AQUATIC INSECTS OF ADHIKHOLA RIVER SYSTEM IN WALING, SYANGJA

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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).

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This is to recommend that thesis entitled "**Aquatic insect of Aadhikhola River System in Waling, Syangja**" has been carried out by Miss Rounika Pokhrail 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 Rounika Pokhrail entitled "**Aquatic Insect of Adhikhola River System in Waling, Syangja**" 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 Rounika Pokhrail entitled "**Aquatic Insect of Adhikhola River System in Waling, Syangja**" 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
Adh	Adhikhola
Arm	Armadi Khola
ASPT	Average Score per taxon
Au	Autumn
Aq	Aquatic
BOD	Biological Oxygen Demand
BMWP	Biological Monitoring Working Party
EPT	Ephemeroptera Plecoptera Tricoptera
m/s	meter per second
Md	Madi khola
mg/l	milligram per liter
Mir	Mirdi khola
NEPBIOS	Nepalese Biotic Score
TA	Total Alkalinity
Win	Winter

ABSTRACT

Insects which spend fully or partially part of their life in water is known as aquatic insect. Aquatic insects are important part of aquatic ecosystem which play vital role in ecosystem functioning. Major Orders representing aquatic insects are Ephemeroptera, Plecoptera, Tricoptera, Odonata, Megaloptera, Diptera, Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera and Collembola. This study was conducted in Adhikhola River System, Waling, Syangja. Adhikhola River System in Waling consists of 4 River Mirdi Khola, Armadi Khola, Madi Khola and Adhikhola River of which Mirdi Khola, Armadi Khola, Madi Khola are tributaries of Adhikhola River. Twelve sampling site has been ascertained, three sites on each stream on the basis of different habitat (Forest, Agriculture and Urban). Each site was further divided into 3 point on the basis of heterogeneity. Insect collection was done by “Sweeping” method for littorial zone, “1minute kick method by D-Frame kick net for benthic zone, “Sieving” for sandy bottom of rivers and “All out search” was done for microhabitat. Sampling was done for two seasons Autumn and Winter. Identification was done by the use of standardized taxonomic key. A total 45 genera, 31 families and 8 orders were report from different sites of study area. Among 4 river stream Adhikhola River and Mirdi Khola were highly abundant followed by Armadi khola and Madi khola was least abundant. Abundance and Diversity of Insect was seen high in autumn than winter. Habitat wise diversity of Forest was highest followed by agriculture and Urban was lowest. But no significance difference was seen in between Seasonal Variation and Habitat Variation of Insect fauna. Insect Fauna showed significant negative correlation was seen with CO_2 and positive correlation with alkalinity in autumn. Since Diversity and abundance of insect were seen degrading in urban areas hence further research should be carried to know the precise condition of aquatic insect and river.

1. INTRODUCTION

1.1 Background

Insects which spend fully or partially part of their life in water are known as aquatic insect for eg, larvae of mayflies (Ephemeroptera), damselflies and dragonflies (Odonata), stoneflies (Plecoptera), alderflies and dobsonflies (Megaloptera), and caddisflies (Trichoptera) whereas adult and larvae of the true bugs (Heteroptera), beetles (Coleoptera) and flies (Diptera). There are nearly 100,000 described aquatic insects (Dijkstra et al. 2013).

Aquatic insects are important part of aquatic ecosystem which play vital role in ecosystem functioning (Barman and Gupta 2015). They are structure and function of freshwater ecosystem due to their high number, high birthrate with short generation time, large and rapid colonization (Choudhary and Ahi 2015). They play large role in the processing of organic matter in headwater streams. Aquatic insect function on multiple tropic levels such as shredders, collectors, scraper and predators. They interact in nutrient cycling within aquatic systems (Lundquist and Zhu 2018).

The species which are sensitive to specific environmental factor, such as change in their abundance directly relates to change in aquatic environment are known as bio indicators (New 1984). Aquatic insects are also used as bioindicator for eg. Odonata species requires well oxygenated freshwater to live (Needam 2000) whereas Chironomids are sensitive to eutrophic (Langdon et al. 2006). Aquatic insect like stonefly, mayflies and caddisfly needs water of good quality to live, they are sensitive to pollution. On the other hand Chironomidae (Diptera) can tolerate pollution. Presence of Chironomids and absence stonefly, mayfly and caddisfly indicates water pollution. Like that presence of certain organism indicates certain quality of water, hence determines quality of water (Che 2000). Aquatic insect are used to monitor anthropogenic stress over ecosystem as bio indicators (Barman and Gupta 2015). Mainly Ephemeroptera, Plecoptera, and Trichoptera species are known as good biological indicators in stream ecosystems (Rosenberg and Resh 1993).

1.2 Aquatic Insect Order

Major Orders representing aquatic insects are Ephemeroptera, Odonata, Plecoptera, Tricoptera, Megaloptera, Diptera, Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera and Collembola.

Ephemeroptera

Mayfly is the oldest insect order. Their larval stage is adapted to freshwater. Adult stage is very short whose main purpose is only reproduction. They have intermediate winged stage between nymph and adult called subimago (Brittain and Sartori 2015). Distinguishing character of Ephemeroptera form other Order are gills on dorsal side of abdomen, single tarsal claws, enlarged mesothorax and three caudal filaments sometime two (Bouchard 2004). Ephemeroptera is small insect order with 42 Families, 400 Genera (Barber et al. 2007) and 3500 described Species world wide (Salles et al. 2018) whereas in Nepal there are 29 species belonging to 10 genera of which 17 were newly described (Thapa 2015).

Plecoptera

Plecoptera is named after its ability to fold its wing horizontally. Plecoptera nymphs are aquatic and adult terrestrial. Nymph have stream line body, mouthpart is chewing type, legs have two claws, tarsi is three segmented, femur stout, abdomen is 10 segmented with two long cerci, thoracic is three segmented which are dorsally nota. For swimming tibia and femur have setae (DeWalt et al. 2015). Plecoptera consist of two Suborders: Arctoperlaria consists of 12 Families of two groups first is Euholognatha which is herbivore and second group is Systellognatha which is predator, each group consists of six Families and second group is Antarctoperlaria consists of 4 Families (Stewart 2009). In total there are 3,718 Species and 286 Genera world wide (Fochetti and Figueroa 2008). In Nepal there are 62 species under 15 genera of which 30 species were newly described and 8 were endemic (Thapa 2015).

Tricoptera

In Greek trich means hair and pteron means wing hence tricoptera are hairy winged flies (Gibb 2015). Tricoptera are caterpillar like in appearance but can be distinguished from other by sclerotized head and thorax, soft abdomen, short antenna, and prologs with hook at the end of abdomen, these are also main character to distinguish between families (Bouchard 2004). Tricoptera larvae construct case which is made of sand grains, twig and other tiny things found in the stream. Some are retreat makers who do not make case but construct fixed case and some do not construct net but spin silk net for filter feeding, while some are free living (Gibb 2015). Tricoptera includes 15000 Species, 600 Genera and 49 Families, approximately world wide (Holzenthal et al. 2015). In Nepal there are 324 species of 68 genera and 24 families of which 22 were newly described (Thapa 2015).

Odonata

Odonata larvae can be distinguished from other Orders of aquatic insect by the presence of spoon shaped labium which covers the other mouth part. They catch their prey by rapid extension of labrum (Pritchard 1965). Two Suborders Anisoptera and Zygoptera can be distinguished by their abdomen as Anisoptera abdomen body is more slender than Zygoptera. Anisoptera have three leaf like caudal filament whereas Zygoptera have two cerci, two paraproct and one epiproct at the end of abdomen (Bouchard 2004). There are approximately 5,956 Species of 659 Genera, 39 Families and three suborders. Suborder Anisozygoptera consist of two species, one genus and one family, suborder Zygoptera consists of 2,942 Species, 309 Genera and 27 Families and suborder Ansioptera consists of 3,012 Species, 348 Genera and 11 Families world wide (Suhling et al. 2015). In Nepal there are 209 species of 91 genera of which six were newly described and one was found to be endemic (Thapa 2015).

Coleoptera

Coleoptera is huge Order in which its most species are terrestrial whereas some are aquatic and semi aquatic. Coleoptera larvae can be identified by the presence of sclerotized head, three pairs of thoracic segmented legs and absence of wing pad whereas adult can be identified by presence of vein less elytra (Bouchard 2004). Globally there are approximately 12,600 described Species of aquatic coleoptera but it is estimated to have 18,000 Species world wide. There are 30 Families belonging to 3 Suborders Myxophaga, Adephaga, and Polyphaga (Jach and Balke 2008). In Nepal there are 287 spcies of 68 genera and 5 families of which 93 were newly described (Thapa 2015).

Hemiptera

Like Coleoptera, Hemiptera is also mostly associated with terrestrial habitat but some are aquatic or semiaquatic. Aquatic hemiptera can be distinguished from aquatic group by its basic order character half sclerotized elytra while antenna, beak and legs can be helpful in distinguishing between families (Bouchard 2004). Aquatic bugs are mainly found in tropical area (Polhemus and Polhemus 2008). Globally there are 4,810 Species, 343 Genera and 23 Families of which 4,656 Species, 326 Genera and 20 Families belong to fresh water habitat. In Nepal there are 25 species of 15 genera and 8 families (Thapa 2015).

Diptera

Diptera are also terrestrial but some larvae are aquatic. Diptera can be found on various level of water pollution from no pollution to heavy pollution. Diptera larvae are worm like in appearance. They lack wing pad and segmented legs (Bouchard 2004). Aquatic diptera consists of 160,000 described Species of 30 Families and 3 Suborders: Nematocera, Brachycera and Cyclorrhaphan world wide (Courtney and Cranston 2015). Nematocera have well developed head with mandible moving laterally. Brachycera larvae have head sclerotized, but more or less reduced and retractile. Mouth hooks move vertically (Borror and Delong 1971). In Nepal there are 182 species of 32 genera and 3 families (Thapa 2015).

Megaloptera

Larvae of Megaloptera can be distinguished from other as they have sclerotized head, mandibulated tooth, legs are five segmented with two tarsal claws, abdomen consists of seven to eight pairs of lateral filaments and spiracles (Resh and Carde 2009). Being a predator they have strong mandible for catching their prey. Mandibles are robust and sharply pointed (Kelsey 1954). Megaloptera consist of 382 described Species globally, where Chauliodinae consist of 116 Species, Corydalinae 131 and Sialidae 81 (Cover and Resh 2008).

Neuroptera

Neuroptera larvae consist of unsegmented stylets which are modified form of maxilla and mandible used for piercing and sucking. Shape of these stylets differs among three families (Cover and Bogan 2015). Out of 17 Families only 3 are aquatic. Nevrorthidae which has 12 Species, Sisyridae has 61 Species and Osmylidae has 45 Species (Cover and Resh 2008). In Nepal there are 29 species of 8 genera of which three are endemic.

Lepidoptera

Subfamily Acentropinae and Pyraustinae of Crambidae and Arctiidae (Noctuoidea) belong to aquatic group. Acentropinae have 50 Genera and 737 described Species, Species known for Pyraustinae are *Samea multiplicalis* and *Niphograpta albiguttalis* and from Arctiidae is *Paracles* (Mey and Speidel 2008). They are morphologically identified by the presence of segmented thoracic legs three pairs, ventral prologs on the abdomen segment 3-9 and in some case filamentous gills (Bouchard 2004).

Hymenoptera

In total 150 species of 11 Families have been recognized of aquatic hymenoptera larvae (Bennett 2008).

Collembola

There are 525 water dependent species associated with water-saturated atmosphere like caves, snow or ice in high mountains. Out of these 103 is related to fresh water and 109 to marine water (Deharveng et al. 2008).

1.3 Ecological Factor affecting aquatic life

Factors that affect the occurrence and distribution of aquatic insect are velocity, temperature, altitude, season, total suspended solid, vegetation (Bispo et al. 2007) pH, availability of food, turbidity, conductivity and competition (Gage et al. 2004). Anthropogenic activities such as releases from domestic sewage, runoff from agricultural lands, laundering into streams and mining activities leads to increase pollution, affect water quality and alters the physico-chemical properties of water e.g. temperature, dissolved oxygen, alkalinity, phosphates, nitrates and metal concentrations. Variations in these water properties greatly influence the distribution patterns of aquatic insects (Hepp et al. 2013).

Physical Factors

Physical factors which affect the aquatic life are pH, Temperature, Velocity, Turbity, depth etc.

pH value of water is reciprocal of log of hydrogen ion concentration. It indicates acidity and alkalinity of the water. pH value ranges from 0-14, 0 to 6.9 mean acidic 7 is neutral and 7.1 to 14 is alkalinity. pH values for the survival of aquatic insect lies in between 5.0-8.5.

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. Temperature impacts both the chemical and biological characteristics of surface water (Payakka and Prommi 2014).

Velocity is responsible for temporary reduction in macro invertebrate’s abundance and diversity. Velocity of water is directly and indirectly important as it influences the river-bed and the amount of silt deposition which in-turn affects the distribution of benthic organisms (Feifarek 1994).

Chemical Factor

Various Chemical factors which affect the aquatic life are DO, CO_2, Alkalinity, Nitrates, Ammonia etc.

Dissolve oxygen is very important for aquatic life. Fresh water stream with highest dissolved oxygen have greater number of benthic insects. Therefore, many forms of aquatic larvae can supplement atmospheric oxygen with dissolved oxygen. Good range of DO concentration in aquatic ecosystem is above 5 mg/l. Concentration of oxygen levels below 2 mg/L may reduce the fitness and chances of survival for many aquatic insects (Hasami et al. 2017).

Alkalinity in the River is caused by the presence dissolve carbonates, bicarbonates hydroxides of calcium, magnesium, sodium, potassium and ammonia. Its values of 20-200 mg/L are common in fresh water ecosystems. Alkalinity below 10 mg/L indicates poorly buffered rivers (Biggs 1995).

Carbon dioxide highly dissolves in water and can increase acidity of water and lowers the pH value (Small et al. 2012).

1.4 Objectives

General objective

To study the aquatic insects of Adhikhola River System in Waling region of Syangja.

Specific objective

a. To assess the aquatic insect of Adhikhola River System.
b. To determine abundance and diversity of aquatic insect.
c. To find the relation of aquatic insect with water quality parameter (pH, Temperature, Velocity, CO_2, DO and Alkalinity).

1.5 Significance of the study

Aquatic insects are ecological indicator to evaluate the water quality. They are important for maintenance of aquatic ecosystem function. Therefore it is necessary to study the aquatic insects from different part of Nepal.

