AQUATIC INSECTS OF MODI KHOLA RIVER IN PARBAT, NEPAL

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date. 13-04-2021

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RECOMMENDATIONS

This is to recommend that the thesis entitled "**Aquatic insects of Modi Khola River in Parbat, Nepal**" has been carried out by Meena Sharma for the partial fulfilment of Master's Degree of Science in Zoology with special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor "Dr. Daya Ram Bhusal" this thesis submitted by Meena Sharma entitled "**Aquatic Insects of Modi Khola River in Parbat, Nepal**" is approved for the examination in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Meena Sharma entitled "**Aquatic Insects of Modi Khola River in Parbat, Nepal**" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

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List of Abbreviations

Abbreviated form	Details of abbreviations
WT	Water temperature
DO	Dissolve Oxygen
TA	Total Alkalinity
Temp.	Temperature
CDZ	Central Department of Zoology
WHO	World Health Organization
m/s	Metre per second
mg/L	Milligram per litre
Fig.	Figure

ABSTRACT

Aquatic insects are those insects that spend some part of their lifecycle closely associated with water, either living beneath the surface or skimming along on top of the water and they are abundant in most freshwater habitat. In aquatic ecosystem they play vital role or used as indicator of water. In this study, aquatic insects were collected from nine sampling sites of river across different habitats (near to forest area, near to agricultural field and near to human settle area). Each sampling site further divided into three sampling points on the basis of river heterogeneity. Insect collection was done by Sweeping method for littorial zone and D-Frame kick net for benthic zone by One minute kick method, Sieving was used for sandy places of rivers and All out search method was used in all possible substrata. The relation of aquatic insects with physical parameters was showed by using Karl Pearson's Correlation method. A total of 2,230 insects belonging to 48 genera under 33 families and eight orders including of two unidentified species were recorded. During the study period the highest abundance of insect species was from order Ephemeroptera of the total insects sampled. It was followed by Trichoprera, Diptera, Plecoptera, Odonata, Megaloptera, Coleoptera and Hemiptera. Seasonally, abundance of orders of insect was highly varied. The diversity index and species richness of the insects were recorded higher in the pre monsoon in comparison to post monsoon. Analysis of variance shows no significant relation between aquatic insects and seasons. Near to forest area, diversity of insects was high followed by near to agricultural field and human settle area. The number of aquatic insects shows positive relation with DO but negative relation with temperature, velocity and CO_2 in both seasons. In pre monsoon, diversity shows positive correlation with alkalinity and negative with pH.

1. INTRODUCTION

1.1 Background

Aquatic insects are those insects that spend some part of their lifecycle closely associated with water, either living beneath the surface or skimming along on top of the water. The immature stages are truly aquatic while the adult is a winged terrestrial form. They are abundant in most freshwater habitat. Different substratum like stones, muds, logs and in all type of fresh water habitat aquatic insects have high majority. In Nepal the study of aquatic insects was started in the 1950s and most of the studies have been carried out by researchers from abroad, mainly through expeditions to Nepal; in 1990s Nepali researcher were started extensive study on aquatic insects (Shah and Shah 2011). The aquatic insects are important part of aquatic ecosystem which play vital role in ecosystem functioning and are known to be representative of structure and function of freshwater ecosystem due to their high abundance, high birthrate with short generation time, large and rapid colonization (Choudhary and Ahi 2015). Aquatic insect function on multiple trophic level such as shredders, collectors, scraper and predators. They interact in nutrient cycling within lentic and lotic systems and are regarded as an effective bioindicator (Lundquist and Zhu 2018).

1.2 Order of Aquatic Insects

Nearly, 100,000 aquatic insects were describe representing 12 order such as Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Hemiptera, Diptera, Megaloptera, Neuroptera, Lepidoptera, Hymenoptera and Collembola (Dijkstra et al. 2013).

Ephemeroptera (Mayflies) is the oldest order of insects and they are widely distributed in all type of running and standing freshwater habitats. Typically, the nymphs have tracheal gills on their abdomen, unpaired tarsal claws, an enlarged mesothorax, usually three or sometime two caudal filaments. The adult stage of Mayfly having two wings called subimago and imago which are unique among the insects (Brittain and Sartori 2015). Mayflies are pollution sensitive insects and they were used in the bioassessment and monitoring of freshwater bodies worldwide because of their relative abundance in a wide variety of substrates and their increasing chances of detecting pollution impacts (Arimoro and Muller 2010).

Plecoptera is commonly called as stonefly, small order of hemimetabolous insects. Nymph of stonefly are aquatic whereas adult are terrestrials. Morphologically stonefly have soft body, three segmented tarsi, elongate filiform antennae, mandibulated mouthparts, two compound eyes, two or three ocelli, two usually long cerci, 10-segmented abdomen with vestiges of the eleventh segment. They are used extensively as indicators of pollution and environmental change. Mostly, greatest diversity of stonefly nymphs in running water point out well-oxygen level of water and they are also called cold water specialists (Hynes 1976).

Trichoptera is an order of holometabolous insects, closely related to the Lepidoptera, the moths and butterflies. Which are commonly known as Caddisfly and their larval and pupal stages are aquatic. Morphologically the larva is easily recognized by their segmented thoracic legs, a pair of anal prologs with a single curved terminal claw (very short), sometimes almost invisible, single segment antennae and hair like abdominal gills. On the basis of case making behaviour the larvae are divided into five groups (Ward and Whipple 1966) namely purse-case makers (Hydroptilidae), Saddle-case makers (Glossosomatidae), tube-case makers (Limnephilidae), retreat makers (Philopotamidae, Hydropsychidae, Polycentropidae) and free-living (Rhyachophilidae). They are important in aquatic ecosystem because they process organic material and important food source for fish. Like Ephemeroptera, Plecoptera and many Tricoptera species are sensitive to pollution and use as water quality indicator (Diantari et al. 2017).

The order Odonata is regarded as a monophyletic group, divided into three suborders Zygoptera (damselflies), Anisoptera (true dragonflies) and a small suborder Anisozygoptera (damsel dragons). The adult of Odonata is terrestrial and larva is aquatic. Morphological variation occurs in all three suborders larvae, Damselflies larva have three or sometimes two caudal gills for respiration (also used as flippers for swimming) While Dragonfly larvae have lack of caudal gills and Damsel dragons also have no caudal gills, like dragonfly absorb oxygen through gills in the rectum (Thorp and Covich 2015). Mainly the Odonata larvae inhabit in freshwater but some species tolerate moderate pollution of water system (Kalkman et al. 2007).

Coleoptera commonly called as order of beetle, large group of holometabolous insects constitute almost one–fourth of all known life-forms on earth. Beetles are aquatic or semiaquatic in nature sometimes larvae or adult or both are spending their part of lifecycle in water bodies. Typically the adults have strongly sclerotized body with the forewings hardened into elytra while larvae have sclerotized head, three pair of segmented thoracic legs and have no wing pad (Bouchard 2004). Mostly Coleoptera are inhabits to pools and riffles area of rivers. Some aquatic beetle acts as good biomonitoring agent such as family Hydrophilidae, good biomonitor for heavy element and they are present in low dissolve oxygen content water (Aydogan et al. 2018).

The aquatic Hemiptera are composed of semi-aquatic bugs (Gerromorpha) that live primarily on the water's surface and aquatic bugs (Nepomorpha) that live submerged beneath the water. About 97% of this diversity is associated with freshwater habitats (Thorp and Covich 2015). Aquatic bugs are characterized by their half sclerotized elytra, piercing and sucking mouth parts, segmented antenna, some without wings have wing pad. Most of the aquatic bugs are carnivorous in nature and have modified leg for seizing and holding the prey. They are important as fish food, bioindicators and predators. The Red Data Book of Japan, predatory species Nepoidea, including Belostomatidae and Nepidae have been designated as threatened vulnerable species (IUCN 1990) and are regarded as effective predators of freshwater snails and mosquito larvae (Ohba and Nakasuji 2006, Saha et al. 2007).

The order Diptera includes "true" or two-winged flies, divided into three suborders Nematocera, Brachycera and Cylorrhapha. Larval stage of Diptera inhabits water bodies and adults are terrestrial. Morphologically the larvae are distinguished by lacking jointed thoracic legs. On the basis of presence of their cranial structure larval dipterans show tremendous variation in morphological character. Nematocera larvae have well develop head with stout and toothed mandible, moving horizontally or obliquely, Brachycerans larvae are more claw-like, has fewer inner teeth, and moves vertically and Cyclorrhaphan larvae lack sclerotized head, and mouth hooked move vertically (Courtney and Cranston 2015). Aquatic dipteran larvae play significant role in bio-monitoring of water quality, some species of chironomids are tolerant to heavy metals, whereas others are sensitive (Clements et al. 1988). The genus *Chironomus* is recognized as a taxon characteristic of organic enrichment and has been widely used as an indicator of aquatic ecosystem health (Johnson et al. 1993, Lindegaard 1995).

Megaloptera is a smallest order of neuropterous insects which include the alderflies, dobsonflies, fishflies, and hellgrammites. Their larvae can be distinguished from other orders larvae by their well-sclerotized head, with long toothed mandibles, four or five segmented antennae, and six lateral eyespots, dorsally sclerotized thorax with a quadrate pronotum, meso and metathoracic spiracles, and elongate five segmented legs with two tarsal claws; and the abdomen is soft, with seven or eight pairs of lateral filaments, and spiracles on segments 1 to 8 (Resh and Carde 2009). Typically the larvae are found in muddy water and high water current rivers. The larvae of family Corydalidae are important for evaluating a metal contamination of rivers (Fujino and Li 2015).

Neuroptera is commonly called as nerve-winged insects, are mostly terrestrial but larvae are aquatic. There are three families of Neuroptera namely Nevrorthidae with 12 species, Sisyridae with 61 species and Osmylidae with 45 species inhabits to aquatic system (Cover and Resh 2008).

The order of Butterfly and Moth are mostly terrestrial group of insects but their eggs and larvae are aquatic. There are few Lepidoptera spend their part of lifecycle in aquatic habitat. Which represent 50 genera and 737 described species of sub family Acentropinae (Mey and Speidel 2008). Aquatic Lepidoptera were tested and used for the biological control of many invasive weeds (Solis 2007).

Most species of Hymenoptera are terrestrial; a small and little-known group is adapted to the aquatic environment. There are about 150 species with 11 families of Hymnoptera larvae are identified (Bennett 2008).

The order Collembola is very small hexapods (animals with 3 pairs of legs), they occur in large numbers near water and on the surface of water where there is vegetation or organic detritus. There are 103 species are related to fresh water habitats and 109 to marine water habitats (Deharveng et al. 2008).

Nepal is rich in freshwater habitats there are more than 6000 rivers, 3252 glaciers, 2323 glacial lakes, 5358 tectonic and ox-bow lakes (NLCDC 2019). Among them the Modi Khola is one of the major tributary of Kali Gandaki River in Parbat district of western Nepal. It is a snow-fed perennial river originates from the melting of snow and glaciers of the Annapurna Range, in Kaski district and finally joins the Kali Gandaki River at Modi-Beni of Parbat district. The total length of the main-stream of the Modi Khola is about 50 km. This river is rich in water resources in terms of average annual flow and the hydropower development is accelerating day by day. Various studies in the Modi Khola reveals that in the quest of harnessing more rivers for hydropower generation, the environmental concerns are not being properly addressed (JVS 2016).

1.3 Ecological factor affecting aquatic insects

Ecological factors are any abiotic or biotic factor which influences living organisms. In lotic ecosystem aquatic insects are affected by various ecological factors (chemical and physical) such as water temperature (WT), pH, water velocity, Concentration of Dissolve Oxygen (DO), Free Carbondioxide (CO_2), Total Alkalinity (TA) and other various factors. When changes occur in abiotic ecological factors that directly affects the distribution, abundance and diversity of aquatic insect fauna (Bream et al. 2017).

