DIVERSITY AND EVENNESS OF AQUATIC INSECTS AS A TOOL FOR BIOLOGICAL ASSESSMENT OF GODAWARI RIVULETS

A Dissertation

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ABSTRACT

During the work, from Godavari Rivulets, altogether 47 taxa belonging to 9 orders, 40 families and 33 genera were reported from 5 sampling sites. Among the total species collected species richness was highest of Odonata followed by Diptera, Ephemeroptera and Trichoptera, Coleoptera, Plecoptera, Hemiptera and Neuroptera respectively. As diversity and eveness of different sites were calculated, site I was found to be the most stable and site IV to be the least stable aquatic community on the basis of eveness value.

Seasons were also found to affect the species richness of the aquatic insects.The species richness was found to be highest in Autumn (37 species), followed by Rainy (35 species), Winter (23 species) and Spring (16 species) respectively.

NEPBIOS/ASPT Values were calculated to assess the water quality. For the rivulets water quality-classII was obtained which means good except for site III for which water quality class I-II was obtained which indicates intermediate between excellent and good. There was variation in values that indicates the condition of the quality is deteriorating. NEPBIOS/ASPT Values were found slightly varying in different seasons in different sites. Human interference was frequently noticed at all the sites, which enhanced the degradation of natural resources including freshwater.

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1. INTRODUCTION

1.1 General Background

Ranking high in the scale of animal life is the largest of all phyla, is the Arthropoda. It represents a vast assemblage of segmented animals with a chitinous exoskeleton and jointed appendages such as crustaceans, centipedes, millepedes, insects, scorpions, spiders, and their allies. Of the Arthropoda, class Insecta is the largest. Insects are characterized by the presence of 3 pairs of legs. They are adapted to the both mode of life i.e, terrestrial and aquatic. Thus they are able to utilize the favourable facilities of both the environment.

Of the total animal species recorded globally, insect comprises at least 75%. The biogeographical diversity along with a rich floral diversity obviously offers favourable niches for insect diversity in the country. So here in our country there are as our country is of extreme geographical contrast and diversity is a very favourable area for investigating numerous scientific problems as it provides shelter for various lives.

Unspoiled head water streams are considered to be one of the most threatened habitats for aquatic life as insects, molluscs and fish, while small spring- fed streams are known to be unique habitats harboring a number of obligate species (Illies and Botosaneanu, 1963). Organisms of flowing streams continue to face ever increasing threats from land development including erosion and deposition, ecological disruption from small and large scale pesticide applications, and decreased flow due to water draw-down (SaintsOurs, 20004). Human land use affects running water ecosystem by altering or reducing the nutritional resources of small stream. Biological production in a stream is based on terrestrial sources of organic matter, mostly in the form of fallen leaves and branches. The composition of riparian vegetation, surrounding forest, and human constructions directly and indirectly affect water temeperature and flow, habitat structure, and the characteristics of organic matter in small streams

(Wallace and Merritt, 1980), which in turn affect benthic invertebrate assemblages (Lammert and Allen, 1999). Therefore, if a stream site is inhabited by organisms that can tolerate pollution and the more plloution sensitive organisms are of course missing for e.g., stonefly nymphs are very sensitive to most pollutants and cannot survive if a stream's dissolved oxygen falls below a certain level. If a biosurvey shows that no stoneflies are present in a stream that used to support them, a hypothesis might be that dissolved oxygen had fallen to a point that keeps stoneflies from reproducing or has killed them outright (USEPA, 1997).

The insects which need substrrate to attach as some Ephemeroptera (e.g. Heptageniidae), Plecoptera, Si*mulium*, etc. rarely present if the streams are devoid of substrates. Some beetles are present in aquatic vetgetation. Thus from above it can be said that the presence of aquatic insects depend on the abiotic environment of the river system as well.

Water provides shelter not only for invertebrates but also for vertebrates as frog, fish, raccoons, otter, and a variety of birds. Most people are familiar with these larger animals mentioned above but these animals aren't always around when you are. On the otherhand, you are almost guaranted to find aquatic insects in any stream you visit. These small creatures provide a window into the fascinating and complex world of an aquatic ecosystem. It's amazing to know that most of the insects flying around the air began their life under water. Infact, insects outnumber most other forms of aquatic life in an aquatic ecosystem. It's good thing because aquatic insects are an extremely important part of the food web. They are the main food for many larger animals including fish, forgs, and birds. If the streams or ponds are without aquatic insects then it is like desert for fish, frogs, etc. Some beetles and bugs act as scavengers in keeping the water fresh by removing the decayed leaves and other faecal materials. They are useful in increasing the oxygen percentage of ponds for dispersal of algae, fungi, and protozoans and also for the removal of harmful bacteria. Some like diving beetles (*Dytiscus* sp), larvae of whirligig beetle

(*Gyrinus* sp), naids of dragonfly, water boatman (*Notonecta* sp), water scorpion (*Nepa* sp), etc. are also harmful to us in being predators of fingerlings.

The macro- invertebrates (mainly insects) are found in almost every water body and reflect the effect to any kind of environmental perturbations in different types of aquatic ecosystem. All macroinvertebrates have their specific niche. Some are tolerant of water pollution (e.g. Culicidae C*hironomus*) where as others are very sensitive (e.g.Plecoptera) (Chessman 2003). So a specialist of Aquatic- biology can interpret the environmental condition of a water body from the type of macro - invertebrate present there.

High temperature is mostly favourable for the insects hence their diversity and abundance are more in summer than in winter. In summer the reproduction as well as other activities are at higher rate hence they are seen in large numbers but during winter all the activities are slowed and they do behave different than that of summer. They pupate, burrow or remain in other inactive stages hence are found in less number.

Truly aquatic insects are those that spend part of their life- cycle closely associated with water, either living beneath the surface or skimming along on top of the water as pond - skater. Aquatic insects can be found in the given taxonomic orders-Collembola, Diptera, Plecoptera, Ephemeroptera, Trichoptera, Odonata, Coleoptera, Hemiptera, Lepidoptera, Neuroptera and Orthoptera. Almost all the more important orders of insects are represented in the wet element. Only a few species spend their lives uninterruptedly in water. Some live out of water as pupae. But most pass through all their developmental stages in water and take to the air as adults. To the latter type belong those 4 orders - Ephemeroptera, Plecoptera, Trichoptera, and Odonata - that may be regarded as "the most genuine" aquatic insects since all of their members without exception are bound to the water. Among the other orders only a very few species or groups generally are water insects.

