaridae Gen. sp.	7
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	6
Neychhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	6
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	5
Neychhu	25.11.2005	Post-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	4
Neychhu	25.11.2005	Post-monsoon	Hydrachnidia	Ph: Hydrachnidia	Hydrachnidia	Hydrachnidia Gen. sp.	3
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	3
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	3
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Hydroptilidae	*Stactobia*	*Stactobia* sp.	3
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Stenelmis*	*Stenelmis* sp.	3
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	3
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	2
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	2
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Euthraulus*	*Euthraulus* sp.	2
Neychhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	2
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Hydroptilidae	*Hydroptila*	*Hydroptila* sp.	2
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Polycentropodidae	*Polyplectropus*	*Polyplectropus* sp.	2
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	2

Neychhu	25.11.2005	Post-monsoon	Diptera	Athericidae	*Athericidae*	*Athericidae Gen. sp.*	1
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	1
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	*Choroterpides*	*Choroterpides* sp.	1
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	1
Neychhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	1
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	1
Neychhu	25.11.2005	Post-monsoon	Diptera	Chironomidae	*Eukiefferiella*	*Eukiefferiella* sp.	1
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Gyrinidae	Gyrinidae	Gyrinidae Gen. sp.	1
Neychhu	25.11.2005	Post-monsoon	Coleoptera	Hydrophilidae	Hydrophilidae	Hydrophilidae Gen. sp.	1
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Polycentropodidae	Pseudoneureclipsis	*Pseudoneureclipsis* sp.	1
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
Neychhu	25.11.2005	Post-monsoon	Trichoptera	Ord:trichoptera	Trichoptera	Trichoptera Gen. sp.	1
TOTAL (*n*)							**936**
TOTAL TAXA (*S*)							**46**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	131
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	62
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	51
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Choroterpides*	*Choroterpides* sp.	39
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	37
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	36
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	35
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Crinitella*	*Crinitella* sp.	31
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	30
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	27
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Helodidae	Helodidae	Helodidae Gen. sp.	25
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	24
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Notacanthurus*	*Notacanthurus* sp.	21

Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	14
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Limnocentropodidae	Limnocentropodidae	Limnocentropodidae Gen. sp.	12
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	8
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	7
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	6
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	3
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	3
Nyarachhu	18.04.2006	Pre-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	2
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Gyrinidae	Gyrinidae	Gyrinidae Gen. sp.	2
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	2
Nyarachhu	18.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Plecoptera	Peltoperlidae	Peltoperlidae	Peltoperlidae Gen. sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Hydroptilidae	*Ugandatrichia*	*Ugandatrichia* sp.	1
Nyarachhu	18.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Wormaldia*	*Wormaldia* sp.	1
TOTAL (*n*)							**617**
TOTAL TAXA (*S*)							**32**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Nyarachhu	25.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	145
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	68
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	64
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	49
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	47
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	28

Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	24
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	23
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	22
Nyarachhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	19
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	17
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	17
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	14
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	8
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	7
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	6
Nyarachhu	25.11.2005	Post-monsoon	Heteroptera	Aphelocheiridae	*Aphelocheirus*	*Aphelocheirus* sp.	5
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	5
Nyarachhu	25.11.2005	Post-monsoon	Odonata	Euphaeidae	Euphaeidae	Euphaeidae Gen. sp.	5
Nyarachhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	3
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Limnocentropodidae	*Limnocentropus*	*Limnocentropus* sp.	3
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	2
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Glossosomatidae	*Agapetinae*	*Agapetinae* Gen. sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	1
Nyarachhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	1
Nyarachhu	25.11.2005	Post-monsoon	Trichoptera	Uenoidae	*Uenoa*	*Uenoa* sp.	1
TOTAL (*n*)							**591**
TOTAL TAXA (*S*)							**32**

Annexure 3. Site-wise distribution of taxa from different sampling sites across Eastern Himalayan Broadleaf Forests of Bhutan.