Various insect species are depending in water temperature (WT) for their emergence, metabolism and respiration. The order Hemiptera is temperature dependent species, as this favors their rate of feeding and metabolism (Oben 2000). Similarly WT has been a significant determinant of the structure and distribution of aquatic beetle communities (Taher and Heydarnejad 2019). Mayflies are greater demand of WT for their egg development, low thermal conductivity affect the proper development of eggs (Brittain 1990). Stoneflies are rarely found from water temperature above 25^0C (Baumann 1979). The emergence and survivable of various insect species affected by water pH, the pH of water decreases, the percentage of aquatic insects which emerge successfully also decreases (Bell 1970). Some species of Trichoptera can tolerate low pH in water and survive well. Water velocity is one of the most important abiotic factors influencing the survival of aquatic insects in rivers and streams. Hydropsychidae were most affected taxa caused by the heavy water flow and their distribution was low in rainy season (Ridzun et al. 2020).

Freshwater stream with highest dissolved oxygen have greater number of benthic insects. Concentration of oxygen levels below 2 mg/L may reduce the fitness and chances of survival for many aquatic insects. Dissolved oxygen (DO) play significant role in the diversity of benthic insects, where their number was greater with highest dissolved oxygen (Arimoro and Ikomi 2009). The sensitive group of insects that Ephemeroptera, Plecoptera, Trichoptera (EPT) were very sensitive to concentration of DO in water. TA values of 20-200 mg/L are common in fresh water ecosystems and TA below 10 mg/L indicates poorly buffered rivers. These rivers are least capable of resisting changes in pH, therefore they are more susceptible to problems which occur as a result of acidic pollutants (Biggs 1995). When free carbon dioxide (CO2) levels increase in fresh water creates weak acidification. These weak acidification influences freshwater biota and ecosystems (Hasler et al. 2018).

1.4 Objectives

1.4.1 General Objective

- To explore the aquatic insects fauna of Modi Khola in Parbat.

1.4.2 Specific Objectives

- To assess the aquatic insects from study area.
- To compare the pre and post monsoon variation of abundance and diversity in aquatic insects.
- To determine the relation of aquatic insects with water quality parameters (Temperature, pH, Velocity, Dissolve oxygen (DO), Free Carbondioxide (CO_2) and Alkalinity).

1.5 Significance of the study

Aquatic insects are the source of food, bio-indicators and bio-control agents in an aquatic ecosystem. They used as indicator of water quality and in bio-monitoring of human impact. Nepal has poorly documented situation about the aquatic insects. Therefore it is necessary to study the aquatic insects from different part of Nepal. The area of Modi Khola has no documentation about aquatic insects so this study is important. Water diversion projects for hydropower generation are increase in number at Modi Khola but the lack of proper guidelines and monitoring mechanism creates loss of aquatic biodiversity. There are no rules for determining the appropriate number of water diversion projects in a single river. The Nepal Biodiversity Strategy and Action Plan (2014-2020) identifies the cascade of high dams and stations on some rivers as serious threat to both aquatic biodiversity and livelihoods of wetland dependent local communities and further predicts that the scale of the threat might further increase in future.

2. LITERATURE REVIEW

2.1 Studies of Aquatic Insects

In Nepal the study of aquatic insect was firstly described by Hope in "Synopsis of Nepal Insects" which was published in 1831 (Atkinson 1980). In 1963 some taxa of aquatic bugs were collected and studied by Chiba University, Rolwaling Himal Expedition (Miyamoto 1965). Similum indicum was first time recorded from Nepal (Lewis 1972). Thereafter, short observations of aquatic insects was carried out from the foothills of central Nepal and Everest/ Khumbu region and recorded seven order of aquatic insects from different altitudinal ranges (McDonald 1976). In same year many species of Caddisflies belonging to families Limnocentropidae, Limnephilidae, Rhyacophilidae, Hydropsychidae, Stenopsychidae, Glossosomatidae and Helicopsychidae were described (Botosaneanu 1976).

Similarly, *Iron siveci*, *Epeorus bispinosus*, *E. rithralis* and *E. unispinosus* were recorded from mid-hill region of Nepal (Braasch 1980). Manca et al. (1998) recorded three chironomid genera (*Pseudodiamesa*, *Orthocladius* and *Micropsectra*) from high mountain lakes in the Khumbu Valley of Nepalese Himalayas. Shrestha and Mahato (1884) were added significant knowledge on Neplese dragonflies and their distribution in Nepal.

Capnia nepalensis, *Rhopalopsole aculeata*, *Paraleuctra tetraedra*, *Phanoperla siwalika*, and *Neoperla katmanduana*, were described from Nepal (Harper 1977). Sixty one species of insects were found from different water habitats of Kathmandu Valley where 37 were new generic and specific records (Malla et al. 1978).

Five different species of Nemouridae larvae, *Indonemoura adunca, Indonemoura indica, Nemoura gosainkundensis*, *Mesomumoura funicular* and *Protonemura paraproctalis* were described (Sivec 1981a). Simarly, two new species *Amphinemura albifasciata* and *A. lebezi* were described. These species were collected from central Nepal (Sivec 1981b). Suren (1994) studied about the macro invertebrate communities from the streams of Western Nepal and listed 138 macro invertebrates belonging to 53 families under eight orders among them order Ephemeroptera was most common especially family Baetidae from stream of western Nepal.

Sharma et al. (2005) studied about the impacts of dam on the macro invertebrates in Tinau River and listed out 2120 macro invertebrates representing 22 families under ten orders of which Chironomidae family was most abundant. The family Gyrinidae was recorded from East Nepal in 1966 (Ochs and Chui 1966). Thereafter, *Pacrillum cycrilloideum* was newly described from the Nepalese Himalaya (Fikacek and Hebauer 2005).

Yadav (2006) carried out a survey on the aquatic insects of Palungkhola at Makwanpur district, 21 genera of aquatic insects belonging to 19 families of 7 orders were found. Total 60 genera and 204 species were list out at Indian sub region of Oriental region (India, Pakistan, Nepal, Bhutan, Myanmar and Sri Lanka) in 2009 (Sivaramakrishnan et al. 2009). Similarly, the family Nymphomyiidae species were frist time recorded in 2012 from central Asia (Hayford and Bauchard 2012).

In Bagmati river total 2583 benthic macroinvertebrates were recorded representing 10 orders and 29 families. The EPT index and EPT to Chironomidae ratio showed that highly sensitive taxa were abundant in the upstream sites of the river whereas the pollution tolerant taxa were abundant at the downstream sites (Basnet 2013). After this, one new species of genus *Amphinemura* (Plecoptera: Nemouridae: Amphinemurinae), *A. baumanni* and another new species of the genus *Sphaeronemoura* (Amphinemurinae), *S. siveci* were described from Darjeeling District of West Bengal and West Garo Hills District of Meghalaya in India respectively (Muranyi and Li 2013).

Simarly, the study were carried out in Bagmati river and its tributaries total identified taxa belonging to 5 invertebrates groups; Insects nymph/larva (18 taxa), Oligochete worms (3 taxa), Leech (3 taxa), Snails (2 taxa), and Bivalves (1 taxon). Also analysed the river is highly polluted with bacteria, aquatic flora or fauna and with sewage (Mehta et al. 2016).

A checklist from China, 1267 described species in 116 genera and 30 families were included. China had added 267 newly described species over past eight years (Yang et al. 2016). Simarly, One new species of Rhyacophilidae family, *Rhyacophila biguensis* was described from Nepal (Kiss 2017).

The study had been done in Liwagu river, total 3126 individuals to 44 genera and 8 order were collected. Among them order Ephemeroptra were highly distributed. Distribution of aquatic insects were high in upstream (forest area) and low in downstream (human settlement area). Biotic indices were analyzed good water quality in both forest and agriculture area while in human settlement area had moderate the bad water quality, there is lack of pollutant sensitive taxa; Ephemeroptera, Plecoptera and Trichoptera (EPT) (Shafie et al. 2017).

A new species *Hydrovatus remotes* was described from Island of Iriomote, Okinawa Prefecture, southernmost Japan. The distribution range of *Hydrovatus* is in all continents but its main occurrence area is tropical and subtropical regions (Bistrom and Watanabe 2017). Furthermore, three new species of aquatic beetles namely *Grouvellinus leonardodicaprioi*, *G. andrekuipersi*, and *G. quest* were collected from Maliau Basin. The genus *Grouvellinus* is widely distributed in the Oriental and Palearctic regions, but these are the first records from the island of Borneo (Freitag et al. 2018).

Ptilomera (Ptilomera) was reviewed in India and new species *Ptilomera (P.) nagalanda* Jehamalar and Chandra, was described from Peren District of Nagaland, India (Jehamalar et al. 2018). The field survey was conducted in western part of Nepal, which revealed 61 Odonata species belonging 40 genera and 11 families. Family Libellulidae was dominant representing 28 species (Sharma et al. 2018). A new species *Microgomphus farrelli* was described from Northern Thailand. In Asian region 10 species were distributed of genus *Microgomphus* (Makbun and Fleck 2018).

In Myanmar two new species of *Simulium* (*Gomphostilbia*), *S.* (*G.*) *myanmarense* and *S.* (*G.*) *monglaense* were described. These two species are similar to eachother but the pupa is distinguished by the presence or absence of an anterodorsal projection of the cocoon and larva is distinguished by their unique pattern of colored markings on the abdomen (Takaoka et al. 2017) and Seven species of the family Corydalidae were newly recorded and new species of Dobsonfly (*Protohermes burmanus*) was also recorded in same time (Liu and Dvorak 2017).

Likewise in northern Thailand new species of Simuliidae *Simulium (Asiosomulium) saeungae* was described based on female, males, pupae and mature larvae (Takaoka et al. 2018). *Anachauliodes* was first time recorded from Oriental region and *Anachauliodes laboissierei* described morphologically (Tu et al. 2019).

A study on macro invertebrate diversity and water quality parameters were conducted in Godawari River of Nepal. A total of 1 phylum, 2 classes, 6 order, 25 families, and 1558 individuals were successfully recorded and Hydropsychidae, Baetidae, and Chironomidae were high abundance (Vaidya 2019).

Family Hydrophilidae represents 2,652 number of species which is highest number than other families (Sharma et al. 2019). Martynov et al. (2019) were reviewed and corrected to the original description and added some new distinguishing characters of the *Cincticostella insolta complex* (Ephemeroptera: Ephemerellidae) on the basis of new and historic material, as well as new field observations. Three new species, *C. richardi* and *C. ranga* were described from India, and *C. sivaramakrishnani* was described from Nepal.

Two new species were added in Asian genus Notacanthurus which are collected from China, Notacanthurus maculates and *N. lamellosus* (Zhang 2020). In Balang Mountains of Sichuan, Southwestern China, new genus and species of Nemourinae; *Sinonemura balangshana* was described. This description was based on morphology and molecular data (Mo et al. 2020). Similarly, in Guizhou Province of southwestern China, new genus of family Perlodidae, *Parisoperla* Huo Du was recently described including two new species (Huo and Du 2020).

Two new species of Diptera: Chironomidae: Chironominae namely *Glyptotendipes (G.) hebetare* and *G. (G.) inflatum* were described from West Bengal India. These species were described on the basis of adult male, pupa and larva (Konar and Majumdar 2020).

In Meghalaya of India four species of the aquatic and semi-aquatic Hemiptera naming *Anisops occipitalis* (Notonectidae), *Hydrometra okinawana* (Hydrometridae), *Neoalardus typicus* (Veliidae) *and Limnometra ciliat* (Gerridae) was recorded first time (Jehamalar and Chandra 2020). Study was conducted in the Eastern Ghats of India showing distribution of *Ptilomera agriodes* in Eastern Ghats regions like Andhra Pradesh, Odisha, Telangana and Tamil Nadu (Deepa et al. 2020).

Likewise, new genus *Philibaetis* gen. n was described from Philippines. In this study two species *Baetis luzonensis and B. realonae* were re-describes and concluded that these two species does not belong to *Baetis* new genus (Kaltenbach et al. 2021). Furthermore, *Rhagovelia freitagi* was described from Cambodia which belongs to *the Rhagovelia sarawakensis* species group (Zettel 2021).

Thereafter, new species *Nevromus jeenthongi* was described from Thailand which inhabits clean and clear flowing streams (Piraonapicha et al. 2021). Simarly, new species *Stylogomphus thongphaphumensis* was described from Thailand (Chainthong et al. 2020). 559 species have been recorded from Nepal, India, Bhutan, Bangladesh, Pakistan and Sri

Lanka (Kalkman et al. 2020). Recently, Caliphaea angka from family Calopterygidae was first time recorded from Yunnan Province, China (Yang et al. 2021).