The insects inhabiting the water are well adapted to that mode of life. They are different from the terrestrial insects, as they inhabit different life. The body, leg, respiratory systems are all well adapted for inhabiting aquatic mode of life. Some dwell on the water surface, some on the bottom while few dwell both on surface as well as the bottom (e.g. Gyrinidae).

Aquatic insect orders that are used in the assessment of water quality and classification of river ecosystem are dealt individually with short description in the separate heading.

1.2. FRESHWATER INSECTS

1.2.1. Plecoptera

The order Plecoptera is also commonly known as Stoneflies. Stonefly nymphs are one of the most pollution sensitive aquatic fauna of freshwater bodies. They prefer specific water temperature, substrate type, and stream size.

In adaptation to swift- flowing waters, the nymphs mostly are flattened and resemble the nymphs of mayflies. But since oxygen uptake occurs predominantly through the skin and perhaps also through the rectum, gills frequently are lacking or are present only as rudimentary clusters at the base of the legs, occasionally at the front and back ends. Stonefly nymphs usually sit on or under stones crawling about and swim with undulating movements, assisted by their hairy legs. For their development they require one, two, or even as much as four years, with up to 33 molts. They are easily recognized with the two tails and the absence of abdominal gills.

Plecopteran nymphs inhabit the same or nearly similar habitat that of other freshwater pollution. They colonize in waters having different content of dissolved oxygen. This group is significantly very important for assessing the water quality (ENPHO, 1997).

1.2.2 Ephemeroptera

Mayfly nymphs are found in all types of freshwater habitats ranging from standing and running water bodies. They are easily recognized from all the other aquatic insects by the presence of tracheal gills on the abdomen, unpaird tarsal claws, an enlarged mesothorax, wing buds or pads more prominent in mature stage and presence of 2 (rarely) or 3 long slender tails (2 cerci and 1 caudal appendage) arising from the tenth abdominal segment.

Corresponding to their dissimilar living conditions the nymphs are categorized into four groups on the basis of their mode of living in particular habitat (Harmer and Mellanby, 1977).

1.2.2.1. Burrowing nymphs-

Some of them are adapted for burrowing. They live in tunnels made in sandy mud near the edge of streams and small rivers. They feed on organic matter. e.g., *Ephemera* sp

1.2.2.2. Flat bodied nymphs

Very flattened types develop in rapidly flowing water; their body and legs are broad and compressed, the separate parts pieced together like the plates of a knight's armor. By means of their almostr knife- sharp contours and the frequent trailing fringes of bristles, these insects are enabled practically to weld themselves to the rocks to which they cling. The violent current finds no surfaces to seize upon, and instead washing of the body away presses it more forcefully against the substratum e.g., *Epeorus* sp.

1.2.2.3. Swimming nymphs

Swimming nymphs are all small with more or less cylindrical spinde-shaped bodies and delicate legs. The nymphs are often found in small streams and marshes clinging among plants. e.g. *Baetis* sp.

1.2.2.4Creeping nymphs

Hairy species creep through the mud. They neither swim nor burrow much but just move slowly along on the surface. They live in mud, water plants or algal threads in still water and few are found creeping on the muddy bottom of river or streambeds.

Ephmeropteran nymphs are pollution sensitive organisms but few are tolerant to some sort of plloution and densely survive in water bodies. They are found colonized >4 mg\L. dissolved oxygen content water. The diversity varies accordingly depending upon water temperature and water discharge (ENPHO, 1997).

1.2.3. Trichoptera

Wading in a brook, we may have seen tiny houses, artistically put together from pebbles or all sorts of rubbish, on the bottom of the stream. The larva with in the case is caterpillarlike and with the six tiny legs that pulled their houses along after it. It is the larvae of Trichoptera. Cadddisflies larvae occur in most of all types of freshwater habitats; spring, streams and seepage areas, rivers, lakes, marshes and temporary pools. Case making larvae are enble to exploit more oxygen from water and thereby can survive longer at low oxygen levels.

The larvae on hatching often make some kind of portable protective cases, fixed net like retreats or simply lay down a ground line of silk. They make the cases by spinning a tube, open at both ends, from a silken thread that flows from the mouth and that is manipulated with the help of special adapted forelegs. Most species disguise the outside of the cases, into which they is anchored with two hooks on the posterior end, with all kind of materials found in the water. For instance, they use minerals such as grains of sands and pebbles, all possible parts of plants, bits of wood, or animal matter as snail shells and the shells of little bivalves by means of sticky silk these things are mounted on the tube lengthwise, crosswise, or spirally. The cases are of varied shapes, according to the type of case and their mode of living they are catagorized into following types-

1.2.3.1 Freeliving

Some caddisflies larvae don't construct a retreat or case of any kind until just before pupation. At the time of pupation a cell of rock fragments is fastened to some large rock substrate. Larvae are active and found in cold, running water; especially abundant in mountain streams. e.g. Rhycophilidae.

1.2.3.2 Purse-case makers

These are the micro caddisflies, and hence are extremely small (not more than 5mm in length). The first four instars build no case, and have long, curved anal claws. The final instar-larvae construct purse shaped or barrrel shaped cases that are portable in most genera. e.g. Hydroptilidae.

1.2.3.3 Retreat makers

Larvae of this group are sedentary and construct fixed retreats often with capture nets to restrain food particles from the water current. Different types of retreat makers are:

- Philopotamid larvae construct silken tunnels chiefly under stones. They usually inhabit in rapid water, and are confined to hilly or mountainous terrain.
- Psychomyid larvae build retreats such as like tunnels on aquatic plants or burrow into sandy streambeds.

Hydropsychid larvae are abundantly found in rivers and streams with moderate current. Larvae live in retreats connecting with a net spun in the current.