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Balakhachhu	28.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	224
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	94
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	54
Balakhachhu	28.04.2006	Pre-monsoon	Plecoptera	Leuctridae	*Paraleuctra*	*Paraleuctra* sp.	45
Balakhachhu	28.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	10
Balakhachhu	28.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	8
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	6
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	6
Balakhachhu	28.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	6
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	5
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	3
Balakhachhu	28.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	1
Balakhachhu	28.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	1
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	1
Balakhachhu	28.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Balakhachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	Heptageniidae	Heptageniidae Gen. sp.	1
Balakhachhu	28.04.2006	Pre-monsoon	Coleoptera	Scirtidae	*Scirtidae*	*Scirtidae* Gen. sp.	1
TOTAL (*n*)							**472**
TOTAL TAXA (*S*)							**18**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	786
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	276
Balakhachhu	06.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus unispinosus*	154
Balakhachhu	06.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	146

Balakhachhu	06.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	28
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	18
Balakhachhu	06.12.2005	Post-monsoon	Plecoptera	Nemouridae	*Indonemoura*	*Indonemoura* sp.	14
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Limnephilidae	*Pseudostenophylax*	*Pseudostenophylax* sp.	13
Balakhachhu	06.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	11
Balakhachhu	06.12.2005	Post-monsoon	Oligochaeta	Kl:oligochaeta	Oligochaeta	Oligochaeta Gen. sp.	10
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	8
Balakhachhu	06.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	8
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	6
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	6
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	6
Balakhachhu	06.12.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	5
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Apataniidae	*Apatania*	*Apatania* sp.	4
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	4
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Athericidae	*Atherix*	*Atherix* sp.	3
Balakhachhu	06.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	3
Balakhachhu	06.12.2005	Post-monsoon	Plecoptera	Nemouridae	*Mesonemoura*	*Mesonemoura* sp.	3
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Empididae	Clinocerinae	Clinocerinae Gen. sp.	2
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	2
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	2
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	2
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Psychodidae	*Bazarella*	*Bazarella* sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Blephariceridae	*Blepharicera*	*Blepharicera* sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Polycentropodidae	*Polyplectropus*	*Polyplectropus* sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
Balakhachhu	06.12.2005	Post-monsoon	Diptera	Sciaridae	Sciaridae	Sciaridae Gen. sp.	1
TOTAL (*n*)							**1527**
TOTAL TAXA (*S*)							**32**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	1232
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	60
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	40
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	35
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	32
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	31
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	29
Isunachhu	28.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella* sp.	15
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	12
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	10
Isunachhu	28.04.2006	Pre-monsoon	Oligochaeta	Tubificidae	Tubificidae	Tubificidae Gen. sp.	10
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Empididae	Empididae	Empididae Gen. sp.	8
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Ephydridae	Ephydridae	Ephydridae Gen. sp.	4
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	3
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	Baetidae	Baetidae Gen. sp.	2
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	2
Isunachhu	28.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	*Agapetus*	*Agapetus* sp.	1
Isunachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	1
Isunachhu	28.04.2006	Pre-monsoon	Diptera	Tabanidae	Tabanidae	Tabanidae Gen. sp.	1
TOTAL (*n*)							**1533**
TOTAL TAXA (*S*)							**20**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Isunachhu	06.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	1445
Isunachhu	06.12.2005	Post-monsoon	Oligochaeta	Kl:oligochaeta	Oligochaeta	Oligochaeta Gen. sp.	127

Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	101
Isunachhu	06.12.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	91
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	90
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	71
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	45
Isunachhu	06.12.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	39
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	36
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	25
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	23
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	9
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	5
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Isunachhu	06.12.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	4
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	4
Isunachhu	06.12.2005	Post-monsoon	Coleoptera	Dytiscidae	Bidessini	Bidessini Gen. sp.	3
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	3
Isunachhu	06.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	3
Isunachhu	06.12.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	3
Isunachhu	06.12.2005	Post-monsoon	Heteroptera	Corixidae	Corixidae	Corixidae Gen. sp.	2
Isunachhu	06.12.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	2
Isunachhu	06.12.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	2
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Cheumatopsyche*	*Cheumatopsyche* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	Hydropsychidae	Hydropsychidae Gen. sp.	1
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Philopotamidae	*Kisaura*	*Kisaura* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	1
Isunachhu	06.12.2005	Post-monsoon	Diptera	Muscidae	*Potamia*	*Potamia* sp.	1
Isunachhu	06.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	1