2.2 Aquatic Insects and Water Quality Parameters

Dahal et al. (2007) studied effects of agricultural intensification on the quality of rivers in rural watersheds of Nepal. Which reveals physical parameters like temperature and pH are less sensitive to agricultural land use due to their inconsistency and family Hydropsychidae were more common in agricultural sites, whereas Baetidae dominated forest sites.

The study was conducted in Awba Reservoir in Nigeria, which was recorded pH and temperature correlated negatively, Dissolved oxygen (DO) had an inverse correlation with pH and temperature while nitrate-nitrogen, phosphate-phosphorus, alkalinity, and velocity had a direct correlation with DO (Popoola and Otalekor 2011).

After this, the study was carried out in temple pond of Cachar District, Assam, northeastern India. The study was done in pre monsoon, monsoon and post monsoon period and seven families, 11 genera and 14 species of hemipteran insect community were recorded and also found Hemiptera was higher diversity in post monsoon (Gupta and Das 2012). EPT were considered as semi tolerant organism and were not seen sensitive to pollution. They were positively correlated to phosphorus, nitrate and BOD and negatively correlated to DO in Erechim and its tributaries (Hepp et al. 2013).

The study was conducted in Bhalu khola, a tributary of Budhigandaki River, Nepal which was recorded high diversity of macro invertebrates. Total 103 macro invertebrates were identified from 11 families and five orders. Similarly, water quality index (WQI) and NEPBIOS index were showed same result as the quality of water was good. This study reveals that the macro invertebrates can be used as economic tools for determining water quality of streams and rivers as efficient water quality indicators (Rana and Chhetri 2015).

Barman and Gupta (2015) found that high level of Dissolve Oxygen (DO) in stream shows the positive relation of insect species richness. Later on Purkayastha and Gupta described the ecology of Monabeel flood plain, Assam with reference to aquatic insect diversity. The study investigated about the diversity and distribution of insects in relation to physical properties of water like pH, DO, free CO_2, nitrate etc. The insects recorded were 11 species belonging seven families under four orders (Purkayastha and Gupta 2015). Similarly, (Kubendran and Ramesh 2016) examined the Composition and distribution of aquatic insect communities in relation to water quality in two freshwater streams of southern western ghats, India and found that the abundance of aquatic insect was positive relation with DO and negative relation with CO_2.

Likewise, Hasami et al. (2017) studied influence of physicochemical parameters on abundance of aquatic insects in rivers of Perak, Malaysia. Which reveals out the Trichopteran prefers to low flow rate of streams. Furthermore, Nwaniba River was under pollution stress as there was absence of pollution sensitive taxa Ephmeroptera, Plecoptera and Tricoptera. DO and BOD level was lower than the value recommended by NESREA for aquatic life in tropical region. (Esenowo et al. 2017).

The research on Aahoo stream by Adu and Oyeyini (2019) showed that stream was somewhat polluted which was proved by the presence of chironomids, which are pollution tolerant species. Whereas Odonata species found were eurotypic type which could thrive pollution. Total 1456 individuals of aquatic insects were found belonging to 12 genera, 9 families and 3 order (Odonata, Diptera and Hemiptera). This result shows low diversity of insect in the stream.

The aquatic insect community was affected by water quality. Low diversity and abundance of aquatic insects were indicating poor quality of water so they are use as bioindicator (Vian et al. 2018). Kaur et al. (2020) reported maximum distribution of aquatic Coleoptera and Hemiptera exhibited increase abundance during the wet seasons and decrease during dry seasons this is due to low temperature and metabolic rate.

Bo and Tot (2020) carried out the study in trophical freshwater of Nigeria showed negative relation of aquatic insects abundance with Alkalinity of water. High concentration of Alkalinity indicates low abundance of certain sensitive insects group.

The study was conducted in the river’s mainstem and tributaries of the Karnali River Basin of western Himalaya, Nepal. A total of 128 taxa of macroinvertebrates belonging to 84 families and 22 orders were recorded and this study showed high taxa richness was recorded in tributaries compared to the river’s mainstem while abundance was similar between river types, water temperature and pH as major environmental predictors for benthic macroinvertebrate variability between river types (Shah et al. 2020)

3. MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Modi Khola River of Parbat district, western region of Nepal. Geographically the area is located between $28^{0}12^{'}7.1^{''}$N and $28^{0}17^{'}56.4^{''}$N latitudes and $83^{0}40^{'}24.1^{''}$E and $83^{0}45^{'}53.0^{''}$E longitude. The area is surrounded by forest land, agricultural field and human settle area.

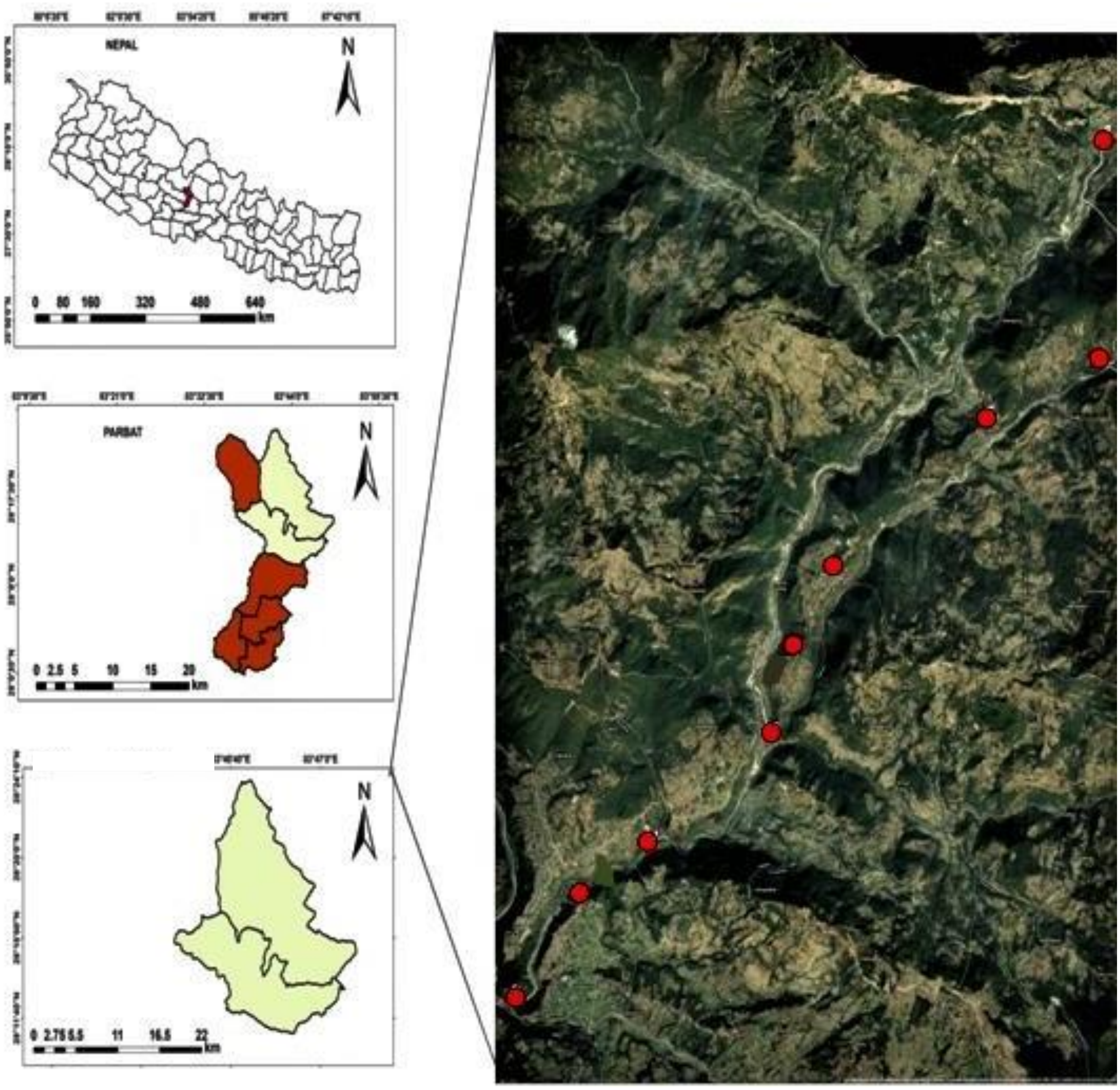

Figure 1. Map showing study area (Modi Khola River)

Red point showing sampling sites

3.2 Site Selection

The sampling site selection was designed to include different habitats that near to forest area, near to agricultural field and near to human settle area. Nine sampling sites of each 100m area were fixed with the help of field measuring tape for taking replicate sample of aquatic insects from the river. Each sampling sites consist of three sampling points on the basis of river heterogeneity.

3.3 Sampling Frequency

The sampling sites were visited in post monsoon and pre monsoon for the collection of aquatic insects. The insects were collected seasonally, each season three times from each sampling site. The insects were collected from sampling site between 10 am to 4 pm. For physicochemical test water was collected each season from each selected sampling sites.

3.4 Materials Used

Measuring tape, BOD bottle for the collection of water samples, Camel hair brush, Camera, D- frame net, Forceps, GPS, Hand lens, Microscope, pH meter, Preservative (70% Ethanol), Sweeping net, Thermometer, White enamel tray, Conical flask, Burette, Measuring Cylinder, Seive, Tags, field note, pen and marker were used.

For titration Manganese Sulphate, Alkaline potassium iodide, Sulphuric acid, Sodium thiosulphate (0.025N), Starch, Sodium hydroxide (0.05N), Hydrochloric acid (0.1N), Phenolphthalein and Methyl orange were used.

3.5 Sample Collection Method

All out search method was used for insect collection in all possible substrata such as bedrocks, boulders, cobbles, under side of stones, leaf litter and dead woods (Subramanian and Sivaramakrishnan 2007).

In the area of unsteady movement of water flow over gravel and sand or in benthic zone the insects were collected by one minute kick method using D-frame kick-net (Subramanian and Sivaramakrishnan 2007).

A nylon pond net was used for sweeping method in the pools of streams where water flow is slow and minimum turbulence.

Sieving was used for sandy places of river.

3.6 Preservation, Identification and Photography

All the collected insects were preserved in 70% alcohol in separate vials. The vials were labeled with location of site and date of collection. Those collections were identified on morphological basis in entomology laboratory (CDZ) by observing morphological features with the help of compound microscope and hand lens, using relevant keys Borror and DeLong (1954), Jonathan and Kulkarni (1986), Subramanian and Sivaramakrishnan (2007) for family level.

For genus level Ephemeroptera (Turkmen and Kazanci 2013), (Dias et al. 2006) and (Sites 2001), Plecoptera (Jaihao and Phalaraksh 2013), Trichoptera (Waringer 2013) and (Wallace 1981) Odonata (Wright and Peterson 1994) and (Nesemann et al. 2011), Coleoptera (Hackston 2018), (Shepard and Sites 2016), (Libonatti et al. 2011) and (Shepard and Sites 2019), Diptera (Sundermann et al. 2017), Hemiptera (Moreira et al. 2018), (Cheng et al. 2001) and (Xie and Liu 2015) and Megaloptera (Ramos and Harris 1998) and Megaloptera (Ramos and Harris 1998) and (Camacho and Ramos 2018).

The photographs of the insects were taken in compound microscope under 10x magnifications using Canon digital camera. The species were deposited in entomology laboratory (CDZ).

3.7 Physico-chemical test of River Water

The temperature and pH were recorded in the study site. The pH of water was measured by dipping the pH meter directly into the collected sample of water. The readings shown by the pH meter were noted down in the field record sheet. Water temperature (WT) was measured with the help of a standard mercury thermometer. The temperature of surface water was taken by simply dipping the thermometer bulb into the water body.

Likewise the velocity was measured by surface floating method (m/s) (Trivedi and Goel 1986).