1.2.3.4 Saddle-case makers

Larvae of this family construct a stone case shaped like a tortiose shell and having a stone bridge across the center of the ventral opening. For pupation this bridge is removed and the case is cemented to a rock. All species are denizens of cold running water, chiefly confined to springs or semipermanent streams. e.g. Glossomatidae.

1.2.3.5 Tube-case makers

Larvae construct portable cases, essentially tubular in form of various shapes and materials. Certain genera make cases of particular shape and texture. Pupation occurs with in the case of particular shape and texture. Pupation occurs with in case. e. g. Lepisostomatidae.

Trichopteran larvae are generally intolerant of organic pollution. They are thus can be considered to tbe pollution sensitive organisms but hydropsychid larvae are quite tolerant to pollution to some extent.

1.2.4 Odonata

The dragonflies and damselflies are one of the oldest groups in the animal kingdom; they are incomparably older than man. Their typical form, completed in primeval time, seems inalterable. The dragonflies and damselflies comprise the order odonata, which we divide into following 3 suborders-

- Anisozygoptera is an especially old group, a remnant of which survives only in a single living Japanese species.
- Zygoptera are damselflies.
- Anisoptera are dragonflies.

The larvae are predaceous and prey upon mosquito larvae, other dipteran larvae, tadpoles and some even prey upon small fish. They are inactive and clumsy but this defect is overcome by the structure and color of the naids resembling to their environment. Thus they are mostly overlooked.

The odonata are currently sparking great public and scientific interest, and are a useful group in biological assesments for conservation planning. Because of their habitat specificity, their role as top invertebrate predators, and their conspicuous nature along with a practical number of species those are well known to science. These colorful and charismatic insects work well as both "indicator" and "flagship" organisms (Corbet, 1999; Samways, 1993) to enhance public awareness of the links between land use, water supplies, and biodiversity (Primack *et. al.,* 2000).

Odonata naids aren't considered as very sensitive group though few are tolerant to organic pollution and able to survive to low dissolve oxygen content of river stretches (ENPHO, 1997).

1.2.5 Diptera

Adult dipterans are never truly aquatic, however, all the 3 suborders of Diptera (Nematocera, Brachycera and Cyclorrhapha) consist of aquatic larval forms. The larval stages have become adapted to freshwater and semi-aquatic habitats. Significant number of species can be found abundant near aquatic habitats. The adult females of Simuliidae, Deuterophlebiidae and few others may crawl into the water to lay eggs.

The Nematoceran aquatic larvae have a well- developed head with antennae and biting mandibles. The pupa is free and active. The principal families with aquatic species are the craneflies (Tipulidae), the mothflies (Culicidae), the midges (Chironomidae) and the blackflies (Simuliidae).

The Brachyceran larvae have an incomplete head which generally retractable into the first thoracic segment. The major families with some aquatic species are Stratiomyidae and Tabanidae.

The Cyclorrhaphan larvae have a vestigial head and the pupa enclosed by the last larval skin and is immobile. The chief families with aquatic species are Syrphidae and Antomyidae.

Aquatic dipteran larvae play significant roles in biomonitoring of water - quality, conservation biology and in scientific research on the structure and function of aquatic ecosystems.

1.2.6 Coleoptera

Beetles are enormous group of insects containing a few families, which are entirely aquatic, and also some aquatic genera among families of primarily land dwelling species. Two of the three suborders of Coleoptera (Adephaga, Polyphaga, and Myxophaga) include water beetles (a) The families Haliplidae, Dytiscidae, Noteridae and Gyrinidae, etc. belong to the subnorder Adephaga, (b) while Hydrophilidae, Psephenidae, Limnichidae, Chrysomelidae, Dryopidae and Elmiidae, etc. belong to the suborder Polyphaga.

Beetles show many gradations from land insects that like moist conditions to the most highly perfected water insects. In the boundary zones between land and water, in wet sand that at times is inundated, in mud or moss of pools, brooks, lakes and seas, underneath stones washed by the water, or on plants sticking out of the water, there is abundant beetle life.

This group of insects is tolerable to some extent of pollution. They are generally absent at high current velocity (Hynes, 1970).

1.2.7 Hemiptera

Water bugs inhabit both surface as well as under water. Waterstrider (Gerridae) are surface dweller. They are adapted to the surface by a dense feltwork of oily hairs, which cause their legs to remain dry and also the claw isn't terminal so the breaking of water surface tension is avoided. The body of the water strider is always dry, too, thanks to an oily, silvery coating of hairs, for if it got wet these insects would be drawn.

Notonectidae (backswimmers), Corixidae (water boatman), Belostomatidae (giant water bugs), and Nepidae are the aquatic bugs.

Though bugs are intolerant to pollution, the air breathing families of Heteroptera (Gerridae and Vellidae) are the most indulgent to pollution than other non-air breathing forms.

1.2.8 Neuroptera

A small minority of nerve- winged insects (Neuroptera) lives in the water, but only during larval stage. These include the families Sialidae (alderflies), Corydalidae (dobsonflies) and Sisyridae (spongillaflies).

- The larvae of alderflies are predators that dismember their prey with their sharp jaws.
- The dobsonflies larvae size is extraordinary (usually more than an inch long) and quixotically shaped head render them especially striking insects. The larvae creep about as voracious predators for 2 to 3 years, and are able to swim backward as well as forward.
- Spongillaflies larvae possess series of abdominal gills. They hunt out freshwater sponges, no doubt homing on the gentle currents that emanate from them, and suck on them with two long, slender, independently movable oral tubes.

Corydalid larvae are found sensitive to water quality but they aren't considered as significant as other indicator organisms.

1.2.9 Lepidoptera

Lepidoptera are primarily terrestrial. There are only very few moths whose larvae live in water. The larvae cheifly reside on water plants. Few species are found under water larvae normally shelter themselves by making a case out of bitten off pieces of the leaves which are portable in some instances.

1.3 Biological Assessment

Chemical, physical and biological stressors impact the biological characteristics of an aquatic ecosystem (Gibson *et.al*. 1996). For example, chemical stressors can result in impaired functioning or loss of a sensitive species and a change in community structure. Ultimately, the number and intensity of all stressors with in an ecosystem will be evidenced by a change in the condition and function of the biotic community. The interactions among chemical, physical, and biological stressors and their cumulative impacts emphasize the need to directly detect and assess the biota as indicators of actual water resource impairments.