Aadhikhola area of Waling, Syangja is still unexplored and it has high and rapid influence of urbanization, hence it is important to find the status of aquatic insects.

Therefore this research will focuses on taxonomic and ecological study of aquatic insects.

2. LITERATURE REVIEW

2.1 Taxonomic review

Various taxonomic works in field of aquatic has done by various researchers in different part of world since last centuries. In Nepal various works on taxonomy of aquatic insect fauna was done during Expedition to Nepal in sixties and seventies period (Allen1973, Harper 1974, Harper 1977, Jewett 1975, Kimmins 1964, Ito 1986, Vick 1985, Miyamoto 1965, Ouch and Chui 1966, Satu 1981). Here is various taxonomic works done globally and in Nepal.

Ephemeroptera

Recently new genus *Philibaetis* was described from Philippines. In this study two species *Baetis luzonensis* and *B. realonae* were re-described and concluded that these two species does not belong to *Baetis* but is a new genus (Kaltenbach et al. 2021). 13 genera belonging to 6 families were identified from Theka River of Kenya where *Acanthiops* (70.4%) and *Afronurus* (13.3%) were dominating (Maina 2021). Study in Jajrood River of Iran showed the presence of 17 species under 7 genera belonging to 4 families i.e., Baetidae, Heptageniidae, Habrophlebidae, and Isonychiidae (Tahmasebi et al. 2020) and three new species of *Epeorus* were described *Epeorus* (*Caucasiron*) *alborzicus* and *Epeorus* (*Caucasiron*) *shargi* from northern Iran and *Epeorus* (*Caucasiron*) *zagrosicus* from central Iran (Hrivniak 2020).

Ephemerella uenoi was collected from Nepal Himalayas by Japanese Himalayas expedition where they kept the species in *Drunella* sub genus (Allen 1973). 20 families 84 genera and 390 species of Ephemeroptera are reported from Oriental region. 41 genera were endemic of oriental region (Barber et al. 2008) Listing done from oriental Indian sub region (India, Pakistan, Nepal, Bhutan, Myanmar and Sri Lanka) shows the presence of 60 genera 204 species of Ephemeroptera (Sivaramakrishnan et.al. 2009). Three new species of *Cincticostella* (Ephemeroptera: Ephemerellidae) *C. richardi* Martynov Palatov and *C. ranga* Selvakumar Subramanian from India and *C. sivaramakrishnani* Martynov Palatov from Nepal were identified (Martynov et al. 2019).

Plecoptera

A check list from Korea showed presence of 95 species of 36 genera and10 families of plecoptera (Hwang and Muranyi 2020). 19 species of 14 genera and 7 families were recorded from Crooked River, British Columbia (Erasmus and Huber 2020). In Damingshan National Natural Reserve of Guangxi, China two new species *Amphinemura, bifascia* and *A. bicornata* were described (Mo et al. 2020a). Whereas *Sinonemura balangshana* new genus and species was described from Balang Mountains of Sichuan, southwestern China (Mo et al. 2020b). In the same year another two new species were described from China *Nemoura lixiana* from Sichuan and *Amphinemura jiaoheensis* from Jilin (Chen 2020). *Kamimuria dabieshana* and *Neoperla mindoroensis* were new species described from Dabie Mountains, Central China and Mindoro, Philippines respectively (Yan 2019, Pelingen and Freitag 2020).

Protenemura new genus collected by Canadian expedition of Himalayas and described (Harper 1974). Jewett (1975) described three new *species Capnia swani, C. triangulipennis and Nemoura unicornis* with other 8 other species of stoneflies from North-West Himalayas from India and Mt. Makalu from Nepal. From families Capniidae Leuctridae and Perlidae 11 species of stoneflies with five new species were recognized from Nepal (Harper 1977). Five new species and 30 species belonging to families Taeniopterygidae, Capniidae, Leuctridae, Nemouridae, Peltoperlidae, Perlodidae and Perlidae were recorded from Central Nepal. Two new species *Amphinemura albifasciata* and *Amphinemura lebezi* were also found and contributed knowledge of Nemouridae of Nepal (Sivec 1981a, Sivec 1981 b).

Tricoptera

In Northwest Algeria 8 species of *Hydropsychi* were identified from 14 sampling site collected for 5 years (Dekkak 2021). In Japan larval species of genus *Hydroptila* of final instar were described (Ito 2021). 11 species of tricoptera were identified from Western Sayan Mountains, South Siberia of which *Hydropsyche valvata, Anabolia laevis, Chaetopteryx villosa, Apataniana tschuktschorum* and *Oecetis testacea* were first time recorded (Baturina 2020). Diversity of tricoptera in Iceland was found to be low. 48 springs were sampled out which in eleven have tricoptera species (Katharina 2020). High diversity of tricoptera has been seen in Pristine headwater streams of Central Palawan, the Philippines with highest number of Leptoceridae (Mey and Freitag 2020). In Moulouya

River basin, Morocco 41 species of tricoptera were identified, sampling was done for 5 year (Mabrouki 2020). New rare family of Kambaitipsychidae was reported from mid-Cretaceous Burmese amber. Two extant species of Kambaitipsychidae has been found in Northeastern Burma and in Thailand (Wichard and Wan 2019).

Kimmins (1964) reported 28 species of Tricoptera and Ito (1986) described three Lepidostomatid Caddisflies from Nepal. Kiss (2013a) recorded new species Rhycophilidae, *Rhyacophila steinmanni*, *Rhyacophila kisszoltani*, *Rhyacophila siposi* and *Rhyacophila szaboi*. Kiss (2013b) *Rhyacophila horvathmargiti* and *Rhyacophila vajoni*. Kiss (2011) recorded *Himalopsyche* first time from Nepal and three new species of *Apsilochorema* was also described (Kiss 2020) . *Chimarra* (two species) (Melnitsky 2005). *Rhyacophila* (six sp.), *Chimarra* (seven sp.), *Wormaldia* (one sp.), *Kisaura* (one sp.), *Plectrocnemia* (one sp.), *Tinodes* (one sp.), *Ecnomus* (one sp.), *Cheumatopsych*e (one sp.), *Hydromanicus* (three sp.), *Macrostemum* (one sp.), *Lepidostoma* (four sp.), *Oecetis* (one sp.), *Setodes* (one sp.) new species had been recorded from Nepal (Malicky 2017).

Odonata

Caliphaea angka from family Calopterygidae was first time recorded from Yunnan Province, China (Yang et al. 2021). Araujo and Pinto (2021) provided a checklist for odonata species of proctected area of Mananciais da Serra. Total of 1,708 specimens were collected of nine families, 43 genera and 84 species. Among these 53 were new to the area. From 200 larvae sample collected from 2000 -2002 A.D 17 species of three subspecies, 14 genera and seven families were identified from Burdur and Isparta Provinces of Turkey (Okur and Salur 2020). Similarly from Antalya and Mugla province of Turkey from same sampling period 282 individuals were collected of 24 species, 16 genera and six families were identified (Salur 2020). Larva of *Agriocnemis* of family Coenagrionidae was described first time based on rear specimen collection of Thailand by DNA barcording. Three species were identified *A. minima A. femina* and *A. pygmaea* (Saetung and Boonsoong 2019).

Vick (1985) recorded 66 spp. of odonata from 23 localities in Shiplake College Trekking Society Expedition to Nepal. From Western Nepal 61 odonata species belonging 40 genera and 11 families were recordes. Libellulidae was dominant family having 28 species (Sharma et al. 2018). 559 species have been recorded from Nepal, India, Bhutan, Bangladesh, Pakistan and Sri Lanka (Kalkman et al. 2020). Twenty eight species of 20 genera and six families were recorded from Debang Lake of Kaski District. Family Libellulidae was dominant representing 16 species *Aciagrion approximans* and *Ceriagrion cerinorubellum* were first time recorded in Nepal (Chettri and Gurung 2020). A study conducted in Sishaghat of Tanahun district showed the presence of 26 species 20 genera and 7 families, with Shannon diversity index 2.25 (Miya et al. 2021)

Hemiptera

Ramphocorixa rotundocephala which is mostly found in Central and North America was first time recorded in Columbia (Ortega et al. 2021). *Rhagovelia freitagi* was described from Cambodia which belongs to *the Rhagovelia sarawakensis* species group (Zettel 2021). (Hayashi et al 2020) reviewed diversity of Hemiptera and Coleoptera in which Hemiptera included 118 species in 13 families, among which 22 species (18.6%) were endemic Japan. *Anisops occipitalis, Hydrometra okinawana, Neoalardus typicus and Limnometra ciliat* was first time recorded from mainland of India from Meghalaya (Jehamalar and Chandra 2020). Zoographical distribution of aquatic and semi aquatic hemiptera were studied in Turkey, 112 species of 37 genera of five Infraorders were reviewed (Gulten 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 (Jaiswal et al. 2020). Diversity pattern of aquatic bug were studied in North East Algeria. There 12 species of 6 genera and 4 families were recorded (Annani 2020). *Heteroplea ornata* and *H. asperscyta* were two new species discovered with which four species were recorded of *Heteroplea* from Neotropical (Cook 2020). Two new species of Pleidae *Neoplea hyaloderma* and *N. melanosoma* were described from Colombia which increased the number of pleids to four from Columbia (Cook et al. 2020).

Miyamoto (1965) studied some aquatic bug collected from Rolwaling Himal Expedition in Nepal.

Coleoptera

Checklist provided by (Benamar 2021) of hydrophilidae shows presence of 52 species of 14 genera and 5 subfamilies. *Peschetius* was first time recorded in Telangana, India. Total

10 species of *Peschetius* are found world wide of which 2 were found in India (Jaiswal et al. 2021). 28 species of aquatic coleopteran of five family Dytiscidae, Haliplidae, Heteroceridae, Hydrophilidae and Noteridae were recorded from Podblanicko region, Central Bohemia, Czech Republic (Ozcan et al. 2021). 132 species in 55 genera and 11 families were recorded from Mississippi, USA. New record of 24 species of families Dytiscidae, Gyrinidae, Haliplidae, Hydraenidae, Elmidae, Helophoridae, Hydrophilidae, Noteridae from the state has been found (Pintar and Resetarits 2020). Subgenera *Coelostoma* and *Holocoelostoma* of genus *Coelostoma* from the Indian subcontinent were revised, 6 species of *Coelostoma* and 2 species of *Holocoelostoma* were found. *C. (Coelostoma) lyratum* and *C. (Coelostoma) nostocinum* were new. Whereas *Coelostoma (Coelostoma) fallaciosum* and *C. (Coelostoma) vividum* were recorded for the first time from India and Bangladesh, respectively (Sheth et al. 2020). 30 species of 24 genera and 8 families Dytiscidae, Hydrophilidae Haliplidae, Scirtidae, Gyrinidae, Noteridae, Elmidae and Psephenidae from Nohwa and Bogil Islands (Jung et al. 2020) 47 species of aquatic beetles were found from Smithsonian Environmental Research Center, Maryland from 2 year sampling (Staines and Staines 2020).

Ouch and Chui (1966) described Gyrinidae of East Nepal, Vazirani (1968) reviewed aquatic beetle of Noterinae, Laccophilinae, Dytiscinae and Hydroporinae of Indian Sub-Continent. Satu (1981) studied about dryopidae of Nepal.

Diptera

313 species of 59 genera and four subfamilies were recorded from Indian Sub-Continent. *Parametriocnemus, Cricotopus, Cricotopus (Isocladius), Oliveiriella, Onconeura, Alotanypus* and *Pentaneura* were found in the area lower temperatures, high dissolved oxygen and low conductivity while *Cricotopus, Rheotanytarsus, Tanytarsus, and Chironomus* were found in area of high conductivity and low concentrations of dissolved oxygen (Villamarin et al. 2021). *Limnophyes minimus* and *L. subtilus* were two new species of chironomidae discovered from China (Liu et al., 2021a). In same year another new species of chironomidae *Polypedilum (Cerobregma) huapingensis* was found by DNA barcording analysis (Liu et al. 2021b). 2245 individual of 12 families and 16 taxa were identified from 29 sampling point of Yesilirmak River of Turkey (Basoren and

Kazanci 2020). *Wiedemannia ljerkae* was first time recorded from Albania. An updated cheacklist of Empidae of Albania was also provided (Slowinska and Jaskula 2020).

Yadav and Shrestha (1982) and Roback and Coffman (1987) report chironomids of Nepal. Takaoka and Shrestha (2010) and (Takaoka et al. 2020) reported 16 new of described *Simulium* from different localities of Nepal. Four new species and three new recorded species from Nepal were reported (Takaoka et al. 2020a, Takaoka et al. 2020b).

Megaloptera

Two species of genus *Nevromus*, *N. aspoeck* and *N. jeenthongi* were identified from Thailand of which *N. jeenthongi* is the new species (Piraonapicha 2021). *Indosialis bannaensis* and *Indosialis siamensi* of family Sialidae were identified from Thailand. *Indosialis siamensi* was new species identified (Piraonapicha 2020).Two species were only identified *Corydalus batesii* and *C. nubilus*, from Tocantins State, Brazi of Megaloptera (Andrade et al, 2020) *Anachauliodes* was first time recorded from Oriental region and *Anachauliodes laboissierei* full morphological description is also given (Tu et al. 2019). A review paper on Canada megaloptera showed the presence of 18 species six of *Corydalidae* and 12 of *Sialidae* (Liu 2019).

Seven species of Megaloptera were recorded from Indian sub continent (Liu et al. 2010). Six species of *Nevromus* were described and re described from oriental region (Liu et al. 2012).

2.2 Aquatic Insect and Water Quality

A study was conducted in Rivers of Western Himalayas, Nepal on 38 river stretches in the mainstem. Sampling was done for two season pre and post monsoon. Richness of function feeding group showed strong negetive correlation with water temperature where DO, alkanity and hardness showed positive correlation (Shah et al. 2020a).

In monsoon dominating rivers of Western Himalayas water diversion showed little effect on microinvertebrates assemblage but reduction in flow discharge leads to increase in water temperature and pollution due to waste discharge from the settlement showed negative impact on benthic microinvertebrated community hence affecting the river health (Shah et al. 2020b)

At the headwaters of Bagmati River there was the dominance of EPT taxa which indicate the good quality of water. Though there is rapid urbanization of Kathamandu valley headstream is seen to be unaffected (Rai et al. 2019).

In West Seti River water quality was explored by using microinvertebrates as bio indicator. Site 3 of study area was seen to be heavily polluted by directed discharge of effulent from Chainpur Municipality. In this site there was dominance of red Chironomides (Matangulu et al. 2017).