The dissolved oxygen in water was determined by Winkler's method. The water sample was collected in 250 ml BOD bottle without air bubbles and was air tightened. Do was fixed at the study site by kept 2ml each of Manganese Sulphate and alkaline Potassium iodide solution. The collected sample was titrated in the lab. Free CO_2 was measured by titration method.

Alkalinity of the collected sample was determined by adding Sulphuric acid to decrease the pH of the sample. In 100 ml of sample 2 drops of phenolphthalein indicator was added. The solution either changed to pink or remains colorless. The total alkalinity was measured by adding methyl orange indicator to the colorless sample solution and titrated until yellow color changed to pink. The amount of acid used was recorded and converted to the equivalent weight for alkalinity.

3.8 Statistical Analysis

All the collected data were analyzed by using statistical tools in Microsoft Office Excel 2013. The abundance (%) and diversity indices were calculated for each season pre monsoon and post monsoon.

The diversity of insects species were determined by Shannon–Wiener's Diversity index (H′). Species richness was based on the number of taxa found in the given area.

The relation between the aquatic insects and the physical parameters were calculated by Karl Pearson's Correlation method.

4. RESULT

4.1 Aquatic Insects of Modi Khola

The aquatic insects collected during the study period (pre monsoon and post monsoon) from the study area which was listed with their diagnostic characters (Annex II, Table 6). The list includes eight orders, 33 families and 48 genera and also two unidentified species. Among them 42 genera was recorded in pre monsoon and 35 genera was recorded in post monsoon (Table 1).

Table 1. Status of aquatic insect in different seasons

S.N.	Order	Family	Genus	Status	
				Pre-monsoon	Post-monsoon
1	Ephemeroptera	Baetidae	*Fallceon* spp.	+	+
			Baetis spp.	+	+
			Acentrella spp.	+	+
		Heptageniidae	*Heptagenia* spp.	+	+
			Epeorus sp.	+	+
			Rhithrogena sp.	+	+
		Ephemeridae	*Ephemera* sp.	+	-
		Ephemerillidae	*Ephemerella* spp.	+	+
			Serratella spp	+	+
		Leptohyphidae	*Leptohyphes* sp.	+	+
		Leptophlebidae	*Cryptopenella* sp.	-	+
			Choroterpes sp.	-	+
2	Plecoptera	Perlidae	*Neoperla* spp.	+	+
			Acroneuria spp.	+	+
			Togoperla sp.	+	-
3	Tricoptera	Hydropsychidae	*Hydropsyche* spp.	+	+
		Stenopsychidae	*Stenopsyche* sp.	+	+
		Glossosomatidae	*Glossosoma* spp.	+	-
		Rhyacophilidae	*Rhyacophila* spp.	+	-
		Leptoceridae	*Leptocerus* sp.	+	-

4	Coleoptera	Gyrinidae	*Orectochilus* sp.	-	+
		Hydrophilidae	*Symbiodyta* sp.	+	-
			Cercyon sp.	+	-
			Amphiops sp.	+	+
		Psephenidae	*Psephenus* spp.	+	+
		Dytiscidae	*Hydaticus* sp.	-	+
			Cybister sp.	-	+
		Dryopidae	*Dryops* sp.	+	-
		Elmidae	*Grouvellinus* spp.	+	+
			Unidentified 1	+	-
5	Diptera	Chironomidae	*Chironomus* sp.	+	+
		Athericidae	*Atherix* sp.	+	-
		Tabanidae	*Tabanus* spp.	+	+
		Tipulidae	*Tipula* sp.	+	-
		Limoniidae	*Hexatoma* sp.	+	-
			Antocha sp.	+	+
		Simuliidae	*Simulium* spp.	+	+
6	Hemiptera	Aphelocheiridae	*Aphelocheirus*	+	+
		Naucoridae	*Ilyocoris* spp.	+	+
		Gerridae	*Ptilomera* sp.	+	-
		Notonectidae	*Notonecta* sp.	-	+
7	Megaloptera	Corydalidae	*Corydalus* sp.	+	+
8	Odonata	Gomphidae	*Ophiogomphus* spp.	+	+
			Hylogomphus spp.	+	+
			Lanthus sp.	+	+
		Cordulegastridae	*Cordulegaster* sp.	-	+
		Libuliidae	Unidentified 2	+	-
		Euphaedae	*Euphaea* sp.	+	-

+ indicate the genera present in sampling season

- indicate the genera absent in sampling season

4.2 Abundance of Aquatic Insects

In the study area the most abundant order was Ephemeroptera comprising 44.1% of the total insects sampled. It was followed by Trichoprera, Diptera, Plecoptera, Odonata, Megaloptera, Coleoptera and Hemiptera with 23.5%, 10.1%, 9.5%, 5.8%, 2.9%, 2.5% and 1.6% respectively.

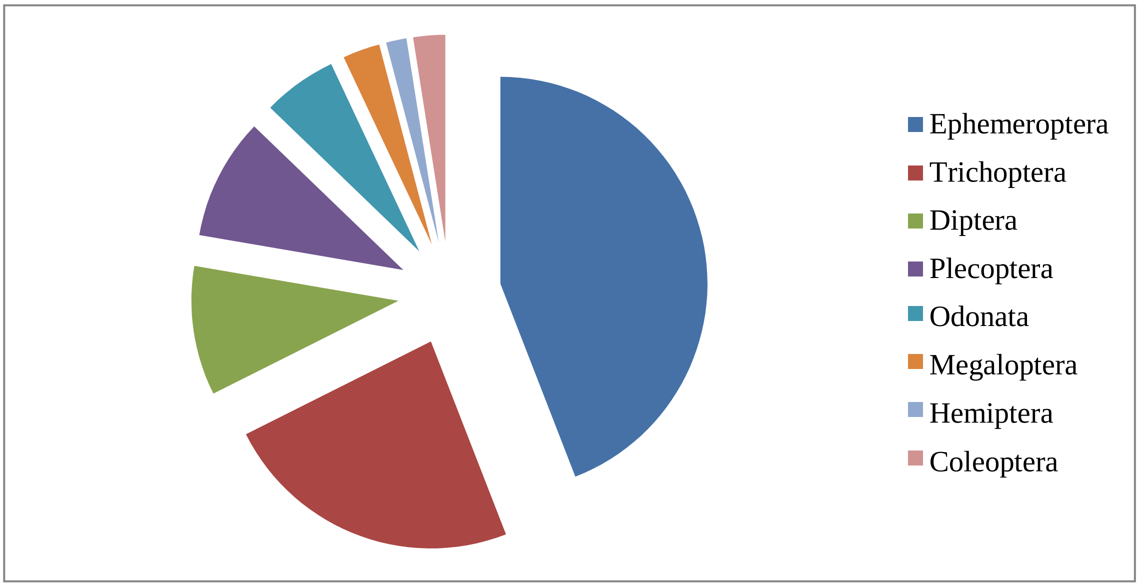

Figure 2. Composition of aquatic insects in study area

4.3 Seasonal variation of Abundance, Diversity and Species Richness in Aquatic Insects

The aquatic insects were found different in pre monsoon and post monsoon. Abundance of order Ephemeroptera was showed higher in post monsoon than in pre monsoon whereas Trichoptera was observed higher abundance in pre monsoon than in post monsoon. Plecoptera was found high abundance in post monsoon and low in pre monsoon. Diptera was mostly abundant in pre monsoon than in post monsoon similarly Odonata also high abundance in pre monsoon. Megaloptera was recorded almost similar abundance in both seasons. Coleoptera and Hemiptera were found very low abundance in compare to other orders in both seasons (Fig. 2 and Annex II Table 5).

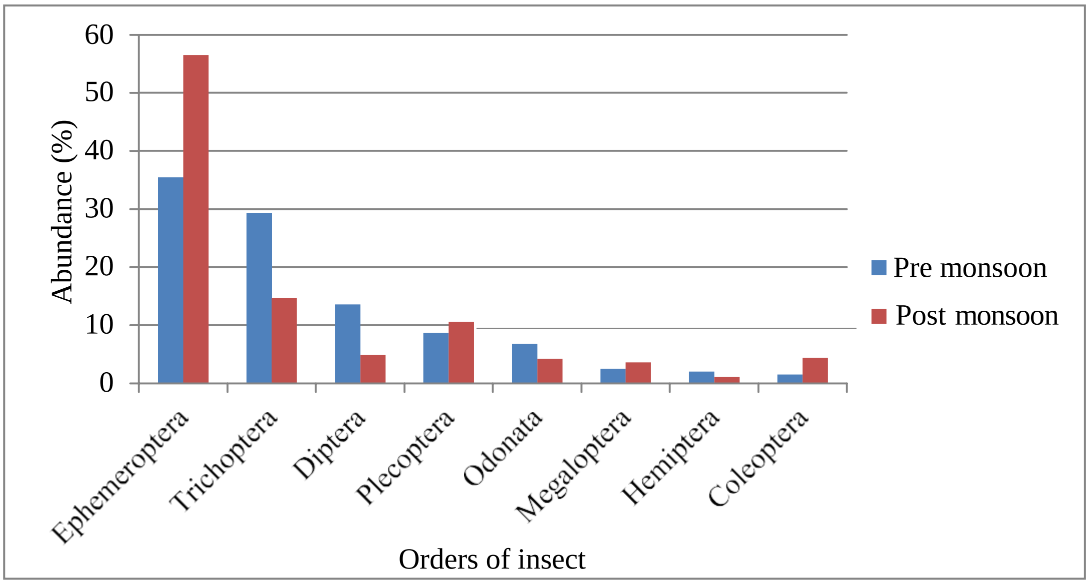

Figure 3. Variation of orders of insect in pre monsoon and post monsoon

Table 2. Diversity of insects in different seasons

River	Season	Shannon-Weiner diversity index (H')
Modikhola	Pre-monsoon	2.72
Modikhola	Post-monsoon	2.57

The diversity index of the aquatic insects was found to be slightly varied from pre and post monsoon. The highest diversity index value was observed in pre monsoon period. The lowest value was observed in post monsoon (Table 2). However one way ANOVA shows that there was no significance difference between insect recorded in pre monsoon and post monsoon with p value 0.07.

Species richness value of the aquatic insects was found in irregular pattern. The highest value (19) in order Ephemeroptera and lowest value (1) in Megaloptera were recorded in pre monsoon whereas highest value (15) and lowest value (1) in post monsoon (Annex II, Table 9).

4.4 Habitat Variation in Abundance and Diversity of Aquatic Insects

The Composition of insect family was different in different habitat. Near to forest area, families Baetidae and Hydropsychidae were higher number of abundance whereas Perlidae and Heptageniidae were moderate abundance and Psephenidae, Athericidae and Limoniidae were lowest abundance during pre monsoon (Annex II, Table 7 and Fig. 4). In post monsoon, Baetidae and Hydropsychidae were also found higher number of abundance whereas Heptageniidae and Perlidae were showed nearly same abundance Elmidae, Dytiscidae, Notonectidae and Cordulegastridae were showed lowest number of abundance (Annex II, Table 8 and Fig. 5). Family Simuliidae was absent in both seasons.