Bio-assessments allow measuring the aggregate impact of the stressors. Biological monitoring is based on the study of biological organisms and their responses to determine environmental conditions (USEPA, 20002). It involves collecting, processing and analyzing aquatic organisms to determine the health of the biotic community in a stream (USEPA, 1997). Biotic community chiefly includes periphyton, benthic invertebrates and fish.

Use of ambient biological communities, assemblages and populations to protect, manage and even exploit water resources have been developing for the past 150 years (Davis, 1995). This method of evaluating water quality has been started more than a century ago with Kolenati (1848), Hassal (1850), Cohn (1853) who observed quite different organisms in polluted water than that found in clean water. In Nepal, Sharma (1996) studied on the biological assessment of water quality of major river systems; Saptakoshi, Karnali, Mahakali including Bagmati, Tinau, Rapati and Babai.This study deals with stream biomonitoring with the help of insects present in the Godavari rivulets. Saprobic, diversity and biotic (Sharma, 1996) are the approaches for biological assessment of water quality.

1.3.1 Biotic Approach

According to Tolkamp (1985), the biotic approach to biological assessment is one, which combines diversity on the basis of certain taxonomic groups with the pollution indication of individual species or higher taxa or groups into a single index or score. There have been developed numerous biotic indices methods but few are described below-

1.3.1.1 Extended Biotic Index (E.B.I.)

This Extended Biotic Index has been developed by the biologists of the Trent River Board in the 1950 as Trent biotic index. This was later modified by Woodwiss in 1964. The biotic index value increases from 0 to 15 for the quality of water ranging from highly polluted to clean water. This value (0 to 15) is based on the known tolerance of specific indicator invertebrate taxa weighted by the number of defined groups present. It has been used sucessully in the United Kingdom, Canada, South Africa and France approaches has come in use hence it isn't so practicable now-a-days.

1.3.1.2 Chandler Biotic Index (Chandler, 1970)

This is modification of the above i.e., E.B.I. The benthic invertebrates are collected according to the standard procedure, identified and counted. Each group is given a score depending on its abundance. The higher the score the cleaner is the water.

1.3.1.3 Biological Monitoring Working Party (BMWP) (Hellawell, 1986; Abell, 1989).

It is a standard method and used in various countries. Here the collected invertebrates need to be identified upto family level. The score or value in this approach ranges from 0-10, which is based on the sensitivity to pollution of the invertebrates (1-tolerant, 10- very sensitive).

1.3.1.4 Nepalese Biotic Score/Average Score Per Taxa-NEPBIOS/ASPT (Sharma, 2000).

Nepalese Biotic Score is again a modified form of Biological Monitoring Working Party system especially claculated for Nepalese families of macro-invertebrates so far identified. The scoring ranges from 1-10 based on the sensitivity of the collected macro-invertebrates to the pollution (1- very tolerant, 10- very sensitive).

NEPBIOS values are obtained from the original NEPBIOS list. Once NEPBIOS/ASPT values are calculated the tables given below describes the quality of water from where the macro-invertebrates were collected.

Table1:Transformation of NEPBIOS/ASPT values to water quality classes.

NEPBIOS /ASPT value obtained	Water quality classes
8.00-10.00	I
7.00-7.99	I-II
5.50-6.99	II
4.00-5.49	II-III
2.50-3.99	III
1.01-2.49	III-IV
1.00	IV

Table 2: Description of water quality classes and uses recommended

Water quality classes	Description	Uses
I	Excellent	Recommended for drinking
II	Good	Drinking possible after treatment
III	Moderate	Hazardous
IV	Poor	Unsuited for any human use.

(Source: Sharma, 2000)

Recently, NEPBIOS has been modified and introduced as GRS_BIOS (Ganga River System Biotic Score-unpublished data).

1.4. Rationale of the Study

Water is very important for living things (plants and animal). Godavari is centre of attraction of Kathmandu. Many people visit it for different purposes as for research, study, recreation, etc. There are present many rivulets and most of the rivulets are used by local people as well as visitors for different purposes as washing clothes, utensils, washing face and hands. It's important to let all know the health of these rivulets as well as the importance of aquatic ecosystem.

By collecting and analyzing the macro-invertebrates of the rivulets we can know it's health and thus we can let others know the condition of the rivulets around them which they are using and role of aquatic ecosystem. Aquatic macro-invertebrates are trustful indicators of stream quality and extensively used as bio-monitoring tool.

1.5 Objectives

The main objectives of the study are to:

- explore aquatic insect fauna in Godavari rivulets
- compare insect diversity at various sites
- use of aquatic insects in biological assessment of the river health.

1.6 Limitations

The limitations during this work are as below-

(a) Time was limited

(b) Work was limited to only insects and non-insect fauna were neglected

(c) Lack of sufficient taxonomic knowledge on Nepalese aquatic fauna and difficult to assess scattered information.

(d) Only species level identification of the fauna can give an exact interpretation regarding the environmental stresses, but it was not possible due to time and resource constraints.

(e) Due to lack of equipments the insects of all the habitat can't be collected

(f) No single group of organism can be used to assess aspects of water quality. Thus when using biological approaches for water quality assessment, a combination of entire adequate organisms can give a more accurate assessment result.

1.7 Study Area

It is situated in Lalitpur district of Bagmati Zone, which is located 16km South-East of Kathmandu city and 10km from Satdobato Lalitpur. Godawari will lies at 85°23'E to 85º27' longitude and 27º33'N to 27º37'N latitudes. It is characterized by typical monsoon type of climate with rainy summer and dry winter. Mean annual precipitation is 115.3mm which is 42% higher as compared to Kathmandu (108.5mm). Eventhough few spells of rainfall occurs also in winter over 80% of total annual precipitation is encountered during monsoon. Annual means of maximum temperature is 27.9ºC (in June) and minimum is 3.4ºC (in January and December) during the study period (i.e, 2005). Likewise, maximum and minimum rainfall recprded are 381.5mm in August and 0 in November to March respectively during the study period. Annual means of minimum and maximum temperature recorded at Fishery Department Godawari are 13ºC and 26ºC respectively. Day temperature in summer (March-May) often rise upto 30ºC and drops down to 20ºC at night and 18ºC to -5ºC during winter (Dec-Feb). Sometimes frost occurs in winter but snowfall is very rare. Soil is of temperate rainforest type with marked acidity, low mineral nutrients and relatively low content of organic matter and slit loam, soil pH ranges from 5.98 to 6.35.