A study conducted in Bhalu khola Tributary of Budhigandaki River showed maximum number of Ephemeroptera order which is one of the sensitive organisms and their presence indicates less environmental stress but there was no dominant species as most of the species were in clumped distribution. According to NEPBIOS index, Hilsenhoff and Lincoln quality index and water quality index water was of good quality and can be used for drinking purpose (Rana and Chettri 2015).

According to Basnet (2013) in Bagmati river total 2583 benthic invertebrates representing 10 orders and 29 families were recorded. Abundance of invertebrates reduces in downward direction. Upper stream were represented by Ephmeroptera, Placeoptera and Tricoptera while downstream were represented by Tubificidae, Baetidae and Ceratopogonidae . Family biotic indice, BMWP, ASPT, and EPT were used which categorized the river from very good quality (upstream) to very polluted (downstream).

A study conducted on 36 km stretch of Bagmati River showed decrease in DO and increase of nitrate nitrogen, ortho-phosphate phosphorus, chloride and BOD_5 downstream. EPT were abundant upstream, while the highly tolerant taxa of worms, leeches and red Chironomids were abundant in downstream (Shah and Shah 2013).

In context of Nepal many works has been done in aquatic fauna for bio monitoring, but still there is lack of taxonomic work till species level. Taxonomic work has been seen of adult of aquatic larvae but there is less identification work of larvae.

3. MATERIAL AND METHODOLOGY

3.1 Study area

This study was carried in Adhikhola River System of Waling area of Syangja. Sampling was done for two seasons, autumn and winter. Waling consist four main river stream Adhikhola River , Mirdi Khola River, Armadi Khola River and Madi Khola River. Adhi Khola run aside the Waling city, Madi Khola near Bhakunde, Mirdi Khola in Mirdi, and Armadi Khola in Rambachha of Waling Municipality. Madi Khola, Mirdi Khola and Armadi Khola mix up with Adikhola from their respective place.

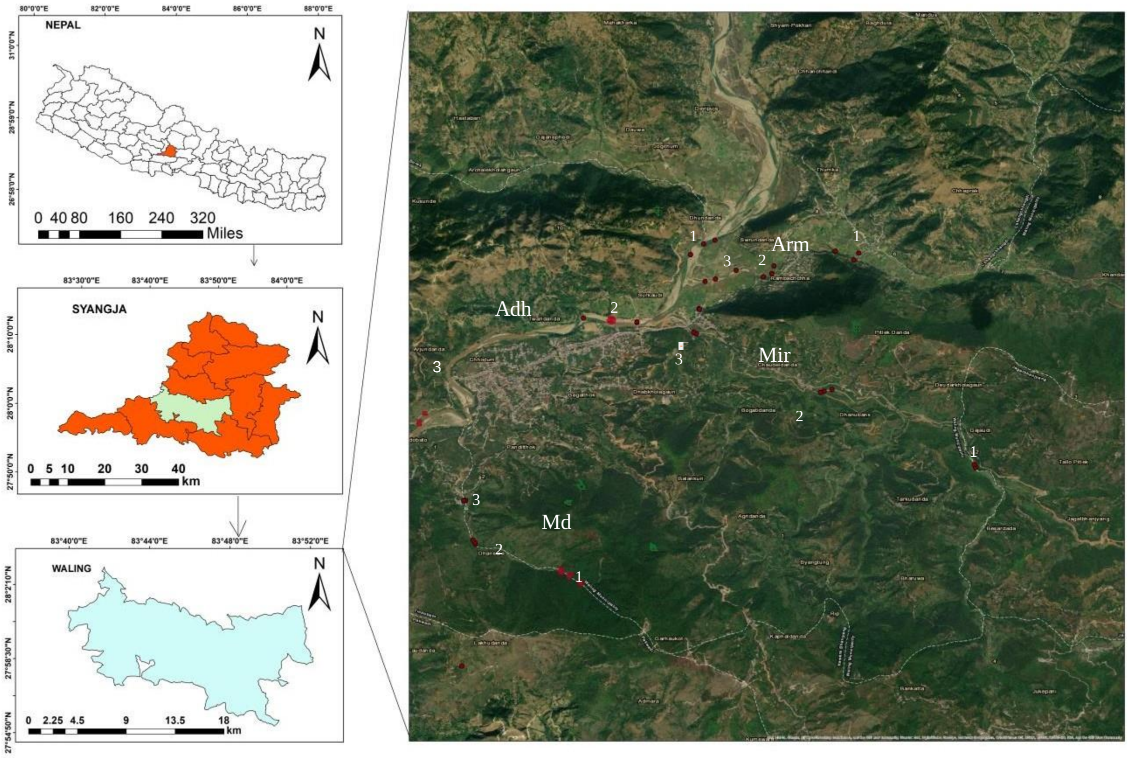

Fig 1: Map Showing Study area of Different Stream.

3.2 Materials

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

Chemicals required for titration are Manganese Sulphate, Alkaline potassium iodide, Sulphuric acid, Sodium thiosulphate (0.025N) and Starch for DO, Sodium hydroxide

(0.05N) and Phenolphthalein for Free CO_2, Hydrochloric acid (0.1N), Phenolphthalein, Methyl orange for Alkalinity.

3.3 Methods

3.3.1 Sampling design

Sampling point was ascertained in different sites of stream Adhikhola, Mirdikhola, Armadi khola and Madi khola. 12 sampling point were fixed. Site selection was done on the basis of three different habitats i.e., Forest, Agriculture and Urban in each stream. Each site was further divided into 3 point on the basis of heterogeneity (smoothness of river, water current, gravel or stone size, riffle or pool, presence of weed on sides). High heterogeneity was selected on the basis of big rock, high water current, Moderate heterogeneity for medium size rock and less number of boulders than high heterogeneity area and Low heterogeneity was considered for pool area. Sampling was done for two seasons Autumn (Asoj) and Winter (Poush)

3.3.2 Insect collection and preservation

Insect were collected by following method:

Sweeping net method was used to collect the insect of littoral zone. It was mainly used in pool areas.

D-Frame kick net was used to collect insect from benthic zone. Aquatic insects were collected by taking three, 1-minute kick-net samples. Net was held against water current, in front of the net, water was disturbed for one minute. It was used in riffle area (Subramanian and Sivaramakrishnan, 2007a).

Sieving was done in sandy places.

An “all out search” method was also used for collection in microhabitats. Within the sampling area, aquatic insects were searched in all the possible substrata such as bedrocks, boulders, cobbles, leaf litter and dead wood. A sable hairbrush or forceps were used to collect all samples (Subramanian and Sivaramakrishnan 2007a).

Insect were preserved on the basis of standardized method of liquid and dry preservation. For soft body insect liquid preservation and for hard bodied insect dry preservation was done. For liquid preservation 70% alcohol was used. For dry preservation pinning for bigger and carding for smaller insects were done.

3.3.3 Insect Identification

Insect were identified by using standardized taxonomy key such as Borror and DeLong (1971) and (Subramanian and Sivaramakrishnan 2007b) and (Bauchard, 2004) for Family level. For Ephemeroptera genera (Turkmen and Kazanci 2013, Dias et al. 2006, Sites 2001), Plecoptera (Jaihao and Phalaraksh 2013), Tricoptera (Waringer 2013, Wallace 1981) Odonata (Wright and Peterson 1994, Nesemann et al. 2011), Coleoptera (Hackston 2018), (Shepard and Sites 2016, Libonatti et al. 2011, Shepard and Sites 2019), Diptera (Sundermann et al. 2017), Hemiptera (Moreira et al. 2018, Cheng et al. 2001, Xie and Liu 2015) and Megaloptera (Ramos and Harris 1998, Camacho and Ramos 2018).

After identification all specimens were submitted in Central Department of Zoology, T.U.

3.3.4 Physico-chemical test

Temperature, pH and velocity were measured in the field. Temperature was measured by using water thermometer; pH was measured by using pH meter, velocity by surface float method (m/s).

For DO Wrinkle method was used. Titrimetric analysis was done to measure free carbon dioxide and Alkalinity.

3.3.5 Data Analysis

Data was managed in excel sheet after the completion of identification process in lab. All analysis was done by MS Excel 2010.

Abundance of insects was shown by graph.

Aquatic insect diversity and evenness was calculated using Shannon- Weiner diversity index (H') and evenness (J). Richness was calculated by counting number of taxa present.

One way ANOVA was used for showing significant relation between insect fauna, different season and different habitat.

Correlation was used for finding the relation of aquatic insect with water parameter.

4. RESULTS

4.1 Composition of Identified Insect of Adhikhola River System

Overall 45 genera, 31 families and 8 orders were report from four river streams: Adhikhola, Mirdikhola, Armadi Khola and Madi khola of two seasons (Table 1, Annex 1). 8 order, 28 families and 36 genera were collected from autumn and 8 order, 33 families and 39 genera from winter (Annex 2).

Table 1. Identified aquatic insect of Adhikhola River System

Order	Family	Genus
Ephemeroptera	Heptageniidae	*Heptagenia* spp.
		Rhitrogena sp.
	Baetidae	*Baetis* spp.
		Acentrella spp.
		Fallceon spp.
	Leptophilibidae	*Cryptopenella* sp.
		Choroterpes sp.
		Choroterpides sp.
	Caenidae	*Caenis* sp.
	Leptohyphidae	*Leptohyphes* spp.
	Ephemerellidae	*Torleya* spp.
Plecoptera	Perlidae	*Neoperla* spp.
Tricoptera	Hydropsychidae	*Hydropsyche* sp.
	Rhyacophilidae	*Rhyacophila* sp.
	Glossosomatidae	*Glossosoma* sp.
	Leptoceridae	*Leptocerus* sp.
		Setodes sp.
Hemiptera	Gerridae	*Ptilomera* spp.
	Naucoridae	*Ilycoris* spp.
	Aphelocheiridae	*Aphelocheiridae* sp.
	Nepidae	*Laccotrephes* sp.
	Herbidae	*Hyrcanus* sp.
Coleoptera	Gyrinidae	*Dineutus* sp.

		Orectochilus sp.
	Dytiscidae	*Hydrovatus* sp.
	Hydrophilidae	*Cercyon* sp.
	Elmidae	*Grouvellinus* spp.
	Psephenidae	*Psephenus* spp.
		Unkown
Diptera	Tipulidae	*Tipula* spp.
	Chironomidae	*Chironomus* sp.
	Tabinidae	*Tabanus* sp.
	Limoniidae	*Hexatoma* sp.
		Antocha sp.
	Simulidae	*Simulium* sp.
	Anthericidae	*Atherix* sp.
Megaloptera	Corydalidae	*Corydalis* sp.
Odonata	Euphaedae	*Euphaea* sp.
	Chlorocyphidae	*Rhinocypha* sp.
	Calopterygidae	*Neurobasis* sp.
	Gomphidae	*Phanogomphus* sp.
		Lanthus sp.
		Ophiogomphus spp.
		Erpetogomphus sp.
	Libellulidae	*Libellula* sp.

4.2 Relative Abundance of Adhikhola River Stream

Among 4 river stream Adhikhola River and Mirdi Khola were highly abundant followed by Armadi khola and Madi khola was least abundant (Fig 2, Annex 2.1). One river has 3 sites so Abundance is total number of individual of 3 sites in every stream.

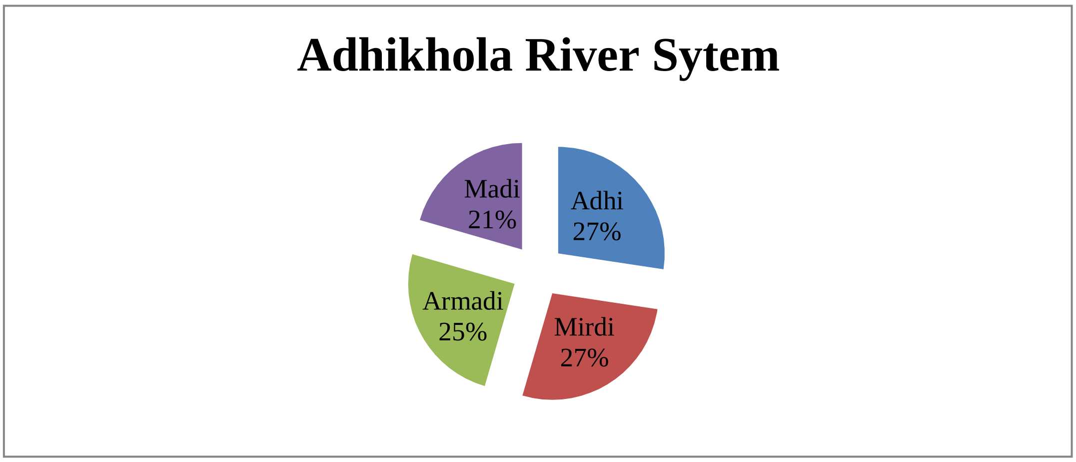

Fig: 2 Relative Abundance of Different Stream of Study Area

Order wise Ephemeroptera has been seen to be highly abundant followed by Tricoptera. Plecoptera and Megaloptera were least abundant in Different streams (Fig:3, Annex 2.1).

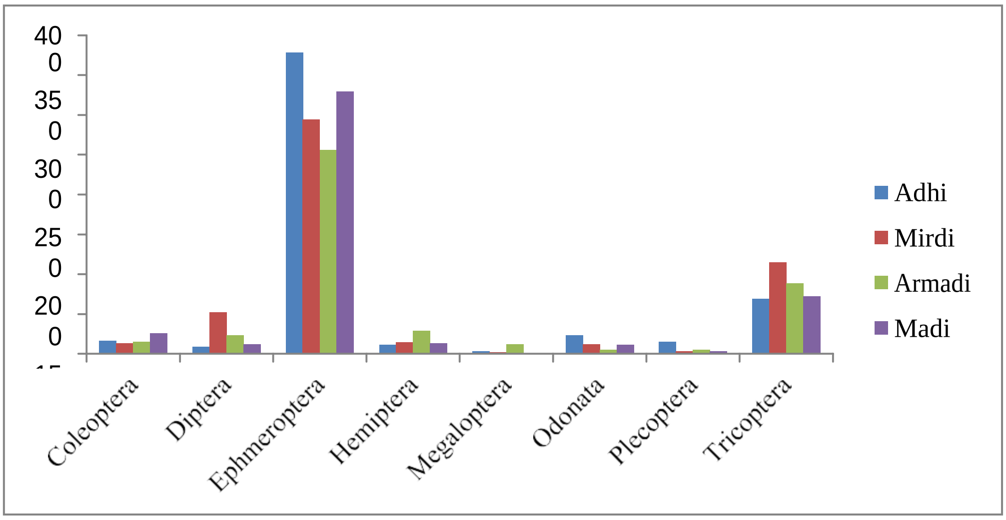

Fig: 3 Relative Abundance of Order of Different Stream of Study Area.