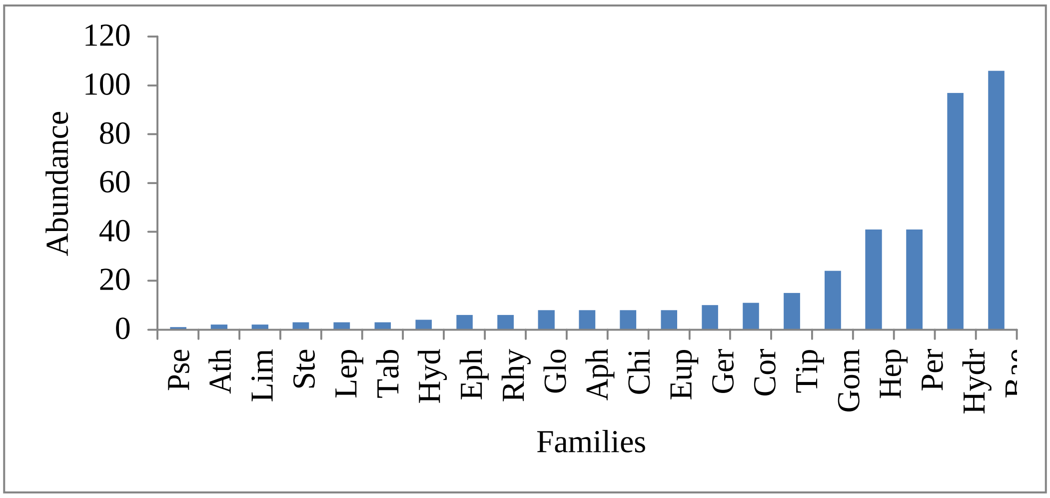

Figure 4. Variation in Families of insects near to forest area (pre monsoon)

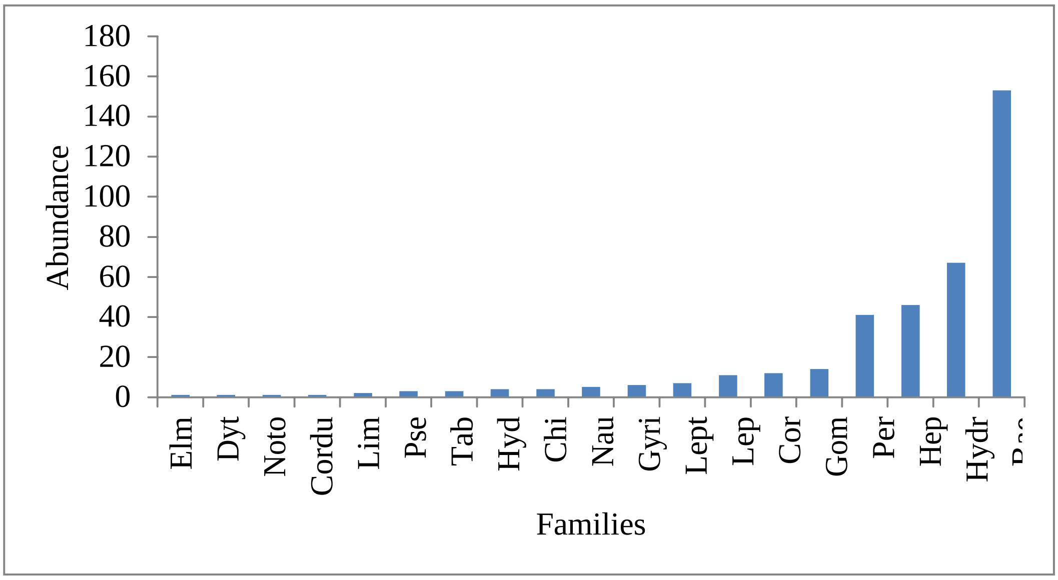

Figure 5. Variation in Families of insects near to forest area (post monsoon)

The sampling area near to agricultural field Hydropsychidae and Baetidae were highly abundant and Athericidae, Stenopsychidae and Elmidae were lowest number of abundance in pre monsoon (Annex II, Table 7 and Fig. 6). During post monsoon period Baetidae was higher number of abundance, Perlidae, Ephemerellidae and Hydropsychidae were showed nearly same range of abundance and Leptophelebidae, Dytiscidae and Limnoiidae were lowest abundance (Annex II, Table 8 and Fig. 7). Aquatic insects from families Leptophlebidae, Stenopsychidae, Psephenidae, Notonectidae and Simuliidae were not recorded in post monsoon.

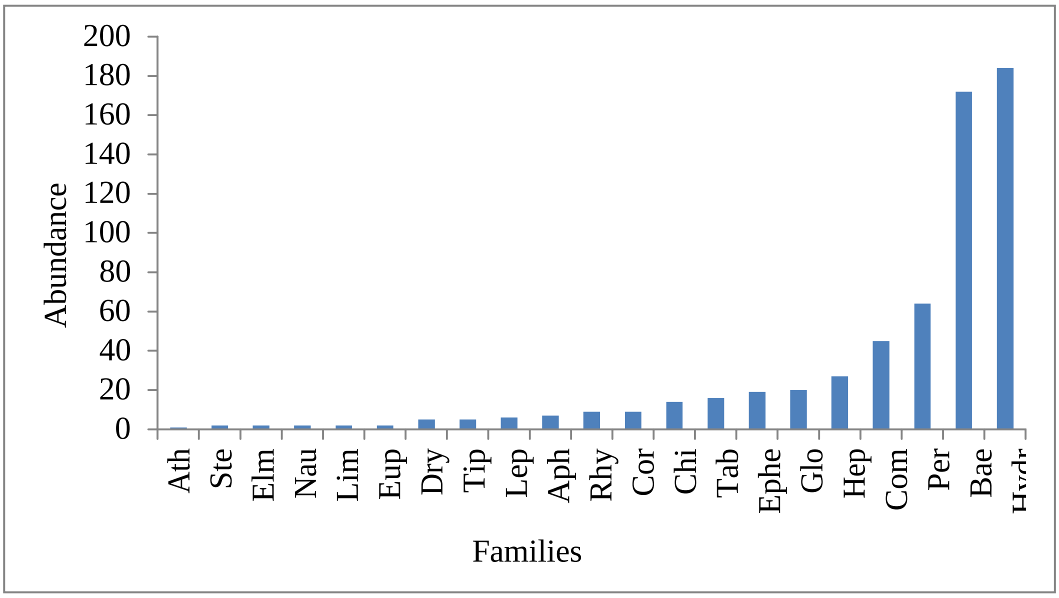

Figure 6. Variation in Families of insects near to agricultural field (pre monsoon)

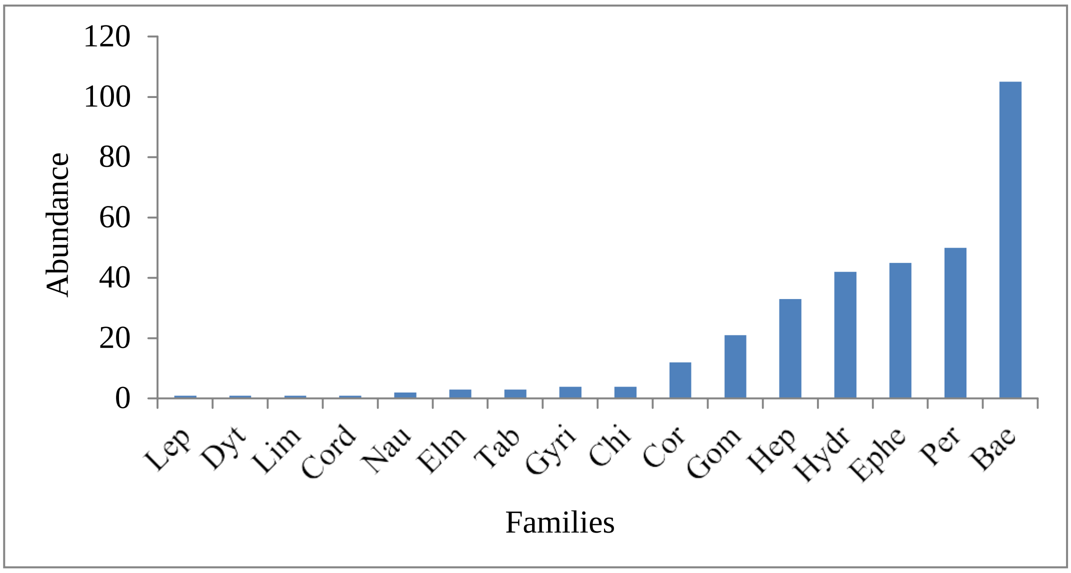

Figure 7. Variation in Families of insects near to agricultural field (post monsoon)

Near to human settle area, maximum numbers of dipteran families were recorded in both seasons. Baetidae, Hydropsychidae, Tipulidae and Chirinomidae were showed higher number of abundance and Libellulidae was found lowest number of abundance in pre monsoon (Annex II, Table 7 and Fig. 8). Gomphidae was found lowest abundance in post monsoon (Annex II, Table 8 and Fig. 10). This study was recorded high abundance of Baetidae and Hydropsychidae in all habitats and in both seasons.

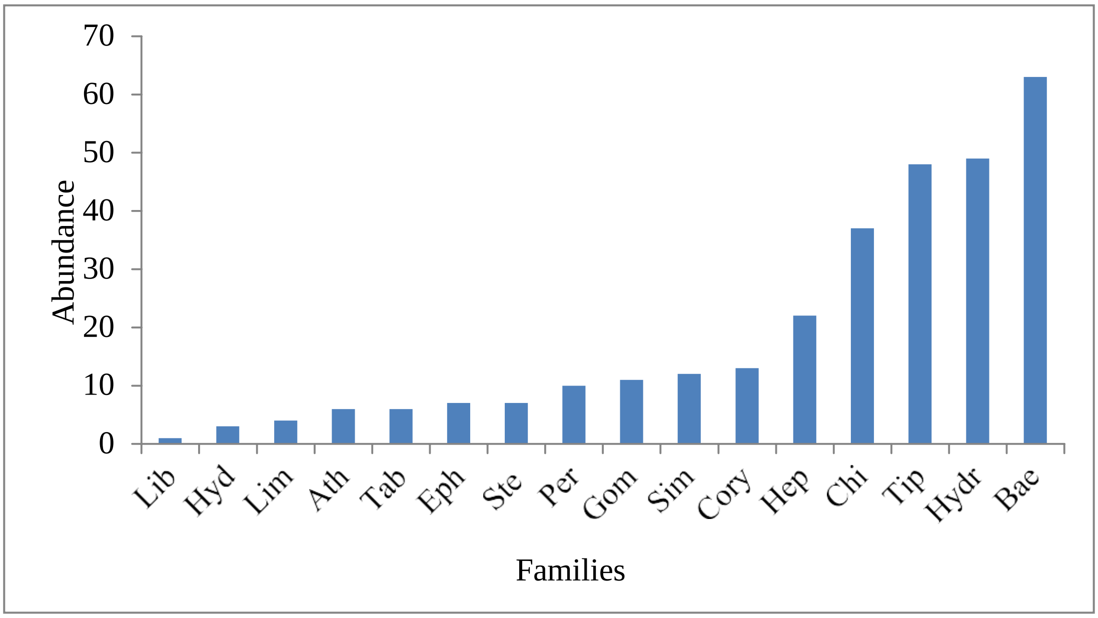

Figure 7. Variation in Families of insects near to human settle area (pre monsoon)

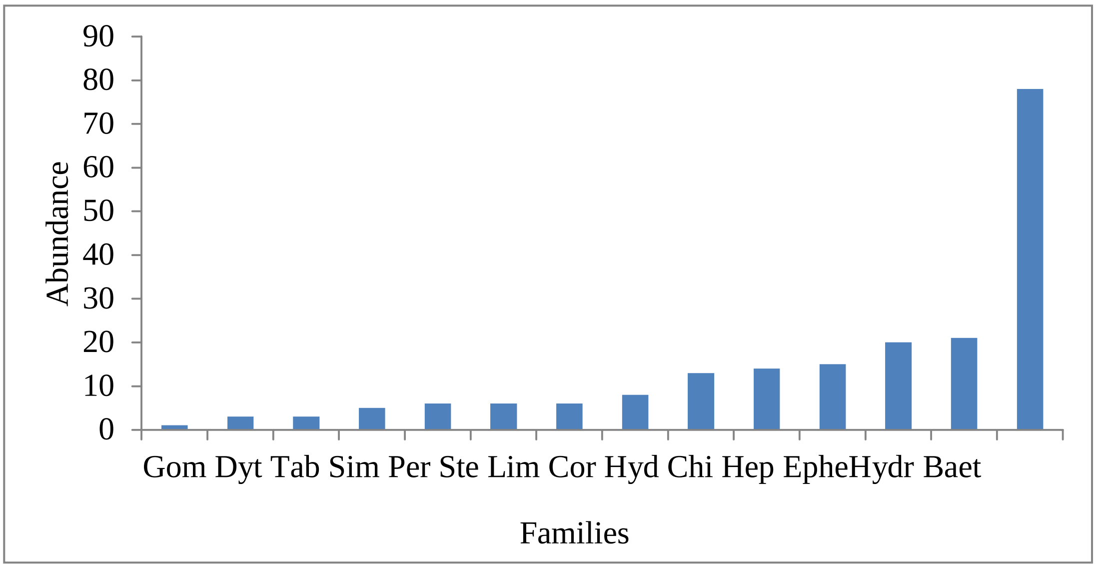

Figure 10. Variation in Families of insects near to human settle area (post monsoon)

(Note:- Bae – Baetidae, Hydr - Hydropsychidae. Per - Perlidae, Aph - Aphelocheridae, Gom – Gomphidae, Hep – Heptageniidae, Glo – Glossosomatidae, Ephe –

Ephemerillidae, Tab – Tabanidae, Chi – Chironomidae, Cor – Corydalidae, Rhy – Rhyachophilidae, Lep - Leptocerus, Tip - Tipulidae, Eup – Eophedae, Lim – Limoniidae, Nau – Naucoridae, Elm - Elmidae, Ste - Stenopsychidae, Ath – Athericidae, Dyt – Dytiscidae, Noto – Notonectidae, Gyri – Gyrinidae, Cordu – Cordulegastridae, Lept - Leptohyphidae, Lep – Leptophlebidae, Sim – Simuliidae, Eph – Ephemeridae, Hyd – Hydrophilidae, Dry – Dryopidae)

Table 3. Seasonal diversity of insect in different habitat

	Season	Shannon-Wiener diversity index		
		Near to forest area	Near to agricultural field	Near to human settle area
Modi Khola	Pre-monsoon	2.69	2.45	2.13
Modi Khola	Post-monsoon	2.39	2.37	2.06

The diversity of insects in different habitats was slightly different in pre monsoon and post monsoon. Diversity of insects near to forest area was found high in both seasons in comparison of near to agricultural field and near to human settle area (Table 3).