The deviation in rainfall from that of Kathmandu could be attributed to the favourable arrangement of the folds of Phulchowki mountain for bringing more precipitation down to Godawari valley. Godawari valley is more humid and coller than Kathmandu. Two perennial sources of water, Naudhara and Godawarikund probably have underground sources of water which get muddy in monsoon due to flood water. Besides, these 2 sources of different water there are perennial rivulets scattering here and there in Godawari valley. Two good sources of stagnant water namely Godawari kund pond and Shripech pokhari inside the Botanical garden are good sites for the Breeding of dragonflies. The green forest of Phulchowki and other surrounding the valley are probably the good sources of water in the valley.

Because of well protection of the place by local people and governments little effort, it is the good source of insect diversity. Due to suitable temperature, altitude and other suitable environment, Godawari is the best place for variety of insects inhabiting water as well as terrestrial.

2. LITERATURE REVIEW

2.1 Review of Taxonomic Studies of Aquatic Insects

Though the study began on the freshwater life before the days of Aristotle (384 B.C), but the presence of microorganisms in fresh water was noticed for the first time by Anton Ven Leeuwenhock 1632-1723(Welch 1952). The first limnological investigations were carried out in high mountain lakes of Khumbu Himal (Mt. Everest region) in 1964, Loffler (1969). A series of UNDP and HMG contributed a project on the limnological study of Lake Phewa. W. Ferrow handled the project Mc. Donald (1976) made a short observation of aquatic insect along the foothills in Central Nepal and Everest/Khumbu region. He recorded seven orders of aquatic insects from different heights ranging from 3000ft to 14000ft. The earliest contributions for insects from Nepal are as described by Hope in "Synopsis of Nepal Insects" published in 1831 (Atkinson, 1980).

Takgawadyl and Namikawa (1952-53) compiled the insect fauna of Nepal Himalayas containing a number of species from different parts of Nepal. Atkinson (1882) made a comprehensive study in the form of 'Fauna of Himalayas' (NorthWest Punjab and Mt. Makalu, Nepal).

Mishra (1975) presented a paper on 'Fauna of Nepal' including aquatic insects at Natural Science Seminar, organized by T.U.Malla *et. al.*(1978) carried out the taxonomic studies on aquatic insects of Kathmandu valley. Altogether 61 species of insects were collected from various water bodies in Kathmandu valley; of these 37 are new generic and specific records from Nepal. Jha (1980) studied on macro-invertebrates of Godavari Khola.Yadav *et.al.* (1980) studied on macro-invertebrates in 3 ponds of Kathmandu valley and the benthic fauna of Ranipokhari in 1981. Yadav and Rajbhandari (1982) studied on the benthic macrofauna of Bansbari khola and Dhobi Khola (tributaries of the Bagmati River) in Kathmandu valley. The major groups of bottom fauna reported were Tubifera, Tipulidae, Dolichopidae and Chironomidae. Yadav *et.al.* (1980) while studied on the macro-fauna of Godavari khola (tributary of Manohara river) reported 25 taxa of macrofauna of which Oligochaetes and Molluscs were the dominant groups. Basnet (1980), Mehata (1980), Yadav *et.al.* (1983a) and Yadav (1983b) studied the macro-invertebrates of Godavari fish ponds. Yadav (1987) reported 21 taxa of aquatic insects of Palung Khola. Yadav (1994) reported 50 taxa of aquatic insects from feeding streams of the Kulekhani Reservoir.

2.1.1 Plecoptera

Atkinson (1882) described stoneflies of Bangladesh, India and SouthEast Asia.

Stanley (1975) worked on the stoneflies of NorthWest Himalayas in India and Mount Makalu in Nepal Himalaya. Harper (1974) described the stoneflies of the genus *Protonemoura* (Nemouridae) collected in 1967 by Canadian Nepal Expedition. In 1976, he described four new species. *Acroneuria (s.l.) personata*, *Kamimuria senticosa*, *K crocea*, *K himalayana*, collected in Central Nepal by Dr. T. Kumata, a member of the Hokkaido University Biological Expedition of 1968. His significant work on reporting new finding in the field of Plecoptera diversity was continued and in 1977, eleven species of stoneflies belonging the families Capniidae, Leuctridae and Perlidae were recorded from Nepal. Several papers of Zwick (1977), Zwick and Sivec (1980) have added significantly to the knowledge and distribution of Himalayas stoneflies. Sivec (1981) recorded 30 species of Taeniopterygidae, Capniidae, Leuctridae, Nemouridae, Peltoperlidae, Perlodidae and Perlidae collected in Central Nepal during II Yugoslav Entomological Expedition to Nepal. Malla *et.al*. (1978) recorded 5 species from Kathmandu valley viz; *Brachypetera* sp., *Taeniopteryx* sp., *Peltoperla* sp., *Paragnetina* sp. and *Neoperla* sp.

2.1.2 Ephemeroptera

Baetidae, Caenidae, Heptageniidae, Ephemerellidae, Leptophlebidae, etc. are some of the described families.

Dubey (1971) studied the mayflies of Nepal. He described *Ephemera pramodi* of the family Ephemeridae from NorthWest Himalayas. Ueno (1952-53) described 24 nymphs belonging to 6 genera and 3 families of mayflies collected during the Japanese Himalayan Expedition in 1952. Allen and Edmunds (1963) and Allen (1971, 1973) contributed by reporting some Ephemerellidae from Nepal. Braasch (1980-1984) and Braasch and Soldan (1987) described Heptageniidae and partly Baetidae from Nepal. Malla *et.al*. (1978) described *Apobaetis* sp., *Baetis* sp., *Caenis* sp., *Ephemerella* sp., *Epeorus* sp., and *Habrephlebhia* sp. from Godavari, Kirtipur and Sundarijal.