Family wise Baetidae was highly abundant in every stream except Adhikhola where Heptageniidae were highly abundant whereas Dytiscidae, Aphelocheiridae, Herbidae, Rhyacophildae, Tabanidae, Anthericidae were least abundant (Annex 2.2). Genus wise in *Hepatagenia* in Adhikhola, *Hydropsyche* in Mirdi khola and *Acentrella* in Armadi and Madi Khola was highly abundant (Annex 2.3).

4.3 Seasonal Variation in Abundance, Diversity, Evenness and Richness of Aquatic Insect.

Order wise relative abundance Ephemeroptera followed by Tricoptera were highest in every stream of both season (Fig 4, 5 Annex 3.1, 3.4).

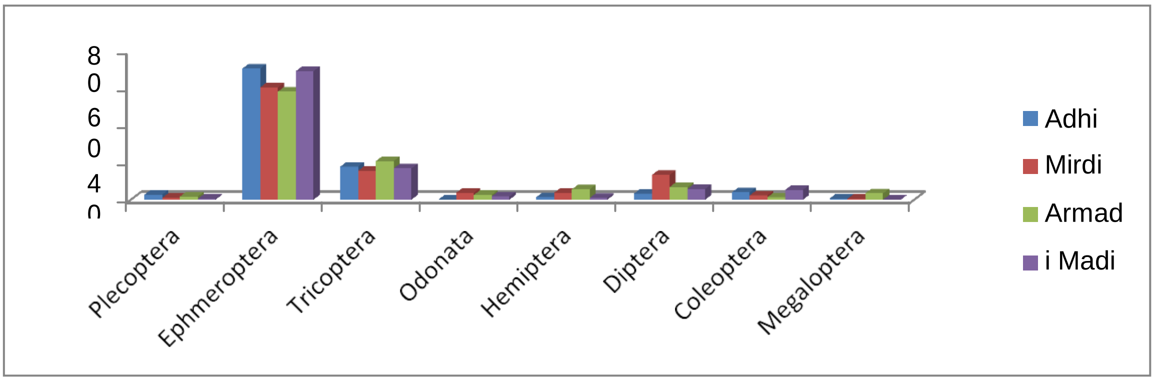

Fig: 4 Order wise Abundance of Aquatic Insect in Autumn

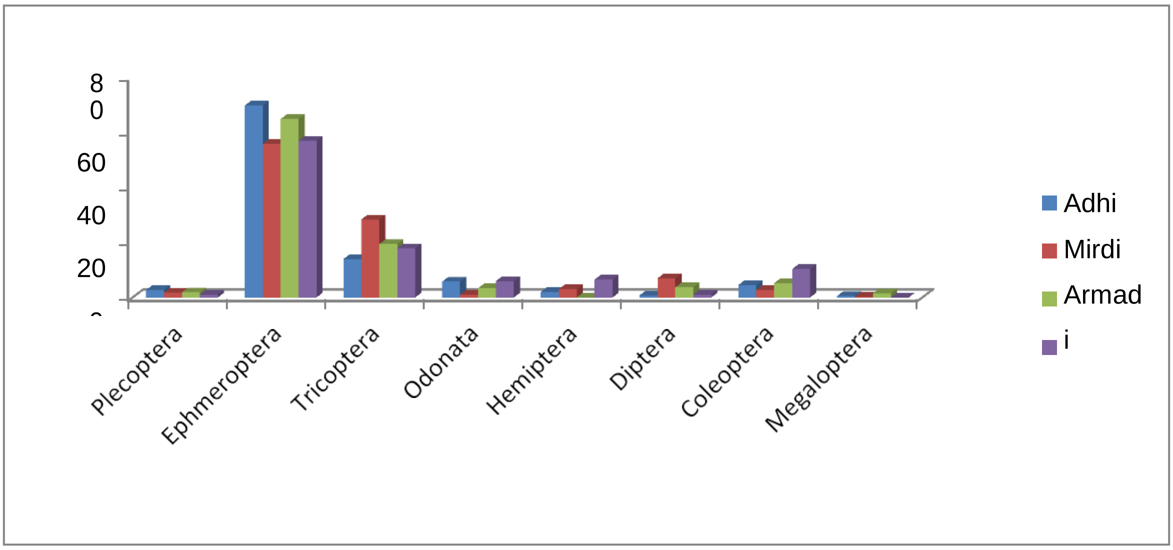

Fig: 5 Order wise Abundance of Aquatic Insect in Winter

Family wise Baetidae in autumn was highest in every stream, but in winter Heptagenidae in Adhikhola, Caenidae in Mirdi khola, Baetidae in Armadi and Madi Khola were highest (Annex 4.2, 4.5). Genus wise *Heptagenia* in Adhikhola and Mirdi khola and *Acentrella* in Armadi khola and Madi khola in autumn and *Heptagenia* in Adhikhola and *Acentrella* in other stream were highest. Lowest were from order Megaloptera, Plecoptera, Coleoptera, Hemiptera, Diptera and Odonata (Annex 4.3, 4.6) (Table 2, 3).

Table 2. Seasonal Variation in Abundance of Families of Aquatic Insect

River	Season	Family	
		Highest	Lowest
Adhikhola	Autumn	Baetidae	Nepidae, Cordalidae
Mirdi Khola	Autumn	Baetidae	Elmidae, Cordalidae, Chlorocyphidae, Euphaedae, Simulidae, Anthericidae
Armadi Khola	Autumn	Baetidae	Leptophibidae, Nepidae, Simulidae
Madi Khola	Autumn	Baetidae	Perlidae, Ephemerelidae, Euphaedae, Gerridae, Herbidae, Chironomidae
Adhikhola	Winter	Heptagenidae	Nepidae, Tabinidae
Mirdikhola	Winter	Baetidae	Chlorocyphidae, Dytiscidae, Elmidae
sArmadi Khola	Winter	Baetidae	Libelulidae
Madikhola	Winter	Baetidae	Leptoceridae, Euphaedae

Table 3. Seasonal Variation in Abundance of Families of Aquatic Insect

River	Season	Genus	
		Highest	Lowest
Adhikhola	Autumn	*Heptagenia*	*Cryptopenella, Ilyocoris, Laccotrephes, Corydalus*
Mirdi Khola	Autumn	*Heptagenia*	*Choroterpes,Grouvellinus, Hexatoma, Tabanus,Simulium, Corydalus, Euphaea, Rhyacophila, Phanogomphus*
Armadi Khola	Autumn	*Acentrella*	*Cryptopenella, Leptohyphes, Simulium, Phanogomphus*
Madi Khola	Autumn	*Acentrella*	*Torleya, Neoperla, Ptilomera, Hyrcanus, Antocha, Corydalus, Euphaea*
Adhikhola	Winter	*Heptagenia*	*Laccotrephes, Hexatoma*
Mirdikhola	Winter	*Acentrella*	*Corydalus, Hydaticus, Antocha*
Armadi Khola	Winter	*Acentrella*	*Choroterpes, Libellula*
Madikhola	Winter	*Acentrella*	*Rhyacophila, Psephenus,* Unknown, *Tipula*

Table 4. Seasonal Variation in Diversity, Evenness, and Richness of Insect

	Autumn			Winter		
River	H'	J	S	H'	J	S
Adhikhola	2.53	0.84	32	2.46	0.79	31
Mirdi khola	2.57	0.80	28	2.26	0.75	27
Armadi khola	2.46	0.79	26	2.38	0.81	28
Madi khola	2.03	0.65	29	2.32	0.77	27

H'= Shannon-Wiener Diversity Index, J= Evenness, S= Species Richness

Diversity of Insect as a whole is seen to be high in Adhikhola River System but comparatively diversity of autumn season is higher than in winter in every stream. In autumn highest diversity was from Mirdi khola but in winter highest diversity of insect was from Adhikhola. In case of Evenness, Adhikhola and Mirdikhola has more species evenness in autumn than in winter whereas Armadi khola and Madi khola has more species evenness in winter season than in Autumn. Species Richness was also found to be more in autumn than in winter except Armadi River where species richness was found more in winter (Table 4). However one way ANOVA shows that there is no significance difference between insect recorded in autumn and winter ($F=0.09$, $p=0.76$).

4.4 Habitat Variation in Diversity and Abundance of Aquatic Insect

Ephemeroptera (*Hepatgenia, Acentrella, Choroterpes, Fallceon*) and Tricoptera (*Hydropsychi*) were dominant in every habitat, stream and season but *Ptilomera* was abundant in forest area of Madikhola in winter. Lowest abundance was found from every Order but majority were from Odonata, Coleoptera, Diptera, Ephemeroptera (*Caenis, Cryptopenella, Choroterpes* and *Choroterpides)* and Tricoptera (*Rhycophila)* was the lowest (Annex 5).

Table 5 Habitat Variation in Diversity of Aquatic Insect

River	Autumn			Winter		
	Near Forest	Near Agriculture	Near Urban	Near Forest	Near Agriculture	Near Urban
Adhikhola	2.35	2.24	2.17	2.31	2.24	2.15
Mirdi	2.30	2.23	2.16	2.15	2.09	2.00
Armadi	2.17	2.05	2.02	2.21	2.13	2.07
Madi	2.01	1.65	1.77	2.11	1.87	1.44

Diversity Index of forest was highest in every stream of both the season followed by agriculture and lowest diversity was recorded from urban area except in Madikhola of autumn season were lowest diversity was from agriculture area (Table 5). But from One Way ANOVA Test no significant relationship has been seen between diversity of insect fauna of three habitats (Forest, Agriculture and Urban) in both Autumn (F= 0.207, p=0.81) and Winter (F= 0.17, p= 0.84) .

4.5 Physico-Chemical Parameter of Adhikhola River System

Temperature and CO_2 was increased and DO and Alkalinity was seen to be decreased from Forest, Agriculture and Urban respectively in autumn. Temperature, Alkalinity and CO_2 was seen to be increased and DO was seen to be decreased from Forest, Agriculture and Urban respectively in winter (Annex 5). Table 6 shows the ranges of water parameter in study area.

Table 6: Water Parameter of Study Area

Physico-Chemical Parameter	Autumn	Winter
pH	7.3-7.8	6.9-8
Temperature	20-25 ^{0}C	19-22 ^{0}C
Velocity	0.19-1.75m/s	0.17-1.43m/s
Dissolve Oxygen	3.24-6.25mg/l	3.24-7.92mg/l
Free carbon dioxide	11-22mg/l	6.2-15.6mg/l
Alkalinity	140-65mg/l	85-65mg/l

Karl Pearson's Correlation Coefficient of different Physico-chemical parameter and no. of insect were calculated and shown in Table 7.

Table 7. Coefficient of Correlation (r) between Aquatic fauna and Water Parameter

Water Parameter	Autumn	Winter
Ph	0.4	-0.25
Temperature	-0.29	0.14
Velocity	0.28	-0.06
DO	0.09	0.3
CO_2	-0.5	-0.08
Alkalinity	0.5	-0.25

From Karl Pearson's Correlation Test assemblage of Insect Fauna Showed Negative correlation with Temperature and CO_2 in autumn and Ph, Velocity, CO_2 and Alkalinity in winter. It implies increase of number of species at lowering of Temperature, Velocity, CO_2 and Alkalinity. Positive Correlation was seen with Ph, Velocity, DO, Alkalinity in autumn and Temperature, DO in winter which implies number of insect increase with high value of these parameter.

But significant negative correlation was seen with CO_2 and positive correlation with alkalinity in autumn.

5. DISCUSSION

In present study, aquatic insect fauna of Adhikhola River System was explored. Altogether 45 genera of 31 families and 8 order were recorded from four river stream: Adhikhola, Mirdikhola, Armadikhola and Madi khola. Ephmeroptera consists of six families Heptageniidae, Baetidae, Leptophilibidae, Caenidae, Leptohyphidae and Ephmerellidae and 11 genera *Heptagenia, Rhitrogena, Baetis, Acentrella, Fallceon, Cryptopenella*, *Choroterpes*, *Chorpterpides*, *Caenis*, *Leptohyphes* and *Torleya*. Plecoptera consist of one family Perlidae and one genus *Neoperla*. Tricoptera consist of 4 families Hydropsychidae, Glossomatidae, Rhycophilidae and Lepoceridae and 5 genera *Hydropsychi, Glossoma, Rhycophila, Setodes* and *Leptocerus.* Coleoptera consist of 5 family Gyrinidae, Dytiscidae, Hydrophilidae, Elmidae and Psephenidae and 7 genera Oretochilus, Dineutus,Hydrovatus, Cercyon, Grouvellinus, Psephenus one genera of Psephenidae was not identified. Hemiptera consist of 5 families Aphelocheiridae Gerridae, Naucoridae, Nepidae and Herbidae and 5 genera Aphelocheirus, Ptilomera, Ilycoris, Laccotrephes and Hyrcanus. Diptera Tipulidae, Chironomidae, Tabinidae, Limoniidae, Simulidae and Anthericidae and 7 genera *Tipula, Chironomus, Tabanus, Hexatome, Antocha, Simulium* and *Atherix.* Odonata consist of six families Euphaedae, Chlorocyphidae, Caloptergidae, Libellulidae and Gomphidae and 9 genera *Euphaea, Rhinocypha, Neurobasis, Libellula, Phanogomphus, Lanthus, Ophiogomphus* and *Erpetogomphus.* Megaloptera consist of 1 family Corydalidae and 1 genera *Corydalis*.. Sharma et al. (2015) reported 7 order and 24 families Baetidae, Heptageniidae, Ephemerelidae, Arthropleidae, Leptophlebiidae, Tabanidae. Chironomidae, Limoniidae, Simulidae, Ceratopogonidae, Hydropsychidae, Philopotamidae, Stenopsychidae ,Polycentropodidae, Glossosomatidae, Psychomidae, Psephenidae, Elmidae, Euphaeidae Gomphidae, Aishnidae, Corydalidae and Perlidae from Adhikhola.

Yadav (2006) reported 21 genera, 19 families and seven orders. Barma and Gupta (2015) showed 21 species of 14 families and seven orders from Bakaumari stream. Ujjawal and Kushwaha (2016) reported 14 families of eight orders. Pokharel (2013) reported 47 genera belonging to 38 families and 12 orders from Mardi and Vijaypur Streams Pokhara.