Isunachhu	06.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	1
TOTAL (*n*)							**2148**
TOTAL TAXA (*S*)							**33**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	384
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	83
Naguchhu	01.05.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	44
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	35
Naguchhu	01.05.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	34
Naguchhu	01.05.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	27
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptocerinae	Leptocerinae Gen. sp.	27
Naguchhu	01.05.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	25
Naguchhu	01.05.2006	Pre-monsoon	Plecoptera	Nemouridae	*Indonemoura*	*Indonemoura* sp.	18
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	16
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	14
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	12
Naguchhu	01.05.2006	Pre-monsoon	Plecoptera	Nemouridae	*Mesonemoura*	*Mesonemoura* sp.	11
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Arctopsyche*	*Arctopsyche* sp.	10
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	8
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	6
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	4
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	4
Naguchhu	01.05.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	3
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	3
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ameletidae	Ameletidae	Ameletidae Gen. sp.	2
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	2
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	2
Naguchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	2

Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	2
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Glossosomatidae	*Agapetus*	*Agapetus* sp.	1
Naguchhu	01.05.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Chimarra*	*Chimarra* sp.	1
Naguchhu	01.05.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Naguchhu	01.05.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	1
Naguchhu	01.05.2006	Pre-monsoon	Turbellaria	Kl:turbellaria	Turbellaria	Turbellaria Gen. sp.	1
TOTAL (*n*)							**783**
TOTAL TAXA (*S*)							**30**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Naguchhu	08.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	151
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	92
Naguchhu	08.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	46
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	42
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	41
Naguchhu	08.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	37
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	21
Naguchhu	08.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	17
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	15
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	15
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	13
Naguchhu	08.12.2005	Post-monsoon	Diptera	Athericidae	*Atherix*	*Atherix* sp.	8
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	8
Naguchhu	08.12.2005	Post-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	6
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	6
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Philopotamidae	*Kisaura*	*Kisaura* sp.	6
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	4
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	3
Naguchhu	08.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	3

Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	3
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	3
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	3
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	2
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	2
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	2
Naguchhu	08.12.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	1
Naguchhu	08.12.2005	Post-monsoon	Diptera	Limoniidae	*Eloeophila*	*Eloeophila* sp.	1
Naguchhu	08.12.2005	Post-monsoon	Ephemeroptera	Ephemeridae	*Ephemera*	*Ephemera* sp.	1
Naguchhu	08.12.2005	Post-monsoon	Odonata	Epiophlebiidae	Epiophlebiidae	Epiophlebiidae Gen. sp.	1
Naguchhu	08.12.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Naguchhu	08.12.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	1
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Polycentropodidae	Polycentropodidae	Polycentropodidae Gen. sp.	1
Naguchhu	08.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenidae	Psephenidae Gen. sp.	1
Naguchhu	08.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	Psychomyiidae	Psychomyiidae Gen. sp.	1
Naguchhu	08.12.2005	Post-monsoon	Diptera	Tipulidae	*Tipulidae*	*Tipulidae* Gen. sp.	1
TOTAL (*n*)							**559**
TOTAL TAXA (*S*)							**35**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	210
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	35
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	18
Pachhu	28.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	13
Pachhu	28.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	7
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	4
Pachhu	28.04.2006	Pre-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	2
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	2
Pachhu	28.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella* sp.	1

TOTAL (*n*)	292
TOTAL TAXA (*S*)	9

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Pachhu	07.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	1514
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Apataniidae	*Apatania*	*Apatania* sp.	731
Pachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	103
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	103
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	100
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	53
Pachhu	07.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	47
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	41
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	30
Pachhu	07.12.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	29
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Caenidae	*Caenis*	*Caenis* sp.	28
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	26
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	26
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	19
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	16
Pachhu	07.12.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	11
Pachhu	07.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	9
Pachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	6
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Pachhu	07.12.2005	Post-monsoon	Oligochaeta	Kl:oligochaeta	Oligochaeta	Oligochaeta Gen. sp.	5
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	3
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	3
Pachhu	07.12.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	1
Pachhu	07.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	1
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	1

TOTAL (*n*)	**2911**
TOTAL TAXA (*S*)	**25**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	100
Pachhu	07.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	76
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	70
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	39
Pachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	35
Pachhu	07.12.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	31
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	25
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	23
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	20
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	18
Pachhu	07.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	15
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	10
Pachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	8
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatidae	Glossosomatidae Gen. sp.	7
Pachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	2
Pachhu	07.12.2005	Post-monsoon	Diptera	Chironomidae	*Diamesa*	*Diamesa* sp.	1
Pachhu	07.12.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	1
Pachhu	07.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
TOTAL (*n*)							**482**
TOTAL TAXA (*S*)							**18**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	112
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	81

Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	79
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	59
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	46
Pachhu	28.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	25
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	21
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	20
Pachhu	28.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	13
Pachhu	28.04.2006	Pre-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	11
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	11
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	10
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	7
Pachhu	28.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	7
Pachhu	28.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	6
Pachhu	28.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	Ephemerellidae	*Ephemerellidae* Gen. sp.	4
Pachhu	28.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	*Athericidae* Gen. sp.	3
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Agapetinae	*Agapetinae* Gen. sp.	2
Pachhu	28.04.2006	Pre-monsoon	Diptera	Blephariceridae	Blephariceridae	*Blephariceridae* Gen. sp.	2
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Glossosomatidae	*Agapetus*	*Agapetus* sp.	1
Pachhu	28.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Pachhu	28.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	*Haploperla*	*Haploperla* sp.	1
Pachhu	28.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	1
TOTAL (*n*)							**523**
TOTAL TAXA (*S*)							**23**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Pachhu	29.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	110
Pachhu	29.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	34
Pachhu	29.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	6
Pachhu	29.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	3

TOTAL (*n*)	**153**
TOTAL TAXA (*S*)	**4**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	36
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	27
Chamkharchhu	22.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	19
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	17
Chamkharchhu	22.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	9
Chamkharchhu	22.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	7
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	5
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	5
Chamkharchhu	22.04.2006	Pre-monsoon	Diptera	Blephariceridae	Blephariceridae	Blephariceridae Gen. sp.	3
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	3
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	2
Chamkharchhu	22.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Indonemoura*	*Indonemoura* sp.	2
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Neoephemeridae	*Potamanthellus*	*Potamanthellus* sp.	2
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	2
Chamkharchhu	22.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	2
Chamkharchhu	22.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	1
Chamkharchhu	22.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	1
Chamkharchhu	22.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	1
TOTAL (*n*)							**144**
TOTAL TAXA (*S*)							**18**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Channachhu	30.04.2006	Pre-monsoon	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae Gen. sp.	155
Channachhu	30.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	139

Channachhu	30.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	127
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	112
Channachhu	30.04.2006	Pre-monsoon	Oligochaeta	Tubificidae	Tubificidae	Tubificidae Gen. sp.	89
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	62
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	61
Channachhu	30.04.2006	Pre-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	29
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	28
Channachhu	30.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	22
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	19
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	16
Channachhu	30.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	13
Channachhu	30.04.2006	Pre-monsoon	Coleoptera	Staphylinidae	*Indosorius*	*Indosorius* sp.	10
Channachhu	30.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	8
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	Heptageniidae	Heptageniidae Gen. sp.	7
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	4
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Goeridae	*Goera*	*Goera* sp.	2
Channachhu	30.04.2006	Pre-monsoon	Plecoptera	Nemouridae	Nemouridae	Nemouridae Gen. sp.	2
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	1
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	1
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Uenoidae	*Neophylax*	*Neophylax* sp.	1
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	Philopotamidae	Philopotamidae Gen. sp.	1
Channachhu	30.04.2006	Pre-monsoon	Ephemeroptera	Potamanthidae	Potamanthidae	Potamanthidae Gen. sp.	1
Channachhu	30.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
TOTAL (*n*)							**911**
TOTAL TAXA (*S*)							**25**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	300
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	90

Channachhu	07.12.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	90
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	78
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	66
Channachhu	07.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	49
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	47
Channachhu	07.12.2005	Post-monsoon	Oligochaeta	Naididae	*Nais*	*Nais variabilis*	43
Channachhu	07.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	35
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	34
Channachhu	07.12.2005	Post-monsoon	Diptera	Athericidae	*Atherix*	*Atherix* sp.	21
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	14
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Philopotamidae	*Kisaura*	*Kisaura* sp.	13
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	12
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Hydroptilidae	Stactobiini	Stactobiini Gen. sp.	11
Channachhu	07.12.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	10
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	10
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	8
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	8
Channachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	7
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	7
Channachhu	07.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	6
Channachhu	07.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	6
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	5
Channachhu	07.12.2005	Post-monsoon	Oligochaeta	Tubificidae	*Limnodrilus*	*Limnodrilus hoffmeisteri*	5
Channachhu	07.12.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	3
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	3
Channachhu	07.12.2005	Post-monsoon	Diptera	Tipulidae	*Tipulidae*	*Tipulidae* Gen. sp.	3
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	2
Channachhu	07.12.2005	Post-monsoon	Turbellaria	Planariidae	*Polycelis*	*Polycelis* sp.	2
Channachhu	07.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	2
Channachhu	07.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	1