1.2.3 Trichoptera

Kimmins (1964) has reported 28 species of Trichoptera from Nepal in "Trichoptera from Nepal" publication. Wiggins and Peterson (1969) reported the caddisflies of the family Limnocentropodidae. Botosaneanu (1976) described the species of the families Limnocentropidae, Limnephilidae, Rycophilidae, Hydropsychidae, Stenopsychidae, Glossomatidae, Helicopsychidae, etc. Ito (1986) described three Lepidostomatid caddisflies from Nepal. Malicky (1933a, 1993b, and 1995) described some species of Goeridae, Philopotamidae, Psychomyidae, Ecnomidae, Hydropsychidae, Leptoceridae collected from different regions of Nepal. Malla et.al (1978) recorded *Leptocerus* sp. (Leptoceridae) and *Psychomyia* sp. (Psychomyiidae) from Jawalakhel (military pond) and Sundarijal respectively.

2.1.4 Odonata

Despite hemimetabolous insects, in odonata the immature stages (called naids) and the adults don't resemble with one another.

Workers like Laidlaw (1917, 1920) and Fraser (1919b) initiated studies on the naids of odonata. Sagal and Kumar (1970a, b) and Kumar (1973a, b) published descriptions of the last instar naids and notes on biology of many species from Dehra Dun Valley, Uttar Pradesh. Kumar himself or jointly with coworkers has published on the naids of 46 species. Kumar and Khanna (1983) reviewed the subject and listed 102 species of which the naids were known. Of these 10 were identified only to genus level, another 10 were unpublished records and 6 species were from Myanmar and Srilanka.

Dragonflies described by Selys (1854) are the earliest records from Nepal as published in Fauna of British India series. A number of odonata from Nepal were recorded in Fraser's work "The Odonata in the Fauna of British Indian (3 volumes, 1933-36).

Ashqhina (1952) studied 100 specimens of dragonfly naids belonging to 20 species from Nepal Himalayas. He in 1963 made a good comparative study of the odonata of Nepal and India collected by Yamada in 1961. In 1964, he studied the odonata collections made by Chiba University, Rowaling Himal Expedition in 1963. In 1964, he studied more Nepalese odonata collected by Botanical Expedition of Tokyo University in 1964. Quentin (1970) studied the odonata of Khumbu Himal in Nepal. Kiuta (1972) remarked the so-called new or little known dragonfly *Macromia moorie* from Nepal. Smith (1978a, 1978b, and 1981) recorded new species from Nepal in the families Calopterygoidae and Gomphidae. A list of 64 taxa was recorded by Kumar and Prasad (1981) from Nepal. Shrestha and Mahato (1984) and Mahato (1985, 1986a, 1986b, 1986c, 1987a, 1987b, 1987c, 1988) have a significant contributions for adding special knowledge about and distribution of dragonflies of Nepal. Vick (1989) produced a list of dragonflies including 172 species with a summary of their altitudinal distribution recorded from Nepal. Mallle *et.al*. (1978) recorded

Octogomphus sp., *Progomphus* sp., *Orthemis ferruginea*, *Pseudoleon* recorded *Anax* sp., *Somatochlora* sp., *Sympetrum* sp., *Macromia* sp. from Kathmandu valley.

2.1.5 Coleoptera

Ochs and Chui (1965) studied the Gyrinidae of East Nepal.Vazirani (1968) has crucial contributions to the study of aquatic beetles chiefly the subfamilies Noterinae, Laccophilinae, Dytiscinae and Hydroporinae of Indian sub-continent. Study of Dryopidae from Nepal has been made by Sato (1979). Malla *et.al.* (1978) recorded *Amphizoa* sp., *Haemonia* sp., *Cybister convexus, Laccophilus rufulus, Megadytes* sp., *Thermonectus* sp., *Gyretes* sp., *Brychi*us sp., *Hydrophilus* sp. from Kathmandu valley.

2.1.6 Hemiptera

Miamoto (1965) explained some taxa of aquatic bugs collected by Chiba University, Rolwaling Himal Expedition in 1963. Most of the researchers who have made the study of benthic fauna, reported some species of aquatic bugs as *Corixa* sp., *Plea* sp., *Notonecta* sp., etc. Malla *et al*. (1978) recorde *Corixa apparens, corixa substriata*, *Macrocorisa geo*, *Micronecta lineata*, *Gerris nepalensis*, *Gerris monticola*, Chimarrhometra orientalis, *Fabatus servus*, *Metrocoris compar*, *Metrocoris illustranius*, *Laccotrephus rubur*, *Enithares paivana*, *Enithares Marginata*, *Anisops niveus* and *Plea frontalis* from Kathmandu valley.

2.1.7 Diptera

Family Syrphidae has been described in COE (1964). Shrestha (1965) studied the Anopheles of Nepal in relation to malaria eradication. Reiss (1968) and Roback and Coffman (1987) described Chironomidae from Nepal. Alexander (1971) described eight new species of Tipulidae from Kumaon and Assam. Yadav and Shrestha (1982) recorded 11 genera of freshwater chironomid larvae collected from different lakes, ponds and rivers of Nepal.Of the 11 genera recorded, 3 species, *Tanytarsus* sp., *Chironomus* sp., and *Polypedilum* sp. were found in both lentic and lotic habitats whereas 4 species, *Tanytarsus* (*Microsepta)* sp., *Endochironomus* sp., *Cardiocladius* sp., and *Orthocladius* sp.were restricted only in the lotic environment and the other 4 species *Pentaneura* sp., *Procladius* sp., and *Stictochironomus* sp. and *Dicrotendipes* sp. only in lentic environment . Malla *et.al*. (1978) recorded *Tendes* sp., *Aedes* sp., *Anopheles* sp., *Culex* sp., *Pericoma* sp., *Tipula* sp., *Atherix* sp. from Kathmandu valley.