In present study Ephemroptera have been seen to be highly abundant followed by Tricoptera. Family wise Baetidae followed by Hydropsychidae and Heptageniidae was seen to be highly abundant. Sharma (1999) conducted research in Sapta Kosi and reported

68 families of benthic invertebrate with highest abundance of Tricoptera followed by Coleoptera. Forty seven taxa including forty morpho families were found from 58 streams from three regions of Himalayas: Anapurna, Langtang and Everest. Baetidae of Ephemeroptera was seen to be highly abundant (Rundle et al. 1993). From Karnali River Basin 124 taxa of 84 families and 22 orders of micro invertebrates were recorded. Ephemroptera, Tricoptera and Diptera were most dominating group (Shah et al. 2020).

Ephemeroptera and Tricoptera were seen to be highly abundant in every stream of both seasons in every habitat but red chironomidae number was also high in urban area of Adhikhola, Mirdikhola and Armadi khola. Ephemeroptera was seen to be highly abundant because they are highly diverse group with greater number of genus. Tricoptera was also high in number as they have broad range of ecological specialization (Morse 2009) Ephemeroptera and Plecoptera are pollution sensitive group and indicate fresh water (Alam et al. 2008). Shah and Shah (2013) found abundance of sensitive invertebrate taxa Epemeroptera, Plecoptera and Tricoptera from rural area, moderately sensitive group of Diptera from semi urban area and highly tolerant taxa worm, leech and midges from urban area from 36 km stretch of Bagmati River.

Baetidae was highly found family in tributaries (Mirdi, Armadi and Madi). Baetidae are tolerant to nutrient and sediment enrichment (Harrington and Born, 2000).

After Ephemeroptera tricoptera was most abundant garoup with genus *Hydropsychi*. *Hydropsychi* was found abundant in almost all site as it is most tolerant genus of tricoptera (Harrington and Born, 2000).

Adhikhola River System was dominated by Ephmeroptera and Tricoptera in both upward and downward stream, but presence of red chironomidae was seen in downstream. Abundance of insect was also decreased down stream due to urbanization. It may be due to low DO value, high CO_2 and increase in urbanization downstream. In Bagmati river total 2583 benthic invertebrates representing 10 orders and 29 families were recorded. Abundance of invertebrates reduces in downward direction. Upper stream were represented by Ephmeroptera, Placeoptera and Tricoptera while downstream were represented by Tubificidae, Baetidae and Ceratopogonidae Basnet (2013). Wahizatul et al. (2011) carried their research work in Sungai Peres and Sungai Bubu found 3409 individuals of aquatic insects representing 42 families from 9 orders and considered these rivers as clean river due to its high abundance and diversity of aquatic insect. But both rivers had Chironomidae down streams means water quality degradation down streams.

Diversity of insect comparatively in autumn or post monsoon was higher in all river streams except Madi River and habitat wise except Armadi all other river stream have high diversity in autumn than winter. Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India also have high diversity of insect in post monsoon (0.302) than winter (0.227) (Barman and Gupta 2015).

Diversity of insect habitat wise was seen highest in Forest area and lowest in urban area. (Matangulu et al. 2017) found high diversity in slightly polluted area and low diversity in moderately and critically polluted area.

In this study evenness of Adhikhola and Mirdikhola was seen higher in autumn and lower in winter whereas evenness of Armadi khola aand Madikhola was higher in Winter and Lower in Autumn. In Bakuamari stream evenness if insect were higher in Autumn and lowest in winter (Barman and Gupta 2015).

Over all in this research value of DO, CO_2 and Alkalinity were higher in autumn or post monsoon than on winter. Similarly in Bakuamari stream DO, CO_2 and Alkalinity value have been seen more in post monsoon than in winter (Barman and Gupta 2015).

DO is inversely proportion to temperature (Wetzel 2001) in each stream with increase of temp there was decrease in DO value.

In this study DO value ranged from 7.97 mg/l -3.24mg/l DO below 5mg/l was found from urban area and also from agricultural area of Armadi River. DO showed positive correlation with No. of insect in both season but did not showed significant relation. It may be because except for certain palce maximum site have DO level above 5mg/l which is favourable for aquatic life (Hershey et al. 2010). (Rai et al. 2019) also showed positive correlation of DO with aquatic insect from headwater of Bagmati River. From Balkhu khola negative correlation of Oligochaetes, Diptera and Bivalvia was shown with DO (Dhakal, 2006). Prommi and Payaka (2015) also showed negative relation DO in Mae Tao and Mae Ku river streams of Thailand.

In this study temperature ranges from 25^0C- 22^0C in autumn and 16^0C-22^0C in winter. No. of insect was negatively correlated with temperature in autumn and positive correlation was seen in winter. Temperature in aquatic life helps in metabolism. It has its direct effect on development of egg to adult. It influences primary production rate and fluid dynamics. Some insect prefers cold temperature where some prefers hot. Temperature fluctuation can limit the type of organism found within the habitat. Aquatic insects are found within the range of 45^0C to -5^0C (Hershey et al. 2010). Negative correlation was seen with temperature of insect in Rivers of Western Himalayas (Shah et al. 2020).

In present study pH value ranges from 6.9 to 8.0 which lie between the normal ranges of water pH. Here pH shows positive relation with no. of insect in Autmn and negative in winter but did not show significant correlation may be because it also lies in favorable level with aqutic insect. Normal pH value of fresh water for sustainability of aquatic life ranges from 5.0 to 8.5. In West Seti River of Bajhang pH valau ranges 7.8-8.7 which represent alkaline nature of water (Matangulu 2017). Ephemeroptera (mayflies) can survive well in an acidic environment (Guerold 2000). But most aquatic insect orders such as Diptera, Hemiptera and Coleoptera are slightly affected by acidification (Venkateswarju 1969).

Velocity in this study ranges from 1.43-0.17m/s and showed positive correlation with post monsoon and negative with winter. Velocity is important in running water as it regulates decomposition of organic water on subatrate and regulate the concentration of oxygen and ionic component in water (Hynes, 1970). RDA analysis showed negative correlation of velocity with taxa richness in monsoon dominated rivers of Western Himalayas in Nepal (Shaha et al. 2020). In Aahoo stream in Nigeria shows significant effect of velocity on taxa richness (Adu and Oyeniyi 2019).

Alkalinity in aquatic ecosystem is because of dissolve carbonates, bicarbonates and hydroxide of calcium, magnesium, sodium, potassium and ammonium. In present study alkalinity ranges from 140-60 mg/l in autumn and 60-90 mg/l in winter. Alkalinity shows positive correlation in autumn. It was because it was accompanied by decrease in DO and increase in Free CO_2. In rivers of western Himalayas shows positive correlation with insect taxa (Shah et al. 2020).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The present study on Aquatic Insect of Adhikhola River Stream in Waling, Syangja reported 45 genera of 31 families and 8 orders. Among four rivers Adhikhola and Mirdi khola were highly abundant followed by Armadi khola and least abundant was Madikhola. Ephmeroptera was highly abundant order followed by Tricoptera

Season wise abundance of aquatic insect in autumn was seen to be more than in winter. Overall diversity and richness was found to be greater in autumn. In case of Evenness, Adhikhola and Mirdikhola has more species evenness in autumn than in winter whereas Armadi khola and Madi khola has more species evenness in winter season than in autumn. But no significance difference between insect recorded in autumn and winter.

Habitat wise Diversity of forest was highest in every stream of both the season followed by agriculture and lowest diversity was recorded from urban area except in Madikhola of autumn season were lowest diversity was from agriculture area. But no significant relationship has been seen between diversity of insect fauna of three habitats.

Significant negative correlation was seen with CO_2 and positive correlation with alkalinity in autumn.

6.2 Recommendation

Aquatic Insect is major component of aquatic vertebrate's assemblage. They play important roles at various tropic levels. They are also used in bio monitoring. Hence here are some recommendations made from this study:

- Study of Aquatic insect at large scale is required in different habitat, stream and at various water quality level to get actual figures of diversity and abundance of insect fauna.
- Since diversity and abundance of aquatic insect was seen to be decreased downstream hence further reaserch should be conducted to get more precise information about condition of aquatic insect and water quality.

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ANNEX 1

Aquatic insect of Adhikhola Khola River System

Annex 1.1 Identified aquatic insect of Different Stream in Autumn and Winter Season.

Order	Family	Genus	Stream	Season
Ephemeroptera	Heptageniidae	*Heptagenia* spp.	Adh, Mir, Arm, Md	Au, Win
		Rhitrogena sp.	Adhi	Au, Win
	Baetidae	*Baetis* spp.	Adh, Mir, Arm, Md	Au, Win
		Acentrella spp.	Adh, Mir, Arm, Md	Au, Win
		Fallceon spp.	Adh, Mir, Arm, Md	Au, Win
	Leptophilibidae	*Cryptopenella* sp.	Adhi	Au
		Choroterpes sp.	Adh, Mir, Arm, Md	Au,Win
		Choroterpides sp.	Adh, Mir, Arm	Au, Win
	Caenidae	*Caenis* sp.	Adh, Mir, Arm, Md	Au, Win
	Leptohyphidae	*Leptohyphes* spp.	Adh, Mir, Arm, Md	Au, Win
	Ephemerellidae	*Torleya* spp.	Adh, Mir, Arm, Md	Au, Win
Plecoptera	Perlidae	*Neoperla* spp.	Adh, Mir, Arm, Md	Au, Win
Tricoptera	Hydropsychidae	*Hydropsyche* sp.	Adh, Mir, Arm, Md	Au, Win
	Rhycophilidae	*Rhyacophila* sp.	Madi	Au, Win
	Glossosomatidae	*Glossosoma* sp.	Mir,	Win
	Leptoceridae	*Leptocerus* sp.	Adhi	Win
		Setodes sp.	Adhi, Arm,	Win

			Mir	
Hemiptera	Gerridae	*Ptilomera* spp.	Adh, Mir, Arm, Md	Au, Win
	Naucoridae	*Ilycoris* spp.	Adhi	Au, Win
	Aphelocheiridae	*Aphelocheiridae* sp.	Adhi	Win
	Nepidae	*Laccotrephes* sp.	Adhi	Au, Win
	Herbidae	*Hyrcanus* sp.	Madi	Au
Coleoptera	Gyrinidae	*Dineutus* sp.	Madi	Win
		Orectochilus sp.	Madi	Win
	Dytiscidae	*Hydrovatus* sp.	Mirdi	Win
	Hydrophilidae	*Cercyon* sp.	Madi	Au
	Elmidae	*Grouvellinus* spp.	Adh, Arm, Md	Au
	Psephenidae	*Psephenus* spp.	Adh, Mir, Arm, Md	Au, Win
		Unkown	Adh, Md	Au, Win
Diptera	Tipulidae	*Tipula* spp.	Mir, Adhi	Au, Win
	Chironomidae	*Chironomus* sp.	Adh, Mir, Arm, Md	Au, Win
	Tabinidae	*Tabanus* sp.	Mir	Au
	Limoniidae	*Hexatoma* sp.	Adh, Mir, Md	Au, Win
		Antocha sp.	Mir, Md	Au, Win
	Simuliidae	*Simulium* sp.	Mir, Md	Au, Win
	Anthericidae	*Atherix* sp.	Madi	Au
Megaloptera	Corydalidae	*Corydalis* sp.	Adh, Arm	Au, Win
Odonata	Euphaedae	*Euphaea* sp.	Madi	Au, Win
	Chlorocyphidae	*Rhinocypha* sp.	Adh, Mir, Md	Au, Win
	Calopterygidae	*Neurobasis* sp.	Arm, Md	Au, Win
	Gomphidae	*Phanogomphus* sp.	Mir, Arm	Au, Win
		Lanthus sp.	Arm	Win
		Ophiogomphus spp.	Mir, Arm Md	Au, Win

		Erpetogomphus sp.	Adh, Mir	Au, Win
	Libellulidae	*Libellula* sp.	Md	Win

Annex 1.2 Diagonostic character of identified insect

S.N.	Genus	Diagnostic characters
1.	*Acentrella* (Bengtsson, 1912) spp. (Ephemeroptera: Baetidae) (Plate A: 1)	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.
2.	*Fallceon* (Waltz & McCafferty, 1987) spp. (Ephemeroptera: Baetidae) (Plate A:2 a, b, c)	Gill present on segment-1 and gills seven rounded, Dorsum of head with keel between antenna, Labial palpi poorly developed.
3.	*Baetis* (Leach, 1815) spp, (Ephemeroptera: Baetidae) (Plate A: 3)	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.
4.	*Heptagenia* (Walsh, 1863) spp. (Ephemeroptera: Heptageniidae) (Plate A: 4)	Three well developed caudal filament. Super linguae of hypopharynx lyre shaped. Gills not actually pointed apically, gills VII with fibrils. Dorsal margin of femora with long setae. Tarsal claw is usually with only single basal denticle.
5.	*Rhithrogena* (Eaton, 1881) sp.	Flattened body with broad head, thorax, and femora.