Channachhu	07.12.2005	Post-monsoon	Diptera	Psychodidae	*Bazarella*	*Bazarella* sp.	1
Channachhu	07.12.2005	Post-monsoon	Diptera	Blephariceridae	Blephariceridae	Blephariceridae Gen. sp.	1
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	1
Channachhu	07.12.2005	Post-monsoon	Diptera	Chironomidae	*Diamesa*	*Diamesa* sp.	1
Channachhu	07.12.2005	Post-monsoon	Turbellaria	Dugesiidae	*Dugesia*	*Dugesia* sp.	1
Channachhu	07.12.2005	Post-monsoon	Odonata	Epiophlebiidae	Epiophlebiidae	Epiophlebiidae Gen. sp.	1
Channachhu	07.12.2005	Post-monsoon	Coleoptera	Hydrophilidae	Hydrophilidae	Hydrophilidae Gen. sp.	1
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Hydroptilidae	Hydroptilidae	Hydroptilidae Gen. sp.	1
Channachhu	07.12.2005	Post-monsoon	Diptera	Pediciidae	Pediciidae	Pediciidae Gen. sp.	1
Channachhu	07.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	1
TOTAL (*n*)							**1001**
TOTAL TAXA (*S*)							**42**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Thimphuchhu	03.05.2006	Pre-monsoon	Oligochaeta	Tubificidae	Tubificidae	Tubificidae Gen. sp.	470
Thimphuchhu	03.05.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	127
Thimphuchhu	03.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	107
Thimphuchhu	03.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	86
Thimphuchhu	03.05.2006	Pre-monsoon	Turbellaria	Dugesiidae	*Dugesia*	*Dugesia* sp.	57
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	37
Thimphuchhu	03.05.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	24
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	20
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Chironomidae	Chironomini	Chironomini Gen. sp.	20
Thimphuchhu	03.05.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	11
Thimphuchhu	03.05.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	6
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	5
Thimphuchhu	03.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	5
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Chironomidae	Tanypodinae	Tanypodinae Gen. sp.	5
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae Gen. sp.	4

Thimphuchhu	03.05.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	4
Thimphuchhu	03.05.2006	Pre-monsoon	Oligochaeta	Kl:oligochaeta	Oligochaeta	Oligochaeta Gen. sp.	3
Thimphuchhu	03.05.2006	Pre-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	2
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	2
Thimphuchhu	03.05.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	1
Thimphuchhu	03.05.2006	Pre-monsoon	Trichoptera	Polycentropodidae	*Polyplectropus*	*Polyplectropus* sp.	1
Thimphuchhu	03.05.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	1
TOTAL (*n*)							**998**
TOTAL TAXA (*S*)							**22**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	128
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	64
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	57
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomini	Chironomini Gen. sp.	50
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	34
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	27
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Tanypodinae	Tanypodinae Gen. sp.	21
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Tanytarsini	Tanytarsini Gen. sp.	14
Cherichhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae Gen. sp.	12
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	11
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	8
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	7
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	7
Cherichhu	16.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	4
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	3
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Potamanthidae	Potamanthidae	Potamanthidae Gen. sp.	3
Cherichhu	16.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	2
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	Ephemerellidae	Ephemerellidae Gen. sp.	2

Cherichhu	16.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	Heptageniidae	Heptageniidae Gen. sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Mesonemoura*	*Mesonemoura* sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	1
Cherichhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	1
TOTAL (*n*)							**461**
TOTAL TAXA (*S*)							**25**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Cherichhu	23.11.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	222
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	194
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	58
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	23
Cherichhu	23.11.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	12
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	11
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	10
Cherichhu	23.11.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	4
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	4
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	4
Cherichhu	23.11.2005	Post-monsoon	Plecoptera	Leuctridae	*Paraleuctra*	*Paraleuctra* sp.	4
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	3
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	3
Cherichhu	23.11.2005	Post-monsoon	Diptera	Athericidae	*Atherix*	*Atherix* sp.	2
Cherichhu	23.11.2005	Post-monsoon	Diptera	Empididae	Clinocerinae	Clinocerinae Gen. sp.	2
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	2
Cherichhu	23.11.2005	Post-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	2
Cherichhu	23.11.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1