4.5 Physico-chemical Parameters of River Water

The physico-chemical parameters of river water were recorded in pre monsoon and post monsoon periods (Table 4). Water temperature fluctuated from 17^{0}C (site 1) to 22^{0}C (site 7) in pre monsoon and in post monsoon it is fluctuated from 15^{0}C (site 9) to 21^{0}C (site 5).

The pH did not show much fluctuation ranging from 7.3 to 7.9 in pre monsoon and 7.2 to 8.1 in post monsoon.

Flow rate of water at site 3 (0.24m/s) and site 9 (0.27m/s) was much faster than other remaining sites in pre monsoon. Similarly, in post monsoon site 6 (0.36m/s) and site 3 (0.38m/sec) were recorded higher rate of water flow than other sampling sites.

The value of DO at different sites were good ranging from 4.01mg/L to 10.7mg/L in pre monsoon whereas in post monsoon obtained moderately good ranging from 4.1mg/L to 6.5mg/L.

Alkalinity and CO_2 of river water in selected sites were recorded high in post monsoon than in pre monsoon (Table 4, column 7).

Table 4. Physico- chemical parameters of different sampling sites in different seasons

Sites	Physico-chemical parameters											
	Temp. (^{0}C)		pH		Velocity (m/s)		DO (mg/L)		CO_2 (mg/L)		Alkalinity (mg/L)	
	Pr m	Pt m	Pr m	Pt m	Pr m	Pt m	Pr m	Pt m	Pr m	Pt m	Pr m	Pt m
Site 1	17	20	7.8	8.1	0.37	0.45	10.7	5.7	6.6	8.2	100	115
Site 2	18	18	7.3	7.8	0.32	0.56	9.32	5.9	7.3	11	120	125
Site 3	17	17	7.9	7.6	0.24	0.38	8.71	5.1	6.82	13	80	100
Site 4	17	18	7.5	7.6	0.30	0.59	8.51	4.3	8.8	17	110	105
Site 5	20	21	7.3	7.9	0.28	0.43	6.69	5.1	11	13	90	130
Site 6	18	17	7.5	7.6	0.33	0.36	8.91	4.8	13.2	9.1	105	125
Site 7	22	19	7.9	7.3	0.45	0.50	5.2	4.1	6.6	14	120	110
Site 8	17	17	7.7	7.5	0.35	0.53	5.87	4.9	8.8	10	125	120
Site 9	17	15	7.3	7.2	0.27	0.48	7.9	6.5	4.4	12	115	100

Pr m indicate pre monsoon and pt m indicate post monsoon

4.6 Correlation of Aquatic Insects with Water Parameters

Table 5. Correlations between aquatic insect number and water parameters

Water parameters	Pre monsoon	Post monsoon
Temperature	-0.34	-0.06
pH	-0.01	0.35
Velocity	-0.12	-0.27
DO	0.55	0.79
CO_2	-0.54	-0.68
Alkalinity	0.34	-0.13

The relation between aquatic insects and the water parameters was varied in pre and post monsoon period. There was a negative relation between number of aquatic insects and temperature during pre monsoon and post monsoon. Similarly, the relation with pH was negative in pre monsoon and positive in post monsoon. Furthermore, the DO was positively correlated and negative correlation was observed with velocity in both seasons. Thereafter, the total alkalinity and number of insect was positively correlated in pre monsoon and negatively correlated in post monsoon.

5. DISCUSSION

Altogether, 2,230 individuals of aquatic insects representing 48 genera from 33 families of 8 orders were recorded from study area. Among them most diverse order was Ephemeroptera with six families Baetidae, Heptageniidae, Ephemeridae, Ephemerillidae, Leptohyphidae and Leptophlebidae with twelve genera (*Fallceon* spp., *Acentrella* spp., *Baetis* spp., *Heptagenia* spp., *Epeorus* sp, *Rhithrogena* spp., *Ephemera* sp., *Ephemerella* spp., *Serratella* spp., *Leptohyphes* sp., *Cryptopenella* sp. and *Choroterpes* sp.). Tricoptera consist of five families Hydropsychidae, Stenopsychidae, Glossosomatidae, Rhyachophilidae and Leptoceridae with five genera namely *Hydropsyche* spp., *Stenopsyche* sp., *Glossosoma* spp., *Rhyachophila* sp. and *Leptocerus* sp. respectively. Plecoptera consist of only one family Perlidae with three genera *Neoperla* spp., *Acroneuria* spp. and *Togoperla* sp. Coleoptera consist of six families Gyrinidae, Hydrophilidae, Psephenidae, Dytiscidae, Dryopidae and Elmidae and nine identified genera *Orectochilus* sp., *Symbiodyta* sp., *Cercyon* sp., *Amphiops* sp., *Psephenus* spp., *Hydaticus* sp., *Cybister* sp., *Dryops* sp. and *Grouvellinus* spp. One unidentified genus was recorded from family Elmidae. Diptera consist of six families Chironomidae, Athericidae, Tabanidae, Tipulidae, Limoniidae and Simulidae with seven genera *Chironomus* sp., *Atherix* sp., *Tabanus* spp., *Tipula* sp., *Hexatoma* sp., *Antocha* sp. and *Simulium* spp. Hemiptera consist of four families Aphelocheiridae, Naucoridae, Gerridae and Notonectidae with four genera *Aphelocheirus* spp., *Ilyocoris* spp., *Ptilomera* sp. and *Notonecta* sp. Megaloptera consist one family Corydalidae and one genus *Corydalus* sp. Odonata consist of four family Gomphidae, Cordulegastridae, Libuliidae and Euphaedae with five identified genera *Ophiogomphus* spp., *Hylogomphus* spp., *Lanthus* sp., *Cordulegaster* sp. and *Euphaea* sp. Family Libuliidae consist of one unidentified genus. The present finding of aquatic insect fauna correlates with the previous studies made by Yadav (2006) which is conducted at Palung Khola in Makwanpur District; 21 insects belonging to 19 genera (8 species of Ephemeroptera, 2 species of Plecoptera, one species of Hemiptera, 3 species of coleoptera, 2 species of Trichoptera, one species of Lepidoptera and four species of Diptera) were documented.

In the present study, the abundance of order Ephemeroptera was higher in both seasons. Mayflies are more abundant and diverse in tropical streams and rivers. The lotic ecosystems provide suitable microhabitats for the establishment of macroinvertebrates

(Beisel et al. 1998). In family wise composition Baetidae was highly abundant with three genera. Their richness was found always higher in the riffles area and lowest in the pools (Kubendran et al. 2017). Rundle et al. (1993) were recorded high abundance of Baetidae from streams of three regions in Himalayas: Anapurna, Langtang and Everest. Similarly, Suren (1994) was found that the order Ephemeroptera was most common especially family Baetidae from stream of western Nepal. The order Trichoptera was highly abundant after the order Ephemeroptera. Sharma (1999) observed higher abundance of Tricoptera followed by Coleoptera in Saptakosi river. Plecoptera was found almost same abundance in both seasons. Suhaila et al. (2014) were recorded low and almost constant population of Plecoptera throughout dry and wet seasons from rivers of Malaysia. The abundance of Diptera in pre monsoon was higher with the presence of seven genera in comparison to post monsoon which are typical for many fresh water systems (Heatherly and Whiles 2005). *Chironomus* spp. was showed lowest abundance in the period of post monsoon. Shah et al. (2011) described the abundance of Chironomidae higher in pre monsoon than post monsoon. Coleoptera and Hemiptera were less abundance in study area but in seasonal ratio Coleoptera was high in post monsoon and Hemiptera was high in pre monsoon. Hossain et al. (2015) recorded higher abundance of Hemiptera in wet season from the rivers of Bangladesh. The abundance of Odonata and Megaloptera occurred slightly different in both seasons. Community composition of aquatic insect was varied seasonally, with a trend toward a declining proportion during the wet season and increasing proportion during the dry season (Ohiokhioya et al. 2009).

According to habitat, the abundance of insect's community was observed different in this study. Near to human settle area abundance of insect was lowest in pre and post monsoon. There is a high probability that human-induced change will also result in a change in the composition of the benthic community. Baetidae and Hydropsychidae were showed higher number of abundance in all three habitats. Hydropsychidae were more common in agricultural sites, whereas Baetidae dominated forest sites (Dahal et al. 2007).

Slightly fluctuation in diversity index was observed during both study seasons. The highest value of diversity index was observed in pre monsoon. Present study showed there is no significance different between seasons and number of insects. Barman and Gupta (2015) mentioned high diversity index in pre monsoon and comparatively low in post monsoon from Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam.

In this study, the species richness of 8 orders of aquatic insects was recorded. Highest species richness occurred in order Ephemeroptera in both seasons. The order Megaloptera was recorded low species richness. In compare to pollution sensitive taxa Ephemeroptera, Plecoptera and Trichoptera (EPT), order Plecoptera was found lowest species richness. The study was conducted in streams to predicting species richness of aquatic insects by using a limited number of environmental variables in 2003 which recorded Plecoptera was low species richness and species richness relationships between Ephemeroptera, Trichoptera, and Coleoptera for both observed and predicted data were highly significant (Cereghino et al. 2003)**.**

The quality of water was determined by different physicochemical parameters and these are useful to detected pollution level in water ecosystem. The changes occurs in trophic conditions of water are reflected in the biological community structure including species pattern, distribution and diversity (Ishas and Khan 2013). In this study shows comparative difference of water quality between both seasons. Water quality in tropical rivers indicates substantial differences between seasons (Jerves-Covo et al. 2019).

The measurement of water temperature is common physical parameters of water which impacts both the chemical and biological characteristics of surface water. The maximum temperature recorded was 22^0C in pre monsoon. Similar type of finding was listed by Barman and Gupta (2015) which shows maximum water temperature in pre monsoon than in post monsoon. The differences of water temperature in study area were caused by the covering and heterogeneity of the vegetation in the river side in each study site. In the present study the coefficient of correlation between number of insect and temperature was showed strongly negative correlation in both seasons with value -0.34 (pre monsoon) and -0.06 (post monsoon). Shah et al. (2020) were finding negative correlation between insects and water temperature. Water temperature affects the number of aquatic insects since each species requires specific temperature range to survive because of their different respiratory rate and metabolism (Devi et al. 2013).

The pH value was observed ranging from 7.2 to 8.1 at sampling sites. According to WHO water has pH value in between 6.5 to 8.5 is normally acceptable. In lotic habitat pH content depends organic matter which entering from terrestrial source. Therefore low pH value occurs due to increase in rate of decomposition of organic matters, source of high water temperature and mixing of domestic sewage (Dubey et al. 2006). Present study showed negative correlation with pH in pre monsoon and positive correlation in post monsoon.