	(Ephemeroptera: Heptageniidae) (Plate A: 5)	Dark spot on top of each femur First gills large and meets its fellow beneath the body. Three tail.
6.	*Choroterpides* (Ulmer 1939) sp. (Ephmeroptera: Leptophilibidae) (Plate A: 6)	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.
7.	*Cryptopenella* (Gillies 1951) sp. (Ephmeroptera: Leptophilibidae) (Plate A:7)	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.
8.	*Choroterpes* (Eaton, 1881) sp. (Ephmeroptera: Leptophilibidae) (Plate A: 8)	Mandibular tusk present. Gills on 2nd abdominal segment operculate. Other gills are dorsally borne. Head rectangular. Posterolateral spine on abdominal segment 5-9, segment 8-9 not curved with inner edge. No tooth like process on maxilla.
9.	*Caenis* (Stephens, 1835) sp. (Ephemeroptera: Caenidae) (Plate A: 9 a, b)	Gills on abdominal segment 2 operculate and overlap along mid line. Gill cover have Y-shaped ridge. Gills covers without stout spines on upper surface, but row of marginal spines present.
10.	*Leptohyphes* (Eaton, 1882) sp. (Ephmeroptera: Leptohyphidae) (Plate A: 10)	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.
11.	*Torleya* (Klapalek, 1905) sp. (Ephmeroptera: Ephemerellidae) (Plate A: 11a, b)	Abdomen shorter than head and thorax together. Legs covered with hair, gills on 3-7 segments. Gills on 3rd segment are semioperculate and covers rest of the gills. Maxillary palpi absent.
12.	*Hydropsyche* (Pictet 1834)	Ventrolateral gills on abdominal segments.

	sp. (Tricoptera: Hydropshychidae) (Plate B: 1 a, b, c)	Anal prolegs with a terminal brush of long setae, Thoracic segment sclerotized. Fore trochantin usually forked.
13.	*Rhyacophila* (Pictet, 1834) sp. (Tricoptera: Rhycophilidae) (Plate B: 2 a, b)	Larva without prosternal plate. Anal larvapod with large hook. Anal claw without dorsal accessory hooks. Fore trochantin projecting forward. Free living
14.	*Glossosoma* (Curtis, 1834) sp. (Tricoptera: Glossomatidae) (Plate B: 3 a, b, c)	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.
15.	*Leptocerus* (Leach in Brewster, 1815) sp. *(*Tricoptera: Leptoceridae*)* (Plate B: 4)	Hook-shaped tarsal claws of middle leg. Hind leg provided with 2 long setal fringes. Case strongly tapering and curved.
16.	*Setodes* (Rambur, 1842) sp. (Tricoptera: Leptoceridae*)* (Plate B: 5)	Anal prologs with sclerite and 2 rows of strong posteriorly directed spines. Case of sand-grains, curved but not conspicuously tapering.
17.	*Neoperla* (Eaton, 1881) sp. (Plecoptera: Perlidae) (Plate B: 6)	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.
18.	*Erpetogomphus* (Selys, 1858) sp. (Odonata: Gomphidae) (Plate C: 1)	Third segment of antenna nearly straight-sided, lateral margin usually slightly convex Posterior margins of segment 2–9 tergites with fairly uniform sharp spinules. Cerci nearly as long as to slightly longer than epiproct

		Gap between mesothoracic coxal processes equal to or greater than gap between prothoracic coxal processes.
19.	*Lanthus* (Needham, 1897) sp. (Odonata: Gomphidae) (Plate C: 2)	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.
20.	*Ophiogomphus* (Selys, 1854) spp. (Odonata: Gomphidae) (Plate C: 3)	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
21.	*Phanogomphus* (Carle, 1986) sp. (Odonata: Gomphidae) (Plate C: 4)	Third segment of antenna cylindrical, much longer than wide. Segment 8-9 middorsum broadly rounded or with a low. Poorly defined middorsal ridge continuous with low middorsal hook
22.	*Libellula* (Linnaeus, 1758) sp. Odonata: Libellulidae (Plate C: 5)	Compound eye protruding beyond lateral margin of head in dorsal view Frontoclypeal ridge with numerous long setae across entire width, some equal in length to first three segments of antenna. Prementum with five or more primary setae separated from secondary setae by length of adjacent short seta or less
23.	*Euphaea* (Selys, 1840) sp. (Odonata: Euphaedae) (Plate C: 6)	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.
24.	*Rhinocypha* (1842) sp. (Odonata: Chlorocyphidae) (Plate C: 7)	Antenna 1st segment long but shorter than combined length of other segment. Labium triangular, dark spot on anterolateral margin of prementum and basal palpal hook. Two forceps like caudal hook and triangular shaped projection in cross section of two gills.
25.	*Neurobasis* (Selys, 1853) sp. (Odonata: Caloptergidae) (Plate C: 8 a, b)	Long slender leg. Antenna 1st segment much longer than combined length of other segment. Labium elongated with deep cleft on prementum. Long movable palpal hook to hold prey, three swords like caudal filament.
26.	*Cercyon (*Leach, 1817) sp. (Coleoptera: Hydrophilidae) (Plate D: 1)	Front tibia rounded with apical spur. Elytra with distinct puncture. Sutural stria extending well toward front.
27.	*Dineutus* (Macleay, 1825) sp. *(*Coleoptera: Gyrinidae*)* (Plate D: 2, 3)	Compound eye two pair one pair dorsal one pair ventral. Labrum short and broad without compact setae. Antenna with 6 antennomeres. Pronotum convex without transverse groove. Scutellum concealed elytra without puncture and setae.
28.	*Orectochilus (*Dejean, 1833) sp. (Coleoptera: Gyrinidae) (Plate D: 4)	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.
29.	*Psephenus* (Haldeman, 1853) spp. (Coleoptera: Psephenidae) (Plate D: 5)	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.
30.	*Grouvellinus* (Champion, 1923) spp. (Coleoptera: Elmidae) (Plate D: 7)	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.
31.	*Hydrovatus* (Motschulsky, 1853) sp. (Coleoptera: Dytiscidae) (Plate D: 8)	Mesiepimeron not separating metaepisternum from mesocoxal cavity. Metacoxal process incision medially, incision longer than wide. Apical portion of elytron not acuminate. Dorsal color reddish. Antennomere 3-5 and Metatarsomere 4.
32.	*Aphelocheirus* (Westwood, 1833) sp. (Hemiptera: Aphelocheiridae) (Plate E: 1)	Antenna shorter than head, head longer than wide, tarsi of foreleg three segmented. Rostrum long and slender, extending hind coxae.
33.	*Hyrcanus sp.* (Hemiptera: Herbidae) (Plate E: 2)	Antenna longer than head and stout, claws of foreleg inserted at apex. Tarsi 2 segmented. Deep longitudinal groove on ventral surface of head and thoracic. Head narrower and pointed apically.
34.	*Ilyocoris (*Stal, 1861) sp. (Hemiptera: Naucoridae) (Plate E: 3)	Antenna shorter than head, body dorsoventrally flattened, fore femora enlarge. Mid and hind leg with fringe of swimming setae. Body exceeding 10mm, protonum yellowish.

35.	*Ptilomera* (Amyot and Serville, 1843) spp. (Hemiptera: Gerridae) (Plate E: 4)	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 seven.
36.	*Laccotrephes* (Stal, 1866) sp. (Hemiptera: Nepidae) (Plate E: 5)	Antenna shorter than head, concealed below eye. Beak cylindrical with segment. Abdomen terminating with elongating breathing tube. Respiratory siphon longer than inner hemi elytra commisure.
37.	*Antocha* (Sacken, 1860) sp. (Diptera: Limoniidae) (Plate F: 1 a, b)	Spiracles on the last abdominal segment are missing. Dorsal and ventral creeping welts on abdominal segments 2-7.
38.	*Atherix* (Meigen, 1803) sp. (Diptera: Anthericidae) (Plate F: 2)	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.
39.	*Chironomus* (Meigen, 1803) sp. (Diptera: Chironomidae) (Plate F: 3)	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
40.	*Hexatoma* (Latreille, 1809) sp.(Diptera: Tipulidae) (Plate F: 4)	Elongated dorsally flattened body, large jaws projection forward, all three thoracic notum sclerotized.

		Last abdomen segment with two pair of hook. Abdominal segment 1-8 with lateral filaments.
41.	*Simulium* (Latreille 1802) sp. (Diptera: Simuliidae) (Plate F: 5 a, b)	Hexatome can be identified by swollen 7th segment. Head capsule retracted.
42.	*Tabanus (*Linnaeus, 1758*)* sp. (Diptera: Tabanidae) (Plate F: 6)	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.
43.	*Tipula* (Linnaeus, 1758) sp. (Diptera: Tipulidae) (Plate F: 7)	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.
44.	*Corydalus* (Latreille, 1802) sp. (Megaloptera: Corydalidae) (Plate F: 8)	Head capsule sclerotized and retracted. Mandibles moving horizontally against each other Body with short hairs evenly distributed. Anal gills not branched.

Annex 2

Total Relative Abundance of Adhikhola River Stream

Annex 2.1 Order wise Relative Abundance of Aquatic Insect of Adhikhola River System

Order	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Coleoptera	16	3.053	13	2.574	15	3.456	26	5.579
Diptera	9	1.717	52	10.29	23	5.299	12	2.575
Ephemeroptera	378	72.13	294	58.21	256	58.98	329	70.60
Hemiptera	11	2.099	14	2.77	29	6.682	13	2.789
Megaloptera	3	0.572	2	0.39	12	2.764	0	0
Odonata	23	4.389	12	2.37	5	1.152	11	2.360
Plecoptera	15	2.862	3	0.59	5	1.152	3	0.643
Tricoptera	69	13.16	115	22.77	89	20.50	72	15.45

Annex 2.2 Family wise Relative Abundance of Aquatic Insect of Adhikhola River System

Family	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Anthericidae	0	0	1	0.002	0	0	0	0
Aphelocheiridae	2	0.004	0	0	0	0	0	0
Baetidae	113	0.205	185	0.339	179	0.357	211	0.511
Caenidae	78	0.142	46	0.084	38	0.076	3	0.007
Calopterygidae	0	0	0	0	5	0.01	3	0.007
Chironomidae	5	0.009	25	0.046	23	0.046	1	0.002
Chlorocyphidae	0	0	1	0.002	0	0	5	0.012
Corydalidae	3	0.005	2	0.004	12	0.024	0	0
Dytiscidae	0	0	0	0	0	0	3	0.007
Elmidae	2	0.004	1	0.002	0	0	5	0.012
Ephemerelidae	27	0.049	17	0.031	28	0.056	1	0.002

Euphaedae	0	0	1	0.002	0	0	2	0.005
Gerridae	0	0	18	0.033	10	0.02	13	0.031
Glossosomatidae	4	0.007	2	0.004	0	0	0	0
Gomphidae	23	0.042	9	0.016	9	0.018	3	0.007
Gyrinidae	0	0	0	0	0	0	17	0.041
Heptageniidae	123	0.223	55	0.101	37	0.074	29	0.07
Herbidae	0	0	0	0	0	0	1	0.002
Hydrophilibidae	0	0	0	0	0	0	3	0.007
Hydropsychidae	77	0.14	119	0.218	101	0.201	70	0.169
Libellulidae	0	0	0	0	1	0.002	2	0.005
Leptoceridae	2	0.004	0	0	0	0	1	0.002
Leptohyphidae	40	0.073	0	0	10	0.02	8	0.019
Leptophilibidae	6	0.011	14	0.026	19	0.038	9	0.022
Limoniidae	0	0	0	0	0	0	2	0.005
Naucoridae	6	0.011	0	0	2	0.004	0	0
Nepidae	2	0.004	0	0	1	0.002	0	0
Perlidae	15	0.027	8	0.015	9	0.018	3	0.007
Psephenidae	22	0.04	12	0.022	17	0.034	6	0.015
Rhyacophilidae	0	0	7	0.013	0	0	0	0
Simuliidae	0	0	14	0.026	1	0.002	7	0.017
Tabinidae	1	0.002	9	0.016	0	0	5	0.012
Tipulidae	2	0.004	3	0.005	2	0.004	0	0

Annex 1.3 Genus Wise Relative Abundance of Aquatic Insect of Adhikhola River System

Genus	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Acentrella	36	6.51	100	18.18	112	22.672	125	30.562
Antocha	0	0	1	0.182	0	0	2	0.489
Aphelocheirus	2	0.362	0	0	0	0	0	0
Atherix	0	0	0	0	0	0	2	0.489
Baetis	28	5.063	23	4.182	27	5.4656	10	2.445

Caenis	6	1.085	14	2.545	19	3.8462	9	2.2005
Cercyon	0	0	0	0	0	0	3	0.7335
Chironomus	5	0.904	25	4.545	23	4.6559	1	0.2445
Choroterpes	71	12.84	41	7.455	36	7.2874	3	0.7335
Choroterpides	6	1.085	5	0.909	1	0.2024	0	0
Corydalis	3	0.542	2	0.364	12	2.4291	0	0
Cryptopenella	1	0.181	0	0	1	0.2024	0	0
Dineutus	0	0	0	0	0	0	5	1.2225
Erpetogomphus	23	4.159	3	0.545	0	0	0	0
Euphaea	0	0	1	0.182	0	0	2	0.489
Fallceon	49	8.861	62	11.27	40	8.0972	76	18.582
Glossosoma	0	0	7	1.273	0	0	0	0
Grouvellinus	2	0.362	1	0.182	0	0	5	1.2225
Heptagenia	113	20.43	55	10	27	5.4656	29	7.0905
Hexatoma	1	0.181	8	1.455	0	0	3	0.7335
Hydropsyche	77	13.92	119	21.64	101	20.445	70	17.115
Hydrovatus	0	0	1	0.182	0	0	0	0
Hyrcanus	0	0	0	0	0	0	1	0.2445
Ilyocoris	6	1.085	0	0	2	0.4049	0	0
Laccotrephes	2	0.362	0	0	1	0.2024	0	0
Lanthus	0	0	0	0	2	0.4049	0	0
Leptocerus	2	0.362	0	0	0	0	0	0
Leptohyphes	40	7.233	0	0	10	2.0243	8	1.956
Libellula	0	0	0	0	1	0.2024	2	0.489
Neoperla	15	2.712	8	1.455	9	1.8219	3	0.7335
Neurobasis	0	0	0	0	5	1.0121	3	0.7335
Ophiogomphus	0	0	5	0.909	3	0.6073	3	0.7335
Orectochilus	0	0	0	0	0	0	12	2.934
Phanogomphus	0	0	1	0.182	4	0.8097	0	0
Psephenus	13	2.351	12	2.182	9	1.8219	4	0.978
Ptilomera	0	0	18	3.273	10	2.0243	13	3.1785
Rhinocypha	0	0	1	0.182	0	0	5	1.2225

Rhitrogena	10	1.808	0	0	0	0	0	0
Rhyacophila	2	0.362	0	0	0	0	1	0.2445
Setodus	2	0.362	2	0.364	0	0	0	0
Simulium	0	0	14	2.545	1	0.2024	7	1.7115
Tabanus	0	0	1	0.182	0	0	0	0
Tipula	2	0.362	3	0.545	2	0.4049	0	0
Torleya	27	4.882	17	3.091	28	5.668	0	0
Unknown	9	1.627	0	0	8	1.6194	2	0.489

ANNEX 3

Seasonal Variation of Relative Abundance of Aquatic Insect in Adhikhola River Stream

Annex 3.1 Relative Abundance of Order of Identified Insect in Different Stream in Autumn

Order	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Plecoptera	4	2.632	2	0.913	4	1.695	1	0.442
Ephemeroptera	107	70.39	132	60.27	137	58.05	156	69.03
Tricoptera	27	17.76	34	15.53	49	20.76	38	16.81
Odonata	0	0	8	3.653	6	2.542	4	1.77
Hemiptera	2	1.316	8	3.653	13	5.508	2	0.885
Diptera	5	3.289	29	13.24	16	6.78	13	5.752
Coleoptera	6	3.947	5	2.283	3	1.271	12	5.31
Megaloptera	1	0.658	1	0.457	8	3.39	0	0

Annex 3.2 Relative Abundance of Families of Identified Insect in Different Stream in Autumn

	Adhikhola		Mirdi		Armadi		Madi	
Family	No.	%	No.	%	No.	%	No.	%
Perlidae	4	2.632	2	0.913	4	1.695	1	0.442
Heptageniidae	28	18.42	41	18.72	18	7.627	19	8.407
Baetidae	49	32.24	50	22.83	68	28.81	126	55.75
Leptophilibidae	6	3.947	14	6.393	17	7.203	7	3.097
Caenidae	17	11.18	17	7.763	25	10.59	3	1.327
Leptohyphidae	4	2.632	0	0	1	0.424	0	0
Ephemerelidae	3	1.974	10	4.566	8	3.39	1	0.442
Hydropsychidae	25	16.45	34	15.53	49	20.76	38	16.81
Leptoceridae	2	1.316	0	0	0	0	0	0
Gomphidae	0	0	6	2.74	4	1.695	3	1.327

Calopterygidae	0	0	0	0	2	0.847	0	0
Chlorocyphidae	0	0	1	0.457	0	0	0	0
Euphaedae	0	0	1	0.457	0	0	1	0.442
Gerridae	0	0	8	3.653	10	4.237	1	0.442
Naucoridae	1	0.658	0	0	2	0.847	0	0
Nepidae	1	0.658	0	0	1	0.424	0	0
Herbidae	0	0	0	0	0	0	1	0.442
Tipulidae	0	0	2	0.913	2	0.847	0	0
Simuliidae	0	0	1	0.457	1	0.424	7	3.097
Chironomidae	5	3.289	18	8.219	13	5.508	1	0.442
Anthericidae	0	0	1	0.457	0	0	0	0
Limoniidae	0	0	0	0	0	0	2	0.885
Tabinidae	0	0	7	3.196	0	0	3	1.327
Psephenidae	4	2.632	4	1.826	3	1.271	4	1.77
Dytiscidae	0	0	0	0	0	0	3	1.327
Hydrophilibidae	0	0	0	0	0	0	0	0
Elmidae	2	1.316	1	0.457	0	0	5	2.212
Corydalidae	1	0.658	1	0.457	8	3.39	0	0

Annex 3.3 Relative Abundance of Genera of Identified Insect in Different Stream in Autumn.