2.2 Reviews for Assessment of Water Quality

The biological indicators of the Bagmati River studied by Shrestha (1980) and stated that the pollution was less in the upstream and downstream rural areas but the pollution was maximum in the town sections. Yadav and Rajbhandari (1982) studied on the benthic macrofauna of Bansbari Khola and Dhobi Khola. Upadhyaya and Roy (1982) reported Manohara River to be less poluted than Dhobi Khola, Bishnumati River and the Bagmati River. Timilsina (1982) carried out an investigation regarding the impact of Bansbari tannery effluent in Bansbari Khola and Dhobi Khola.

RONAST (Now NAST) has been frequently monitoring the pollution level in Bamati River and its influence on the aquatic biodiversity since 1987. The microbiological study was undertaken to determine the quality of drinking water in Kathmandu by Sharma (1987) and CEDA (1989). Bottine *et.al*. (1988) studied the Bagmati River in Kathmandu valley and found Pashupatinath slightly polluted, Chobar polluted and Dhobi khola, Bishnumati River are almost extremely polluted. Pradhananga *et.al.* (1988) studied the water quality of the Bagmati River in Pashupati area and reported that Pashupati area was less polluted as most of the parameters didn't exceed the permissible value for its use as a water supply for fishery and industries. Vaidya *et.al*. (1989) reported biological, physical and chemical water quality of Pashupati Development Area in Bagmati River as moderately polluted.

Koirala (1990), Prasad (1995) and Bashyal (1999) carried out investigations on both physico-chemical and biological parameters. Sharma (2000) proposed an inexpensive, convenient and effective biological assessment method for Nepalese Rivers, Nepalese Biotic Score (NEPBIOS).

3. METHODOLOGY

3.1 Site Selection

Five sampling sites were selectd for the collection of aquatic insects. The sampling sites were chiefly designed to include various types of habitats so that the insects in different habitats were included. Types of habitats are-

(a) Riffles- areas of flowing water constituting stones of different sizes.

(b) A clove or still water area along the river margin where vegetations are trailing into the water.

(c) Alagal cover, detritus cover, and submerged sticks are also included.

The overall aim of a site selection for sampling a number of habitats is to capture the broadest range of biota as far as possible.

3.2 Sampling Frequency

The sampling sites were visited from Asardh (2062) to Jyestha (2063) for the collection of aquatic insects. The insects were collected once a month from each selected sampling site.

3.3 Materials Used

The materials used during the work were - plankton net, forcep, dropper, vials, 70% alcohol, brush and white-enameled tray.

3.4 Methods Used.

3.4.1 Kicking and sampling method-

Here in this method, the net was fixed to some distance (1m) and than the water was disturbed from above. Thus the disturbed water was collected in the net. The content of the net was then emptied to the tray.

3.4.2 Stone Lifting.

The stones from the bank or margins of the rivulets were lifted and washed in the tray so that the insects attached there were obtained in the tray. Most insects were easily washed by water so as to collect in the tray but some insects were very much strongly attached to the stones and were difficult to wash with the water. For these insects they were made active by touching them with brush dipped in alcohol and thus they were easily washed later. e.g. Psephenidae larvae, *Epeorus* sp.

3.5 Identification and Preservation

The collected samples were brought in the entomology laboratory and were observed with the help of binocular and compound microscope with the magnification power ranging from 10X to 50X using keys for their identification. The keys used were from Ward and Whipple, 1996; A Manual by Morse, Lianfang and Lixin (1994); Needham and Needham; A Revised key to the British Water-bugs by T.T.Macan; A key to the Adults and Nymphs of the British Stoneflies by H.B.N.Hynes; A key to the British Ephemeroptera by T.T. Macan. After the insects were identified upto family/generic levels, a key was prepared for them.

All the identified samples were preserved in 70% alcohol and kept in separate vials. The vials were labelled with specific name, place, and date of collection.

3.6 Photography

Photographs of the collected and identified specimens were taken using binocular and compound microscopes holding camera (Canon Power Shot A520 digital camera, with lens aperture F/3.2 and focal length 8mm) lens above the eyepiece of the microscope. A magnification of 4X to 50X was used to take the photographs. Larger specimens were photographed in lower magnification while smaller specimens and taxonomically minute structures were taken in higher magnification.

3.7 Statistical Analysis

3.7.1. Species Diversity

Insect species diversity in different sites were calculated using Shannon Index of General Diversity ($\overline{H}$). $\overline{H}$ = -Σsummation (ni/N) log (ni/N). Where ni =importance value for each species.

N= total of importance values.

3.7.2 Evenness Index (e)

e= $\overline{H}$ /logS   where S= number of species

3.7.3 Calculation of NEPBIOS/ASPT

Nepalese Biotic Score of each of the identified individual taxon were allocated using NEPBIOS list. The score was allocated according to the sensitivity of the insects ranging from 1 to 10 where 1 denotes to the highly tolerating insects to pollution while 10 denotes to the highly sensitive insects. All these scores were summed up and this value was divided bythe number of scoring taxa. Then the obtained value was used to find the water quality class of the rivulets with the help of transformation table (Table 1).

4. RESULTS

4.1 Aquatic Insects of Godavari Rivulets.

From the selected five sites of Godavari a total of 47 aquatic insects taxa were collected belonging to 9 orders, 40 families, and 33 genera.

Table3: Identified Aquatic Insects of Godavari Rivulets.