Velocity affects the abundance and diversity of macroinvertebrates this is due to high flow event greatly reduced the biomass and change the species composition of invertebrates in aquatic ecosystem (Barman and Gupta 2015). Higher velocity was recorded in pre monsoon than in post monsoon. Adu and Oyeniyi (2019) were observed significant effect of flow rate on the quantity of aquatic insects in Aahoo stream of Nigeria. In this study the correlation between number of aquatic insect and velocity of water were negative in both seasons. Sharma et al. (2008) were found similar relation between insect diversity and water velocity in Chandrabhaga river, Garhwal Himalayas.

Fresh water stream with highest dissolved oxygen have greater number of benthic insects. The concentration of dissolve oxygen (DO) was major component to indicate water purity and determined the distribution pattern of various aquatic fauna (Wahizatul et al. 2011). The highest value of DO was recorded in post monsoon at the sites near to forest area and lowest in pre monsoon period at near to human settle area. Presence of suspended particles in the water absorbs heat thus they could increase water temperature. When water temperature was increase DO was decrease, so the warmer water leads to low DO (Mandal, 2014). The coefficient of correlation between DO and number of insects were showed positive relation in both seasons from this study. Rai et al. (2019) showed similar relation between DO and aquatic insect from headwater of Bagmati River.

Free Carbondioxide levels increase in fresh water creates weak acidification which is not suitable for certain species of insects. The value of CO_2 increase in water the pH of water and DO were decrease (Sharma 2000). The present study showed negative relation with diversity of insects. Alkalinity measures the various substances related to the basic property of water and high value of total alkalinity (TA) is associated with poor quality of water. In this study TA was highest in post monsoon and lowest in pre monsoon.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the results throughout this study period, a total of 48 genera and 33 families representing eight orders with two unidentified genus were recorded. The highest abundance of insect species was from order Ephemeroptera of the total insects sampled. It was followed by Trichoprera, Diptera, Plecoptera, Odonata, Megaloptera, Coleoptera and Hemiptera. Seasonally, abundance of orders of insect was highly varied.

The diversity recorded high in pre monsoon than in post monsoon. The species richness was also recorded high in pre monsoon period. Habitat variation occurs in irregular pattern. Near to forest area has high diversity than near to agricultural field and near to human settle area. This result indicates aquatic insects prefer high diversity in near to forest area. Analysis of variance shows no significant relation between aquatic insects and seasons.

The number of insect species was positively related with DO in both seasons and temperature, velocity and CO_2 were negatively correlated. In pre monsoon, diversity shows positive correlation with alkalinity but negative with pH.

6.2 Recommendations

Based on this research, following are the important recommendations:

- More research work related to aquatic insects such as identification up to species level should be encouraged.
- The pollution must be controlled near to river side to increase the diversity and maintenance of river ecosystem.

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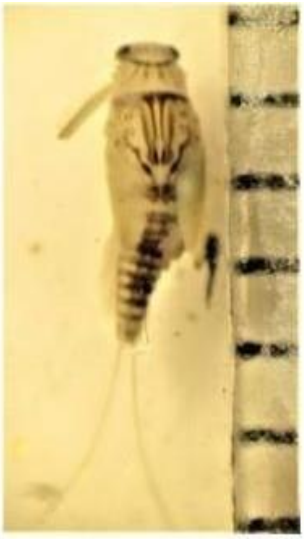
ANNEX

ANNEX I Photographs of Aquatic Insects

Plate A. Ephemeroptera

Fallceon sp.

Gills (*Fallceon* sp.)



Acentrella sp.

Baetis sp.

Heptagenia sp.

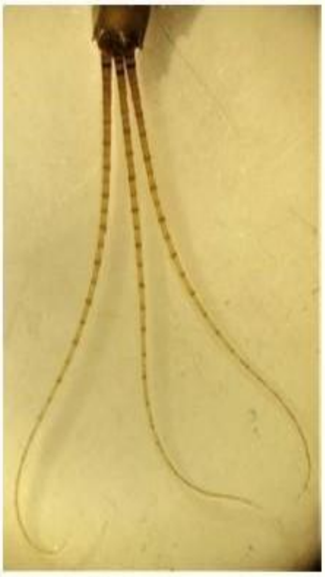
Rhithrogena sp.

Epeorus sp.

Ephemera sp.

Cryptopenella sp.

Ephemerella sp.



Caudal filaments (*Ephemerella* sp.)

Serratella sp.

Leptohyphes sp.

Chorotorpides sp.

Plate B. Trichoptera

Hydropsyche sp . (Dorsal view)

Hydropsyche sp . (ventral view)

Forked Trochantin (*Hydropsyche* sp.)

Rhyachophila sp.

Anal hook (*Rhyachophila* sp.)

Stenopsyche sp.

Glossosoma sp. a- Ventral portion of thorax b- case

Leptocerus sp. in Case

Plate C. Plecoptera

Neoperla sp.

Ocelli (*Neoperla* sp.)

Acroneuria sp.

M-Pattern in head (Acroneuria sp.)

Togoperla sp.

Plate D. Odonata

Lanthus sp.

Euphaea sp.

Cordulegaster sp.

Ophiogomphus sp.

Hylogomphus sp.

Plate E. Coleoptera

Cybister sp. (Dorsal view)

Cybister sp. (Ventral view)

Orectochilus sp.

Hydaticus sp.

Dryops sp.

Amphiops sp.

Cercyon sp.

Grouvellinus sp.

Cymbiodyta sp.

Psephenus sp.

Plate F. Hemiptera

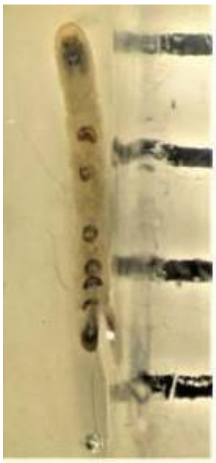
Notonecta sp.

Ilyocoris sp.

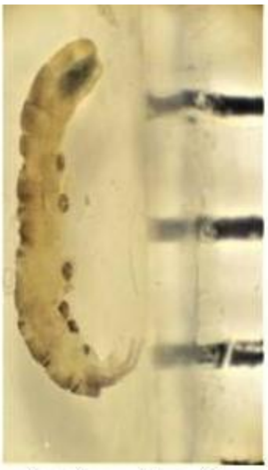
Aphelocheirus sp.

Ptilomera sp.

Plate G. Diptera

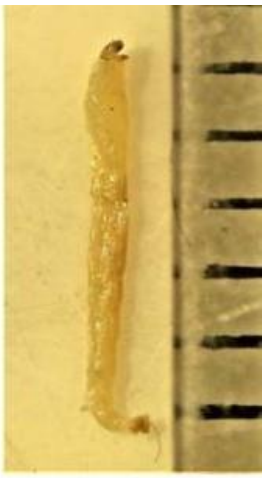


Antocha sp. (ventral)



Antocha sp. (lateral)

Atherix sp.



Chironomus sp.

Hexatoma sp.

Tipula sp.

Simulium sp. (dorsal)

Tabanus sp.

Plate H. Megaloptera and Unidentified species

Corydalis sp.

Unidentified 1

Unidentified 2

Plate I. Other Photographs

Case of Trichoptera on stone

Sampling point (Sandy area)

Sampling point (Stoney and grabel area)

Sampling point (Pool area)

Preserved species

ANNEX II Data Analysis

Table 6. Seasonal abundance of order of aquatic insects in river

S.N.	Order of collected insects	Abundance (%)	
		Pre monsoon	Post monsoon
1	Ephemeroptera	35.5	56.5
2	Trichoptera	29.4	14.7
3	Diptera	13.6	4.9
4	Plecoptera	8.7	10.6
5	Odonata	6.8	4.2
6	Megaloptera	2.5	3.6
7	Hemiptera	2	1.1
8	Coleoptera	1.5	4.4
	Total	100	100

Table 7. Identified insects species with diagnostic characters

S.N.	Genus	Diagnostic characters
1.	*Baetis* (Leach, 1815) spp. (Ephemeroptera: Baetidae)	Middle tail shorter than outer ones; tails never with dark rings but have a median dark band in some species. Gills single, rounded at the tip, and shaped like the head of a tennis racket. Hind wingpad present, tibia and tarsi without row of hair; claws with denticle.
2.	*Acentrella* (Bengtsson, 1912) spp. (Ephemeroptera: Baetidae)	Two tails Gills on segment 1-7 or 2-7 Labial palp not truncated Complete row of setae on femur, tibia and tarsi; claws are not spatulated.
3.	*Fallceon* (Waltz and McCafferty, 1987) spp. (Ephemeroptera: Baetidae)	Gill present on segment-1 and gill 7 rounded Dorsum of head with keel between antenna

		Labial palpi poorly developed.
4. .	*Choroterpes* (Eaton, 1881) sp. (Ephmeroptera: Leptophilibidae)	Mandibular tusk present Gills on 2nd abdominal segment operculate. Other gills are dorsally borne Head rectangular, Maxillary and Labial palpi greatly elongated and extending both side of the head.
5.	*Cryptopenella* (Gillies 1951) sp. (Ephmeroptera: Leptophilibidae)	Mandibular tusk present. Gills on 2nd abdominal segment operculate, other gills are dorsally borne. Head rectangular, Posterolateral spine on abdominal segment 3-9, those on 8-9 curved with inner edge. Tooth like process on anterior apex of maxilla.
6.	*Leptohyphes* (Eaton, 1882) spp. (Ephmeroptera: Leptohyphidae)	Basal beak like process on ventral lamellae of operculate gills Operculate gills without dorsal ribs gills present on 2-6 abdominal segment Abdominal terga without posterolateral projection.
7.	*Serratella* (Edmunds, 1959) spp. (Ephmeroptera:Ephemerellidae)	Caudal filament with whorl of spine at apex of each segment Maxillary palp reduced or absent.
8.	*Ephemerella* (Chitinophora Bengtsson, 1908) sp. (Ephmeroptera: Ephemerellidae)	Caudal filament with whorl of spine at apex of each segment Maxillary palpi well developed.
9.	*Ephemera* (Linnaeus, 1758) sp. (Ephemeroptera: Ephemeridae)	Each gill 2-branched with fine filaments down the sides, held over back, and extend over first half of abdomen Frontal process of head bifid Smooth mandibular tusk on margin, labial palpi 3 segmented.

10.	*Heptagenia* (Walsh, 1863) spp. (Ephemeroptera:Heptageniidae)	Three well developed caudal filament Super linguae of hypopharynx lyre shaped Gill not actually pointed apically; gill VII with fibrils Dorsal margin of femora with long setae Tarsal claw is usually with only single basal denticle.
11.	*Epeorus* (Eaton, 1881) sp. (Ephemeroptera:Heptageniidae)	Two well developed caudal filament Double row of sub-median spines present on the abdominal tergites.
12.	*Rhithrogena* (Eaton, 1881) spp. (Ephemeroptera:Heptageniidae)	Flattened body with broad head, thorax, and femora. Dark spot on top of each femur. First gill large and meets its fellow beneath the body.
13.	*Neoperla* (Eaton, 1881) spp. (Plecoptera: Perlidae)	Two ocelli; occipital ridge with incomplete row of short bristle or absent Lateral margins of pronotum with fringe incomplete No strong bristles along wing pads Anal gills typically present.
14.	*Acroneuria* (Pictet, 1841) spp. (Plecoptera: Perlidae)	Head with 3 ocelli; frontoclypeus usually with a pale stylized M-pattern Setal row or ridge on occiput absent; postocular fringe with row of several thick setae Cerci with basal fringe of silky setae Anal gills present or absent.
15.	*Togoperla* (Klapalek, 1907) sp. (Plecoptera: Perlidae)	Three ocelli; occipital ridge with complete row of short bristle Thorax and abdomen without a median longitudinal row of silky hairs Posterior supracoxal gills on thoracic