Cherichhu	23.11.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	1
Cherichhu	23.11.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	1
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Philopotamidae	*Kisaura*	*Kisaura* sp.	1
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	1
Cherichhu	23.11.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	1
Cherichhu	23.11.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
TOTAL (*n*)							**567**
TOTAL TAXA (*S*)							**24**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Dreychhu	16.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	84
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	43
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	33
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	32
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	32
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	23
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	10
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	9
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	8
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	7
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	*Diamesa*	*Diamesa* sp.	6
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	6
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	5
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	5
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Goeridae	*Goera*	*Goera* sp.	4
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	3
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	3
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	3
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	2

Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	2
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptocerinae	Leptocerinae Gen. sp.	2
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Polycentropodidae	*Polyplectropus*	*Polyplectropus* sp.	2
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	2
Dreychhu	16.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Odonata	Epiophlebiidae	*Epiophlebia*	*Epiophlebia* sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Indonemoura*	*Indonemoura* sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Plecoptera	Nemouridae	Nemouridae	Nemouridae Gen. sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
Dreychhu	16.04.2006	Pre-monsoon	Diptera	Chironomidae	Tanytarsini	Tanytarsini Gen. sp.	1
TOTAL (*n*)							**333**
TOTAL TAXA (*S*)							**30**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Dreychhu	13.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	1679
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	39
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	15
Dreychhu	13.12.2005	Post-monsoon	Diptera	Athericidae	*Atherix*	*Atherix* sp.	13
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	11
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	8
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	6
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	5
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Micrasema*	*Micrasema* sp.	4
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	3
Dreychhu	13.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	2
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	2
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Limnephilidae	*Pseudostenophylax*	*Pseudostenophylax* sp.	2
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	2

Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	2
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Blephariceridae	*Blepharicera*	*Blepharicera* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Blephariceridae	Blephariceridae	Blephariceridae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Odonata	Epiophlebiidae	Epiophlebiidae	Epiophlebiidae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Chironomidae	*Eukiefferiella*	*Eukiefferiella* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	1
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	Rhyacophilidae	Rhyacophilidae Gen. sp.	1
Dreychhu	13.12.2005	Post-monsoon	Diptera	Tipulidae	*Tipulidae*	*Tipulidae* Gen. sp.	1
TOTAL (*n*)							**1809**
TOTAL TAXA (*S*)							**31**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Olarongchhu	01.05.2006	Pre-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	938
Olarongchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	660
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	66
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	*Diamesa*	*Diamesa* sp.	33
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Diamesini	Diamesini Gen. sp.	33
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae Gen. sp.	31
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	27
Olarongchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	27

Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	21
Olarongchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	7
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Tanypodinae	Tanypodinae Gen. sp.	7
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Tanytarsini	Tanytarsini Gen. sp.	7
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	7
Olarongchhu	01.05.2006	Pre-monsoon	Plecoptera	Leuctridae	*Paraleuctra*	*Paraleuctra* sp.	5
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Chironomidae	Chironomini	Chironomini Gen. sp.	4
Olarongchhu	01.05.2006	Pre-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	4
Olarongchhu	01.05.2006	Pre-monsoon	Trichoptera	Glossosomatidae	*Glossosoma*	*Glossosoma* sp.	3
Olarongchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	2
Olarongchhu	01.05.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Uracanthella*	*Uracanthella* sp.	2
Olarongchhu	01.05.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	1
Olarongchhu	01.05.2006	Pre-monsoon	Heteroptera	Nepidae	*Ranatra*	*Ranatra* sp.	1
TOTAL (*n*)							**1886**
TOTAL TAXA (*S*)							**21**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	2147
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	1451
Olarongchhu	15.12.2005	Post-monsoon	Oligochaeta	Naididae	*Nais*	*Nais elinguis*	864
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	289
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	242
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Deuterophlebiidae	Deuterophlebiidae	Deuterophlebiidae Gen. sp.	173
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	145
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Glossosomatinae	Glossosomatinae Gen. sp.	55
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	27
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	27
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	25
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Ord:diptera	Diptera	Diptera Gen. sp.	24

Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	19
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	13
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	7
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	6
Olarongchhu	15.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	5
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	5
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	4
Olarongchhu	15.12.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	4
Olarongchhu	15.12.2005	Post-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella tetraedra*	3
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	3
Olarongchhu	15.12.2005	Post-monsoon	Diptera	Limoniidae	*Limoniidae*	*Limoniidae* Gen. sp.	3
Olarongchhu	15.12.2005	Post-monsoon	Odonata	Gomphidae	*Gomphidae*	*Gomphidae* Gen. sp.	2
Olarongchhu	15.12.2005	Post-monsoon	Coleoptera	Psephenidae	Psephenoidinae	Psephenoidinae Gen. sp.	2
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	2
Olarongchhu	15.12.2005	Post-monsoon	Megaloptera	Corydalidae	Corydalidae	Corydalidae Gen. sp.	1
Olarongchhu	15.12.2005	Post-monsoon	Oligochaeta	Enchytraeidae	*Enchytraeus*	*Enchytraeus* indicus	1
Olarongchhu	15.12.2005	Post-monsoon	Heteroptera	Ord:heteroptera	Heteroptera	Heteroptera Gen. sp.	1
Olarongchhu	15.12.2005	Post-monsoon	Oligochaeta	Tubificidae	*Limnodrilus*	*Limnodrilus hoffmeisteri*	1
Olarongchhu	15.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	1
Olarongchhu	15.12.2005	Post-monsoon	Turbellaria	Kl:turbellaria	Turbellaria	Turbellaria Gen. sp.	1
TOTAL (*n*)							**5553**
TOTAL TAXA (*S*)							**32**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Tabachhu	17.04.2006	Pre-monsoon	Oligochaeta	Lumbricidae	*Eiseniella*	*Eiseniella* sp.	75
Tabachhu	17.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	61
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	47
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	46
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	23

Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	19
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	18
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	15
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	12
Tabachhu	17.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	8
Tabachhu	17.04.2006	Pre-monsoon	Plecoptera	Leuctridae	*Paraleuctra*	*Paraleuctra* sp.	5
Tabachhu	17.04.2006	Pre-monsoon	Diptera	Pediciidae	Pediciinae	Pediciinae Gen. sp.	5
Tabachhu	17.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	4
Tabachhu	17.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	4
Tabachhu	17.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	3
Tabachhu	17.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Mesonemoura*	*Mesonemoura* sp.	3
Tabachhu	17.04.2006	Pre-monsoon	Diptera	Empididae	Empididae	Empididae Gen. sp.	2
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	2
Tabachhu	17.04.2006	Pre-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	2
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	2
Tabachhu	17.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Trichoptera	Hydropsychidae	*Arctopsyche*	*Arctopsyche* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Trichoptera	Philopotamidae	*Dolophilodes*	*Dolophilodes* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Odonata	Epiophlebiidae	*Epiophlebia*	*Epiophlebia* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	Heptageniidae	Heptageniidae Gen. sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Indonemoura*	*Indonemoura* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Nemoura*	*Nemoura* sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	1
Tabachhu	17.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	1
TOTAL (*n*)							**367**
TOTAL TAXA (*S*)							**31**

River	Sampling date	Season	Order	Family	Genus	Species	Abundance (Nos/1.25 m^2)
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Lepidostomatidae	*Lepidostoma*	*Lepidostoma* sp.	481
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	295
Tabachhu	14.12.2005	Post-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	211
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae Gen. sp.	148
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	99
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus bispinosus*	99
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	73
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Parapsyche*	*Parapsyche* sp.	62
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	41
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Ephacerella*	*Ephacerella* sp.	32
Tabachhu	14.12.2005	Post-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	30
Tabachhu	14.12.2005	Post-monsoon	Coleoptera	Psephenidae	Eubriinae	Eubriinae Gen. sp.	18
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	10
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	7
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	7
Tabachhu	14.12.2005	Post-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	5
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Glossosomatidae	Agapetinae	Agapetinae Gen. sp.	3
Tabachhu	14.12.2005	Post-monsoon	Diptera	Limoniidae	*Hexatoma*	*Hexatoma* sp.	3
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Hydropsychidae	Hydropsychidae	Hydropsychidae Gen. sp.	3
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	3
Tabachhu	14.12.2005	Post-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	2
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Himalopsyche*	*Himalopsyche* sp.	2
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Psychomyiidae	*Psychomyia*	*Psychomyia* sp.	2
Tabachhu	14.12.2005	Post-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	2
Tabachhu	14.12.2005	Post-monsoon	Diptera	Pediciidae	*Dicranota*	*Dicranota* sp.	1
Tabachhu	14.12.2005	Post-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	1
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Goeridae	*Goera*	*Goera* sp.	1
Tabachhu	14.12.2005	Post-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	1