Genus	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Heptagenia	22	14.5	41	18.7	18	7.627	19	8.407
Rhitrogena	6	3.95	0	0	0	0	0	0
Baetis	9	5.92	7	3.2	4	1.695	2	0.885
Fallceon	16	10.5	28	12.8	16	6.78	41	18.14
Acentrella	24	15.8	15	6.85	48	20.34	83	36.73
Cryptopenella	1	0.66	0	0	1	0.424	0	0
Choroterpes	14	9.21	16	7.31	24	10.17	3	1.327
Choroterpides	2	1.32	1	0.46	0	0	0	0

Leptohyphes	4	2.63	0	0	1	0.424	0	0
Caenis	6	3.95	14	6.39	17	7.203	7	3.097
Torleya	3	1.97	10	4.57	8	3.39	1	0.442
Neoperla	4	2.63	2	0.91	4	1.695	1	0.442
Hydropsyche	25	16.4	34	15.5	49	20.76	38	16.81
Rhyacophila	2	1.32	0	0	0	0	0	0
Ptilomera	0	0	8	3.65	10	4.237	1	0.442
Ilyocoris	1	0.66	0	0	2	0.847	0	0
Laccotrephes	1	0.66	0	0	1	0.424	0	0
Hyrcanus	0	0	0	0	0	0	1	0.442
Cercyon	0	0	0	0	0	0	3	1.327
Grouvellinus	2	1.32	1	0.46	0	0	5	2.212
Psephenus	4	2.63	4	1.83	3	1.271	3	1.327
Unknown	0	0	0	0	0	0	1	0.442
Tipula	0	0	2	0.91	2	0.847	0	0
Antocha	0	0	1	0.46	0	0	1	0.442
Hexatoma	0	0	6	2.74	0	0	2	0.885
Chironomus	5	3.29	18	8.22	13	5.508	1	0.442
Tabanus	0	0	1	0.46	0	0	0	0
Simulium	0	0	1	0.46	1	0.424	7	3.097
Atherix	0	0	0	0	0	0	2	0.885
Corydalis	1	0.66	1	0.46	8	3.39	0	0
Euphaea	0	0	1	0.46	0	0	1	0.442
Neurobasis	0	0	0	0	2	0.847	0	0
Rhinocypha	0	0	1	0.46	0	0	0	0
Phanogomphus	0	0	1	0.46	1	0.424	0	0
Ophiogomphus	0	0	2	0.91	3	1.271	3	1.327
Erpetogomphus	0	0	3	1.37	0	0	0	0

Annex 3.4 Relative Abundance of Order of Identified Insect in Different Stream in Winter

Order	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Plecoptera	11	2.743	6	1.813	5	1.866	2	1.087
Ephemeroptera	280	69.83	185	55.89	174	64.93	105	57.07
Tricoptera	56	13.97	94	28.4	52	19.4	33	17.93
Odonata	23	5.736	3	0.906	9	3.358	11	5.978
Hemiptera	8	1.995	10	3.021	0	0	12	6.522
Diptera	3	0.748	23	6.949	10	3.731	2	1.087
Coleoptera	18	4.489	9	2.719	14	5.224	19	10.33
Megaloptera	2	0.499	1	0.302	4	1.493	0	0

Annex 3.5 Relative Abundance of Families of Identified Insect in Different Stream in Winter

Family	Adhikhola		Mirdi		Armadi		Madi	
	No.	%	No.	%	No.	%	No.	%
Perlidae	11	2.743	6	1.813	5	1.866	2	1.087
Heptageniidae	95	23.69	14	4.23	19	7.09	10	5.435
Baetidae	64	15.96	135	40.79	111	41.42	85	46.2
Leptophilibidae	0	0	0	0	2	0.746	2	1.087
Caenidae	61	15.21	29	8.761	13	4.851	0	0
Leptohyphidae	36	8.978	0	0	9	3.358	8	4.348
Ephemerellidae	24	5.985	7	2.115	20	7.463	0	0
Hydropsychidae	52	12.97	85	25.68	52	19.4	32	17.39
Rhyacophilidae	0	0	7	2.115	0	0	0	0
Glossosomatidae	4	0.998	2	0.604	0	0	0	0
Leptoceridae	0	0	0	0	0	0	1	0.543
Gomphidae	23	5.736	3	0.906	5	1.866	0	0
Libellulidae	0	0	0	0	1	0.373	2	1.087
Calopterygidae	0	0	0	0	3	1.119	3	1.63
Chlorocyphidae	0	0	0	0	0	0	5	2.717

Euphaedae	0	0	0	0	0	0	1	0.543
Aphelocheiridae	2	0.499	0	0	0	0	0	0
Gerridae	0	0	10	3.021	0	0	12	6.522
Naucoridae	5	1.247	0	0	0	0	0	0
Nepidae	1	0.249	0	0	0	0	0	0
Herbidae	0	0	0	0	0	0	0	0
Tipulidae	2	0.499	1	0.302	0	0	0	0
Simuliidae	0	0	13	3.927	0	0	0	0
Chironomidae	0	0	7	2.115	10	3.731	0	0
Anthericidae	0	0	0	0	0	0	0	0
Limoniidae	0	0	0	0	0	0	0	0
Tabinidae	1	0.249	2	0.604	0	0	2	1.087
Psephenidae	18	4.489	8	2.417	14	5.224	2	1.087
Gyrinidae	0	0	0	0	0	0	17	9.239
Dytiscidae	0	0	0	0	0	0	0	0
Hydrophilibidae	0	0	1	0.302	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0
Corydalidae	2	0.499	1	0.302	4	1.493	0	0

Annex 3.6 Relative Abundance of Genera of Identified Insect of Different stream in Winter

	Adhikhola		Mirdi		Armadi		Madi	
Genus	No.	%	No.	%	No.	%	No.	%
Heptagenia	91	22.69	14	4.23	19	7.09	10	5.43
Rhitrogena	4	0.998	0	0	0	0	0	0
Baetis	19	4.738	16	4.834	23	8.58	8	4.35
Fallceon	33	8.229	34	10.27	24	8.96	35	19
Acentrella	12	2.993	85	25.68	64	23.9	42	22.8
Cryptopenella	0	0	0	0	0	0	0	0
Choroterpes	57	14.21	25	7.553	12	4.48	0	0
Choroterpides	4	0.998	4	1.208	1	0.37	0	0
Leptohyphes	36	8.978	0	0	9	3.36	8	4.35

Caenis	0	0	0	0	2	0.75	2	1.09
Torleya	24	5.985	7	2.115	20	7.46	0	0
Neoperla	11	2.743	6	1.813	5	1.87	2	1.09
Hydropsyche	52	12.97	85	25.68	52	19.4	32	17.4
Rhyacophila	0	0	0	0	0	0	1	0.54
Glossosoma	0	0	7	2.115	0	0	0	0
Leptocerus	2	0.499	0	0	0	0	0	0
Setodus	2	0.499	2	0.604	0	0	0	0
Ptilomera	0	0	10	3.021	0	0	12	6.52
Ilyocoris	5	1.247	0	0	0	0	0	0
Aphelocheirus	2	0.499	0	0	0	0	0	0
Laccotrephes	1	0.249	0	0	0	0	0	0
Hyrcanus	0	0	0	0	0	0	0	0
Corydalis	2	0.499	1	0.302	4	1.49	0	0
Dineutus	0	0	0	0	0	0	5	2.72
Orectochilus	0	0	0	0	0	0	12	6.52
Hydrovatus	0	0	1	0.302	0	0	0	0
Cercyon	0	0	0	0	0	0	0	0
Grouvellinus	0	0	0	0	0	0	0	0
Psephenus	9	2.244	8	2.417	6	2.24	1	0.54
Unknown	9	2.244	0	0	8	2.99	1	0.54
Tipula	2	0.499	1	0.302	0	0	0	0
Antocha	0	0	0	0	0	0	1	0.54
Hexatoma	1	0.249	2	0.604	0	0	1	0.54
Chironomus	0	0	7	2.115	10	3.73	0	0
Tabanus	0	0	0	0	0	0	0	0
Simulium	0	0	13	3.927	0	0	0	0
Atherix	0	0	0	0	0	0	0	0
Euphaea	0	0	0	0	0	0	1	0.54
Neurobasis	0	0	0	0	3	1.12	3	1.63
Rhinocypha	0	0	0	0	0	0	5	2.72
Phanogomphus	0	0	0	0	3	1.12	0	0

Ophiogomphus	0	0	3	0.906	0	0	0	0
Lanthus	0	0	0	0	2	0.75	0	0
Erpetogomphus	23	5.736	0	0	0	0	0	0
Libellula	0	0	0	0	1	0.37	2	1.09

Annex 4

Habitat wise Abundance of Aquatic Insect in Adhikhola River Stream

Annex 4.1 Relative abundance of Aquatic Insect of Forest Area in Autumn

Adhikhola	No.	Mirdi	No.	Armadi	No.	Madi	No.
Rhitrogena	3	*Heptagenia*	12	*Heptagenia*	5	*Heptagenia*	4
Acentrella	7	*Acentrella*	8	*Acentrella*	18	*Fallceon*	8
Baetis	6	*Baetis*	5	*Fallceon*	9	*Acentrella*	30
Leptohyphes	4	*Fallceon*	8	*Baetis*	3	*Baetis*	2
Choroterpes	5	*Choroterpes*	5	*Leptohyphes*	3	*Neuperla*	1
Heptagenia	8	*Torleya*	8	*Choroterpes*	6	*Hydropsyche*	10
Fallceon	3	*Neoperla*	1	*Choroterpides*	1	*Simulium*	4
Caenis	1	*Hydropsyche*	12	*Caenis*	1	*Antocha*	1
Cryptopenella	1	*Grouvellinus*	1	*Neoperla*	4	*Atherix*	1
Torleya	2	*Psephenus*	2	*Hydropsyche*	13	*Grouvellinus*	3
Hydropsyche	9	*Hexatoma*	5	*Phanogomphus*	3	Unknown	1
Psephenus	3	*Tabanus*	1	*Libellula*	1	*Psephenus*	2
Laccotrephes	1	*Simulium*	1	*Torleya*	15	*Hexatoma*	2
Rhinocypha	2	*Rhinocypha*	1			*Hyrcanus*	1
						Euphaea	1
						Ophiogomphus	3
						Caenis	2

Annex 4.2 Relative Abundance of Aquatic Insect of Agriculture Area in Autumn

Adhikhola	No.	Mirdi	No.	Armadi	No.	Madi	No.
Acentrella	11	*Heptagenia*	10	*Heptagenia*	6	*Heptagenia*	9
Fallceon	9	*Baetis*	2	*Choroterpes*	10	*Acentrella*	24
Baetis	3	*Fallceon*	17	*Fallceon*	7	*Fallceon*	24
Heptagenia	8	*Ceanis*	11	*Torleya*	3	*Choroterpes*	1
Rhitrogena	2	*Acentrella*	7	*Hydropsyche*	5	*Torleya*	1

Choroterpides	2	*Hydropsyche*	8	*Corydalis*	2	*Hydropsyche*	10
Choroterpes	5	*Psephenus*	1	*Neurobasis*	2	*Cercyon*	1
Caenis	5	*Hexatoma*	1	*Ilycoris*	2	*Psephenus*	1
Torleya	1	*Tipula*	1	*Ptilomera*	6	*Grouvellinus*	2
Neuperla	1	*Antocha*	1			*Ptilomera*	1
Hydropsyche	11	*Chironomus*	7				
Corydalis	1	*Euphaea*	1				
Ilyocoris	1	*Ophiogomphus*	2				
		Ptilomera	5				

Annex 4.3 Relative Abundance of Aquatic Insect of Urban Area in Autumn

Adhikhola	No.	Mirdi	No.	Armadi	Urban	Madi	No.
Heptagenia	6	*Heptagenia*	19	*Heptagenia*	3	*Heptagenia*	6
Rhitrogena	1	*Fallceon*	3	*Baetis*	3	*Fallceon*	9
Acentrella	6	*Choroterpes*	11	*Fallceon*	3	*Acentrella*	29
Fallceon	4	*Choroterpides*	1	*Acentrella*	31	*Choroterpes*	2
Choroterpes	4	*Caenis*	3	*Torleya*	5	*Caenis*	5
Neuperla	3	*Torleya*	2	*Caenis*	12	*Hydropsyche*	18
Hydropsyche	5	*Neoperla*	1	*Neuperla*	1	*Cercyon*	2
Grouvellinus	2	*Hydropsyche*	14	*Hydropsyche*	11	*Chironomus*	1
Chironomus	5	*Psephenus*	1	*Corydalis*	3	*Simulium*	3
Psephenus	1	*Tipula*	1	*Ptilomera*	4	*Atherix*	1
		Chironomus	11	*Chironomus*	13		
		Erpetogomphus	3	*Phanogomphus*	1		
		Ptilomera	3				
		Corydalis	1				
		Phanogomphus	1				