		segment 2 to 3 double Anal gills absent.
16.	*Hydropsyche* (Pictet 1834) spp. (Tricoptera: Hydropscychi)	Ventrolateral gills on abdominal segments, anal prolegs with a terminal brush of long setae Thoracic segment sclerotized. Fore trochantin usually forked.
17.	*Stenopsyche* (Pictet, 1834) sp. (Tricoptera: Stenopsychidae)	Head prolonged, more than 2 times as long Labium suboval with small palp.
18.	*Rhyachophila* (Pictet 1834) sp. (Tricoptera: Rhyachophilidae)	Larva without prosternal plate Anal larvapod with large hook, Anal claw without dorsal accessory hooks Fore trochantin projecting forward Free living.
19.	*Glossosoma* (Curtis, 1834) spp. (Tricoptera: Glossosomatidae)	Mesonotum membranous Anal claw with accessory teeth similar to the claw; larva builds portable; turtle-shaped case of gravel, with anterior and posterior openings directed ventral.
20.	*Leptocerus* (Leach in Brewster, 1815) sp. (Tricoptera: Leptoceridae)	Hook-shaped tarsal claws of middle leg. Hind leg provided with 2 long setal fringes. Case strongly tapering and curved.
21.	*Chironomus* (Meigen, 1803) sp. (Diptera: Chironomidae)	Two pair of ventral tubules, lateral tubles present on 7^{th} segment Distal edge of frontal apotome convex between antennal bases Two or three eye spot with similar size, usually arranged in vertical line; in some cases eye spot may be jointed.
22.	*Simulium* (Latreille, 1802) spp. (Diptera: Simuliidae)	Head capsule usually a pair of conspicuous fan Abdominal segment 5-8 swollen, terminating in circlets of radiating row of

		minute hooks Prolegs only on prothorax.
23.	*Tipula* (Linnaeus, 1758) sp. (Diptera: Tipulidae)	Head capsule sclerotized and mostly retracted Mandibles moving horizontally against each other Body with short hairs evenly distributed Anal gills not branched.
24.	*Hexatoma* (Latreille, 1809) sp. (Diptera: Limoniidae)	Hexatome can be identified by swollen 7 segment Head capsule retracted.
25.	*Antocha* (Sacken, 1860) sp. (Diptera: Limoniidae)	Spiracles on the last abdominal segment are missing Dorsal and ventral creeping welts on abdominal segments 2 to 7.
26.	*Tabanus* (Linnaeus ,1758) spp. (Diptera: Tabanidae)	Body cylindrical, both end tapering; segment ringed by welts which are covered by setae Head capsule retracted into thorax, mandible moving parallel to each other on vertical plane Distinct proleg absent, anal segment usually tapering tnto extensible siphon.
27.	*Atherix* (Meigen, 1803) sp. (Diptera: Anthericidae)	Abdomen terminating in two lobes fringed with setae, terminal process longer than prologs Abdominal segments 6-8 without such long appendages The hook of the outer and middle row on the pseudopodia are different in length; outer row is shorter than the middle row.
28.	*Ophiogomphus* (Selys, 1854) spp. (Odonata: Gomphidae)	Antenna four segmented; 3rd segment of antenna widening at mid-length Abdomen narrow and spindle-shaped,

		usually more convex dorsally; segment 10 cylindrical but short Wing sheaths divergent Cerci distinctly shorter than epiproct.
29.	*Hylogomphus* (Needham, Westfall and May, 2000) sp. (Odonata: Gomphidae)	Abdominal segment 10 trapezoidal and shorter than segment 9, margins converging posteriorly Apical burrowing hook on prothoracic and mesothoracic tibiae straight to slightly curved, tip blunt Middorsal hook absent in segment 8.
30.	*Lanthus* (Needham, 1987) sp. (Odonata: Gomphidae)	Third segment of antenna oval, widest near or beyond mid-length, with relatively broad apex Palpal blade with majority of inner teeth triangular Posterior margin of segment 5-7 with stubby setal bases lacking elongate setae extending over intersegmental membrane Segment 7 without posterolateral spine.
31.	*Cordulegaster* (Leach, 1815) sp. (Odonata: Cordulegastridae)	Prementum in ventral view with basal transverse suture V-shaped, ventromedial groove usually originating distal to base Dorsolateral rim of palpus with longest marginal setae; frontal ridge with 2–4 scattered piliform setae at most amongst stouter setae; If posteroletral spine present in segment 8, curved upward slightly, tip directed toward segment 9 spine.
32.	*Euphaea* (Selys, 1840) sp. (Odonata: Euphaedae)	Labium flat, row of spine along lateral margin of prementum Lingua sub rectangular dome shaped. No

		setae on prementum, row of spine along antero-lateral margin of eye. Seven pair of abdominal gills.
33.	*Psephenus* (Haldeman, 1853) spp. (Coleoptera: Psephenidae)	Greatly flattened body, discoidal Five pairs of gills on 2-6 abdominal segment Clypeus emarginated, frons with long setae, closed to fronto-clypeal suture and antenna base.
34.	*Orectochilus* (Dejean, 1833) sp. (Coleoptera: Gyrinidae)	Compound eye two pair one pair dorsal one pair ventral Labrum long and subtriangular Elytra with compact setae. Antenna with 9 antennomeres Scutellum visible Pronotum and elytra covered with fine stout hairs, labrum bulging not forming continuous curve with front of head.
35.	*Cybister* (Curtis, 1827) sp. (Coleoptera: Dytiscidae)	Upper and lower surfaces appearing shiny Males with the front tarsi expanded like a disc with either sixteen adhesive pads of increasing size or with three larger and over thirty smaller ones.
36.	*Hydaticus* (Leach, 1817) sp. (Coleoptera: Dytiscidae)	Elytra black with pale lateral margins Black crescent on pronotum.
37.	*Grouvellinus* (Champion, 1923) spp. (Coleoptera: Elmidae)	Antenna shorter than head, clubbed at last three segment, with 11 antennomere. Body less than 4.5 Coxae narrowerly separated pro and meso coxae not visible dorsally Protibia with medio apical fringe of setae.
38.	*Dryops* (Olivier, 1991) sp. (Coleoptera: Dryopidae)	Pronotum with complete sublateral longitudinal sulcus on each side.

39.	*Cercyon* (Leach, 1817) sp. (Coleoptera: Hydrophilidae)	Front tibia rounded with apical spur. Elytra with distinct puncture Sutural stria extending well toward front.
40.	*Cymbiodyta* (Bedal, 1881) sp. (Coleoptera: Hydrophilidae)	Eyes not completely divided into a dorsal and a ventral part Elytral margins not finely serrate Middle and hind tarsi with four segments.
41.	*Amphiops* sp. (Coleoptera: Hydrophilidae)	Body highly spherical. Eyes divided completely into dorsal and ventral part Elytra margin not finely serrated Middle and hind tarsi without swimming hair.
42.	*Ptilomera* (Amyot and Serville, 1843) sp. (Hemiptera: Gerridae)	Claws of fore tarsi inserter before apex of tarsi Hind femur much larger than mid femora and abdomen Male with wooly hair on posterior half of mid femora Female with connexival spine on segment 7.
43.	*Ilyocoris* (Stal, 1861) spp. (Hemiptera: Naucoridae)	Antenna shorter than head, body dorsoventrally flattened, fore femora enlarge Mid and hind leg with fringe of swimming setae Body exceeding 10mm, protonum yellowish.
44.	*Aphelocheirus* (Westwood, 1833) spp. (Hemiptera: Aphelocheiridae)	Antenna shorter than head, head longer than wide, tarsi of foreleg three segmented Rostrum long and slender, extending hind coxae.
45.	*Notonecta* (Linnaeus, 1758) sp. (Hemiptera: Notonectidae)	Here is no hair-lined pit at the anterior joining point of the hemelytra

		He antennae located under the eyes are 4 segmented The middle and hind legs are fringed with swimming hairs.
46.	*Corydalis* (Latreille, 1802) sp. (Megaloptera: Corydalidae)	Elongated dorsally flattened body, large jaws projection forward, all three thoracic notum sclerotized Last abdomen segment with two pair of hook Abdominal segment 1 to 8 with lateral filaments.
47.	Unidentified 1 (Coleoptera: Elmidae)	-
48.	Unidentified 2 (Odonata: Libellulidae)	-

Table 8. Habitat variation in abundance of aquatic insects (Pre monsoon)

Family	Genus	Abundance		
		Near to forest area	Near to agricultural area	Near to human settle area
Baetidae	*Acentrella*	30	45	21
	Baetis	9	8	-
	Fallceon	67	119	42
Heptageniidae	*Heptagenia*	32	24	22
	Epeorus	3	2	-
	Rhithrogena	6	1	-
Ephemeridae	*Ephemera*	6	-	-
Ephemerillidae	*Ephemerella*	-	4	-
	Serratella	-	15	7
Leptohyphide	*Leptohyphes*	-	6	-
Perlidae	*Neoperla*	24	16	-

	Togoperla	1	12	-
	Acroneuria	16	36	10
Hydropsyche	*Hydropsyche*	97	184	49
Stenopsychidae	*Stenopsyche*	3	2	7
Glossosomatidae	*Glosossoma*	8	20	-
Rhyachophilidae	*Rhyachophila*	6	9	-
Leptoceridae	*Leptocerus*	3	-	-
Hydrophilidae	*Cercyon*	2	-	-
	Symbiodyta	2	-	-
	Amphiops	-	-	3
Psephenidae	*Psephenus*	1	-	-
Elmidae	*Grouvellinus*	2	-	-
	Unidentified 1	-	2	-
Dryopidae	*Dryops*	-	5	-
Aphelocheiridae	*Aphelocheirus*	8	7	-
Gerridae	*Ptilomera*	10	-	-
Chirinomidae	*Chironomus*	8	14	37
Athericidae	*Atherix*	1	1	6
Tabanidae	*Tabanus*	3	16	6
Limoniidae	*Antocha*	2	2	4
Tipulidae	*Tipula*	4	2	40
	Hexatoma	11	3	8
Simuliidae	*Simulium*	-	-	12
Corydalidae	*Corydalus*	11	9	13
Gomphidae	*Ophiogomphus*	24	43	11
	Lanthus	-	1	-
	Hylogomphus	-	1	-
Libuliidae	*Unidentified 2*	-	-	1
Euphaedae	*Euphaea*	8	2	-
Total		408	613	299

Table 9. Habitat variation in abundance of aquatic insects (Post monsoon)

Family	Genus	Abundance		
		Near to forest area	Near to agricultural area	Near to human settle area
Baetidae	*Acentrella*	32	29	19
	Baetis	14	-	-
	Fallceon	107	76	59
Heptageniidae	*Heptagenia*	43	33	15
	Epeorus	1	-	-
	Rhitrogena	2	-	-
Ephemerillidae	*Ephemerella*	-	7	13
	Serratella	-	38	7
Leptophlebidae	*Cryptopenella*	3	-	-
	Choroterpes	4	-	-
Leptohyphidae	*Leptohyphes*	11	1	-
Perlidae	*Neoperla*	18	4	-
	Acroneuria	23	45	6
Hydropsyche	*Hydropsyche*	67	42	21
Stenopsychidae	*Stenopsyche*	-	-	6
Gyrinidae	*Orectochilus*	6	4	-
Elmidae	*Grouvellinus*	1	3	-
Hydrophilidae	*Amphiops*	4	-	13
Psephenidae	*Psephenus*	3	-	-
Dytiscidae	*Hydaticus*	1	1	-
	Cybister	-	-	3
Aphelocheiridae	*Aphelocheirus*	-	2	
Naucoridae	*Ilyocoris*	5	2	-
Notonectidae	*Notonecta*	1	-	-
Chironomidae	*Chironomus*	4	4	14
Tabanidae	*Tabanus*	3	3	3
Limoniidae	*Antocha*	2	1	6

Simuliidae	*Simulium*	-	-	5
Corydalidae	*Corydalus*	12	12	8
Gomphidae	*Ophiogomphus*	14	9	-
	Hylogomphus	-	11	1
	Lanthus	-	1	-
Cordulegastridae	*Cordulegaster*	1	1	-
Total		382	329	199

Table 10. Variation in species richness

S.N.	Orders	Pre monsoon	Post monsoon
1	Ephemeroptera	19	15
2	Plecoptera	7	4
3	Trichoptera	8	5
4	Coleoptera	8	7
5	Diptera	10	6
6	Hemiptera	7	6
7	Megaloptera	1	1
8	Odonata	7	8