Tabachhu	14.12.2005	Post-monsoon	Coleoptera	Scirtidae	*Hydrocyphon*	*Hydrocyphon* sp.	1
Tabachhu	14.12.2005	Post-monsoon	Trichoptera	Rhyacophilidae	*Hyporhyacophila*	*Hyporhyacophila* sp.	1
Tabachhu	14.12.2005	Post-monsoon	Diptera	Psychodidae	Psychodidae	Psychodidae Gen. sp.	1
Tabachhu	14.12.2005	Post-monsoon	Diptera	Sciaridae	Sciaridae	Sciaridae Gen. sp.	1
Tabachhu	14.12.2005	Post-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	1
TOTAL (*n*)							**1647**
TOTAL TAXA (*S*)							**33**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Chironomidae	Chironomidae	Chironomidae Gen. sp.	138
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	120
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	99
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	24
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	18
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	18
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	13
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	12
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Lepidostomatidae	*Zephyropsyche*	*Zephyropsyche* sp.	8
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Limoniidae	Limoniidae	Limoniidae Gen. sp.	7
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae Gen. sp.	7
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Chironomidae	Tanypodinae	Tanypodinae Gen. sp.	7
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Tipulidae	Tipulidae	Tipulidae Gen. sp.	7
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	4
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Elmidae	*Grouvellinus*	*Grouvellinus* sp.	4
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	Baetidae	Baetidae Gen. sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Odonata	Gomphidae	Gomphidae	Gomphidae Gen. sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Isonychiidae	*Isonychia*	*Isonychia* sp.	2

Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Pediciidae	Pediciidae	Pediciidae Gen. sp.	2
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Polycentropodidae	*Polyplectropus*	*Polyplectropus* sp.	2
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Hydrophilidae	Hydrophilidae	Hydrophilidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptoceridae	Leptoceridae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Leptoceridae	Leptocerinae	Leptocerinae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Psychodidae	Psychodidae	Psychodidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Rhyacophilidae	*Rhyacophila*	*Rhyacophila* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Serratella*	*Serratella* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Stenopsychidae	*Stenopsyche*	*Stenopsyche* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Chironomidae	Tanytarsini	Tanytarsini Gen. sp.	1
TOTAL (*n*)							**515**
TOTAL TAXA (*S*)							**33**

River	**Sampling date**	**Season**	**Order**	**Family**	**Genus**	**Species**	**Abundance (Nos/1.25 m^2)**
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetis*	*Baetis* sp.	241
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Simuliidae	Simuliidae	Simuliidae Gen. sp.	112
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Cinygmula*	*Cinygmula* sp.	41
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Ecdyonurus*	*Ecdyonurus* sp.	41
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Cincticostella*	*Cincticostella* sp.	35
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Scirtidae	Scirtidae	Scirtidae Gen. sp.	33
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Acentrella*	*Acentrella* sp.	19
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ephemerellidae	*Drunella*	*Drunella* sp.	17
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Iron*	*Iron* sp.	14
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Epeorus*	*Epeorus* sp.	13
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Heptageniidae	*Rhithrogena*	*Rhithrogena* sp.	13
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Limoniidae	*Antocha*	*Antocha* sp.	12

Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*Paraleptophlebia* sp.	10
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Athericidae	Athericidae	Athericidae Gen. sp.	9
Lamchelachhu	23.04.2006	Pre-monsoon	Plecoptera	Nemouridae	*Amphinemura*	*Amphinemura* sp.	5
Lamchelachhu	23.04.2006	Pre-monsoon	Plecoptera	Chloroperlidae	Chloroperlidae	Chloroperlidae Gen. sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Odonata	Epiophlebiidae	*Epiophlebia*	*Epiophlebia* sp.	3
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Pediciidae	Pediciidae	Pediciidae Gen. sp.	2
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Ameletidae	Ameletidae	Ameletidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Ephemeroptera	Baetidae	*Baetiella*	*Baetiella* sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Elmidae	Elmidae	Elmidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Empididae	Empididae	Empididae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Coleoptera	Hydraenidae	Hydraenidae	Hydraenidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Trichoptera	Limnephilidae	Limnephilidae	Limnephilidae Gen. sp.	1
Lamchelachhu	23.04.2006	Pre-monsoon	Diptera	Tipulidae	*Tipulidae*	*Tipulidae* Gen. sp.	1
TOTAL (*n*)							**630**
TOTAL TAXA (*S*)							**25**