Annex 4.4 Relative Abundance of Aquatic Insect of Forest Area in Winter

Adhikhola	No.	Mirdi	No.	Armadi	No.	Madi	No.
Heptagenia	21	*Heptagenia*	11	*Heptagenia*	5	*Heptagenia*	6
Rhitrogena	4	*Acentrella*	35	*Acentrella*	18	*Baetis*	5
Fallceon	7	*Fallceon*	13	*Fallceon*	9	*Caenis*	2
Baetis	11	*Baetis*	3	*Baetis*	3	*Neoperla*	1
Acentrella	12	*Torleya*	4	*Leptohyphes*	3	*Euphaea*	1
Leptohyphes	20	*Ptilomera*	5	*Choroterpes*	6	*Rhynocypha*	5
Chorotorpes	27	*Choroterpides*	1	*Choroterpides*	1	*Neurobasis*	3
Choroterpides	1	*Choroterpes*	3	*Caenis*	1	*Orectochilus*	6
Torleya	7	*Ophiogomphus*	4	*Neoperla*	4	*Psephenus*	1
Neoperla	5	*Psephenus*	5	*Hydropsyche*	13	*Ptilomera*	12
Hydropsyche	9	*Hexatoma*	1	*Ophiogomphus*	3	*Libellula*	2
Erptegomphus	4	*Neoperla*	2	*Libellula*	1		
Psephenus	2	*Hydropsyche*	25	*Torleya*	15		
Corydalis	1	*Setodes*	2	*Psephenus*	2		
		Glossosoma	2				

Annex 4.5 Relative Abundance of Aquatic Insect of Agriculture Area in Winter

Adhikhola	No.	Mirdi	No.	Armadi	No.	Madi	No.
Heptagenia	42	*Acentrella*	22	*Heptagenia*	5	*Fallceon*	11
Fallceon	14	*Baetis*	10	*Baetis*	16	*Acentrella*	15
Choroterpides	3	*Fallceon*	12	*Leptohyphes*	6	*Heptagenia*	3
Leptohyphes	16	*Choroterpes*	5	*Choroterpes*	6	*Baetis*	3
Torleya	8	*Choroterpides*	1	*Acentrella*	20	*Neoperla*	1
Choroterpes	30	*Heptagenia*	2	*Fallceon*	7	*Hydropsyche*	21
Ilyocoris	4	*Neoperla*	4	*Torleya*	5	*Rhycophila*	1
Laccotrephes	1	*Hydropsyche*	45	*Caenis*	1	*Orectochilus*	6
Tipula	1	*Glossosoma*	2	*Hydropsyche*	24	*Dineutus*	5
Hexatoma	1	*Corydalis*	1	*Neoperla*	1	*Hexatoma*	1
Neoperla	1	*Ptilomera*	5	*Corydalis*	2	*Acentrella*	15

Erpetogomphus	10	*Psephenus*	1	*Psephenus*	1		
Hydropsyche	13	*Ophiogomphus*	3	*Chironomus*	3		
Psephenus	5	*Hexatoma*	1				
Unknown	6	*Simulium*	13				
		Tipula	1				

Annex 4.6 Relative Abundance of Aquatic Insect of Urban Area in Winter

Adhikhola	No.	Mirdi	No.	Armadi	No.	Madi	No.
Heptagenia	28	*Heptagenia*	1	*Heptagenia*	9	*Fallceon*	24
Fallceon	12	*Acentrella*	28	*Acentrella*	26	*Acentrella*	27
Baetis	8	*Baetis*	3	*Baetis*	4	*Heptagenia*	1
Torleya	9	*Fallceon*	9	*Fallceon*	8	*Leptohyphes*	8
Neoperla	5	*Torleya*	3	*Hydropsyche*	15	*Hydropsyche*	11
Hydropsyche	30	*Choroterpes*	17	*Setodes*	2	*Antocha*	1
Setodes	2	*Choroterpides*	2	*Phanogomphus*	3	Unknown	1
Leptocerus	2	*Hydropsyche*	15	*Neurobasis*	3		
Aphelocheirus	2	*Glossosoma*	3	*Psephenus*	5		
Ilyocoris	1	*Chironomus*	7	*Lanthus*	2		
Unknown	3	*Hydrovatus*	1	*Chironomus*	7		
Erpetogomphus	9	*Psephenus*	2	*Corydalis*	2		
Corydalis	1						
Tipula	1						
Psephenus	2						

Annex 4

Water parameter of Adhikhola River Sytem

Annex 4.1 Water Parametre of Adhikhola River in Autumn

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.4	24	1.25	6.08	15.4	75	Agriculture
S1P2	7.4	25	0.8				
S1P3	7.3	25	0.91				
S2P1	7.3	25	0.85	3.83	17.6	65	Urban
S2P2	7.3	24	1				
S2P3	7.4	25	0.59				
S3P1	7.5	23	0.19	7.97	11	90	Forest
S3P2	7.6	23	1.75				
S3P3	7.6	23	0.67				

Annex 4.2 Water Parameter of Mirdi Khola in Autumn

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.5	22	0.67	7.49	15.4	125	Forest
S1P2	7.5	22	0.83				
S1P3	7.6	22	1				
S2P1	7.6	22	0.77	6.08	22	105	Agriculture
S2P2	7.6	22	0.67				
S2P3	7.6	22	1.42				
S3P1	7.5	25	0.62	3.24	17.6	95	Urban
S3P2	7.7	25	0.77				
S3P3	7.7	25	0.83				

Annex 4.3 Water Parameter of Armadi Khola in Autumn

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.8	21	0.91	5.45	19.8	140	Forest
S1P2	7.8	21	1				
S1P3	7.8	21	0.71				
S2P1	7.6	21.5	1.25	3.36	22	115	Urban
S2P2	7.8	21.5	1.42				
S2P3	7.6	21.5	0.77				
S3P1	7.6	23	0.77	4.85	15.4	110	Agriculture
S3P2	7.5	23	0.77				
S3P3	7.6	23	1.25				

Annex 4.4 Water Parameter of Madi Khola in Autumn

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.9	19		6.25	15.4	85	Forest
S1P2	7.6	19	0.63				
S1P3	7.5	19	0.67				
S2P1	7.6	19	0.77	5.6	17.6	70	Agriculture
S2P2	7.5	19	0.83				
S2P3	7.5	19	1				
S3P1	7.5	20	1.42	4.76	19.8	60	Urban
S3P2	7.5	20	0.63				
S3P3	7.5	20	0.83				

Annex 4.5 Water Parameter of Adhikhola in Winter

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.4	22	0.67	5.46	6.2	75	Agriculture
S1P2	7.4	22	0.23				
S1P3	7.3	22	0.24				
S2P1	7.3	21	0.17	5.88	8.4	50	Urban
S2P2	7.5	21	0.28				
S2P3	7.4	21	0.52				
S3P1	7.5	21	0.29	6.08	6.6	65	Forest
S3P2	7.6	22	0.34				
S3P3	6.9	21.5	0.42				

Annex 4.6 Water Parameter of Mirdi Khola in Winter

Site	pH	Temperature (^{0}C)	Velocity (m/s)	DO(mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.6	22	0.63	6.68	11	85	Forest
S1P2	7.6	22	0.77				
S1P3	7.8	22	0.71				
S2P1	7.6	22	1	5.08	13.4	75	Agriculture
S2P2	7.6	22	1				
S2P3	7.5	22	0.83				
S3P1	7.7	22	0.58	3.24	15.6	65	Urban
S3P2	7.6	22	0.34				
S3P3	7.7	22	0.37				

Annex 4.7 Water Parameter of Armadi Khola in Winter

Site	pH	Temperature (^0C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	7.8	21	0.71	5.45	10.6	90	Forest
S1P2	7.6	21	0.91				
S1P3	7.8	21	0.77				
S2P1	7.5	22	1.11	3.36	15.4	80	Urban
S2P2	7.6	22	1.43				
S2P3	7.8	22	0.62				
S3P1	7.6	22	0.67	4.85	11.8	85	Agriculture
S3P2	7.5	22	0.47				
S3P3	7.6	22	0.4				

Annex 4.8 Water Parameter of Madi Khola in Winter

Site	pH	Temperature (^0C)	Velocity (m/s)	DO (mg/l)	CO_2 (mg/l)	Alkalinity (mg/l)	Remark
S1P1	8.0	16	0.42	6.08	6.6	85	Forest
S1P3	7.6	16	0.22				
S1P3	7.5	16	0.4				
S2P1	7.6	16	0.42	5.67	6.6	70	Agriculture
S2P2	7.5	16	0.31				
S2P3	7.6	16	0.5				
S3P1	7.5	17	0.42	4.86	11	60	Urban
S3P2	7.5	17	0.4				
S3P3	7.6	17	0.56				

Photograph

Plate A: Ephemeroptera

1. *Acentrella*, 2(a). *Fallceon*, 2(b) *Fallceon* gills, 2(c). Keel between antenna, 3. *Baetis*, 4.*Heptagenia*, 5.*Rhitrogena*, 6. *Choroterpides*, 7. *Cryptopenella*, 8. *Choroterpes*, 9. *Caenis* (a) Dorsal 9(b) operculate giils of *Caenis*, 10(a), (b) *Leptohypes*, 11 (a), (b) *Torleya*.

Plate B: Tricoptera and Plecoptera

1(a) *Hydropsyche* Dorsal, (b) Ventral (c) Forked Trochantin, 2(a) *Rhycaophila*, (b) Anal Hook, 3 *Glossosomma* (a) Dorsal, (b) Ventral portion of Thorax (c) Cage. 4. *Leptocerus* in cage, 5. *Setodes* in Cage, 6. *Neoperla*.

Plate C: Odonata

1. *Erpetogomphus*, 2. *Lanthus*, 3. *Ophiogomphus* 4. *Phanogomphus*, 5. *Libellula*. 6. *Euphaea*, 7. *Rhinocypha*, 8. *Neurobasis* (a) prementum (b) Anteena.

Plate D: Coleoptera

1. *Cercyon*, 2. *Dineutus* Dorsal ,3. *Dineutus* Ventral, 4. *Orectochilus*, 5. *Psephenus* 6. Psephenidae sp. 7. *Grouvellinus*, 8. *Hydrovatus*.

Plate E: Hemiptera

1. *Aphelocheirus*, 2. *Hyrcanus*, 3. *Ilyocoris*, 4. *Ptilomera*, 5. *Laccotrephes*.

Plate F: Diptera and Megaloptera

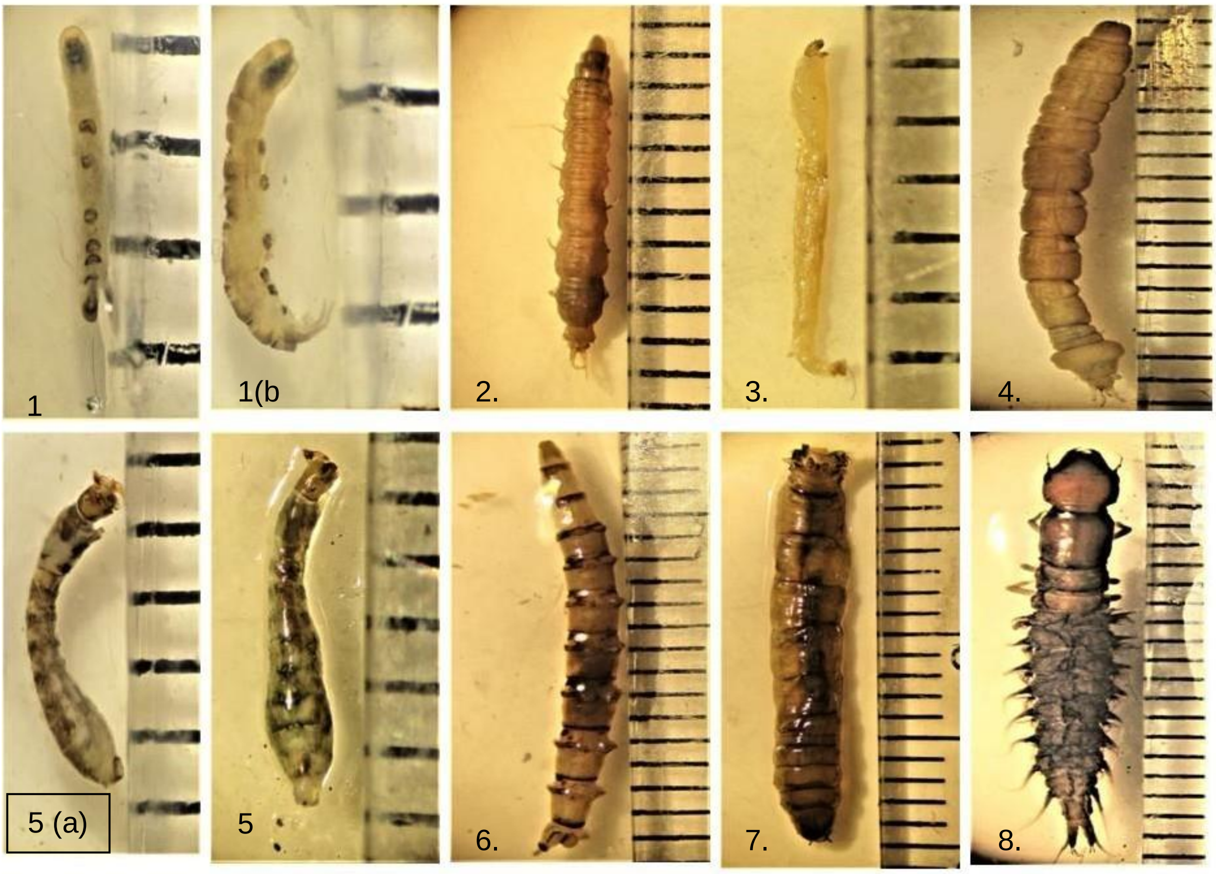

Plate F. 1 *Antocha* (a) Ventral, (b) Lateral, 2. *Atherix*, 3. *Chironomus*, 4.*Hexatoma*, 5 Simulium (a) Lateral (b) Dorsal, 6. *Tabanus*, 7. *Tipula*, 8. Corydalus.

Plate G: Various photographs of field and lab.