Aquatic insects	**Sites**				
Order/Family/Genus	I	II	III	IV	V
PLECOPTERA					
Family-Nemouridae					
Amphinemura sp.	++++	+	+	+	+
Nemoura sp.	+	+	-	-	-
Family-Leuctridae					

Leuctra sp.	+	-	-	-	+
Family-Perlidae					
Calineura sp.	-	+	-	-	++
EPHEMEROPTERA					
Family-Baetidae					
Baetis sp.	+++++	+++	++++	+++++	+++
Family-Caenidae					
Caenis sp.	++	+	++++	+++	+
Family-Ephemerellidae					
Ephemerella sp.	++	+	++	++	++
Family-Ephemeridae					
Ephemera sp.	-	-	-	-	+
Family-Heptageniidae					
Heptagenia sp.	+++	+++	++	++	++
Epeorus sp.	+++	-	+	+	+
TRICHOPTERA					
Family-Calamoceratidae					
Anisocentropus. sp	+	+	-	-	+
Family-Glossomatidae	+	-	-	-	-
Family-Hydropsychidae					
Hydropsyche sp.	++++	+++++	++	+	++++
Family-Lepidostomatidae					
Lepidostoma sp.	+++	+++	++	++	+++++
Family-Leptoceridae	-	-	+	-	-
Family-Phryganeidae	-	-	-	+	-
DIPTERA					
Family-Tipulidae					
Tipula sp.	+++	+	+	++	+
Family-Athericidae					
Atherix sp.	++	++	+	+	+
Family-Chironomidae					
Chironomus sp.	++	+++	+++++	+++++	+
Family-Culicidae					
Culex sp.	+	-	-	+	+
Family-Simuliidae					
Simuliium sp.	+++	+++	+++	++++	+++++
Family-Tabanidae					
Tabanus sp.	+	-	+	+	++
Family-Syrphidae					

Chrysogaster sp.	-	-	-	+	-
SUBORDER-ZYGOPTERA					
Family-Euphaedae	-	-	+	-	+
Family-Amphiterigydae	-	-	-	-	+
Family-Chlorocyphidae	+	-	-	-	-
SUBORDER-ANISOPTERA					
Family- Aeshnidae					
Anax sp.	+	-	-	-	+
Aeschnophlebia sp.	-	-	-	-	+
Family-Lebullelidae					
Somatochlora sp.	-	-	-	-	+
Family-Macromiidae					
Macromia sp.	-	-	-	-	+
Family-Corduliidae					
Somatochiora sp.	-	+	-	-	-
Family-Cordulegasteridae					
Anotogaster sp.	-	-	-	-	+
Chlorogomphus sp.	-	-	-	-	+
Family-Gomphidae					
Heliogomphus sp.	-	-	-	-	+
Leptogomphus sp	-	+	+	-	-
Stictogomphus sp.	+	-	-	-	-
Gasterogomphus sp.	+	-	-	-	-
COLEOPTERA					
Elmiidae*	+	-	+	-	++++
Gyrinidae	+	-	-	+	-
Dytiscidae	-	-	+	-	-
Psephenidae	-	-	+	-	-
Noteridae	-	-	-	-	+
HEMIPTERA					
Family-Gerridae*	++	-	-	-	++
Family-Nepidae *Nepa* sp.	-	-	-	-	+

Mesovellidae	-	-	-	+	-
ORTHOPTERA	+	-	-	-	+
NEUROPTERA					
Family-Corydalidae *Corydalus* sp.	-	++	+	++	++

+=0 to 10, ++=11 to 30, +++=31 to 60, ++++=61 to 100, +++++=above 100

*indicates the insects taxa which were found as adult as well as larvae.

Altogether four species of stoneflies were identified upto generic level. These four species belong to 3 families viz; Nemouridae, Leuctridae and Perlidae. Four identified species were *Amphinemura* sp., *Nemoura* sp., *Leuctra* sp., and *Calineura* sp. Among these 4 species, *Amphinemura* sp. was recorded from all the 5 sites but it was most abundant in site I in comprarison to other sites In remaining 4 sites they were recorded to be evenly distributed. *Nemoura* sp. was recorded only from the site I and site II with even distribution and weren't recorded in remaining sites. Likewise, *Leuctra* sp was recorded from site I and site V with similar abundance. *Calineura* sp. was also recorded from only site II and site V and abundance was greater in site V.

6 species of Ephemeroptera were identified belonging to 5 families viz; Baetidae, Caenidae, Ephemerellidae, Ephemeridae and Heptageniidae. Of the recorded species of Ephemeroptera Baetis sp. was recorded from all the 5 sites with more or less even distribution. They were obtained bountiful from all the sites. *Caenis* sp. was also found in all the sites which was most abundant in site III and then followed by site IV, site I, and site V and site II.Similarly, *Ephemerella* sp. was recorded from all the sites with more or less even distribution. *Ephemera* sp. was recorded only in site V in rainy season. Likewise, *Heptagenia* sp. was also recorded from all the sites with similar distribution in site I and site II and again similar distribution in the remaining sites. *Epeorus* sp. was recorded from all the sites except site II.

Altogether 6 species of Trichoptera were recorded belonging to 6 families viz; Calamoceratidae, Glossomatidae, Hydropsychidae, Lepidostomatidae, Leptoceridae, and Phryganeidae. Leptoceridae and Phryganeidae were limited upto family level while others were identified upto genus level. *Hydropsyche* sp and *Lepidostoma* sp. were collected bountiful in all the sites except III and IV where their abundance was less.

Overall 7 species of Diptera were recorded belonging to 7 families viz; Tipulidae, Athericidae, Chironomidae, Culicidae, Simuliidae, Tabanidae and Syrphidae. *Tipula* sp. was recorded from all the sites and was most abundant in site I and with more or less even distribution in the remaining sites. Likewise, *Atherix* sp. was also recorded from al the sites with more or less even distribution. *Chironomus* sp. was also pentiful in all the sites except site V where it was less abundant. *Culex* sp. and *Tabanus* sp. were less abundant. Likewise, *Chrysogaster* sp. was recorded only from the site IV. *Simuliium* sp was plentiful in all the sites.

In the order odonata there are two suborders viz; Zygoptera and Anisoptera .In Zygoptera 3 families (Euphaedae, Amphiterygidae and Chlorocyphidae) and in Anisoptera 11 species were recorded belonging to the 6 families (Aeshnidae, Lebullelidae, Macromiidae, Cordulidae, Corduleogasteridae and Gomphidae). Euphaedae was recorded only from the site IIIand site V. Also in the latter site Amphiterygidae was recorded. Chlorocyphidae was recorded from site I. They were site specific and less abundant. Site specific condition was also recorded from sites I and site V. Similarly *Aeschnophlebia* sp., *Somatochlora* sp., *Macromia* sp., *Anatogaster* sp., *Chlorogomphus* sp., *Heliogomphus* sp., were recorded only from site V. *Leptogomphus* sp. and *Somatohchiora* sp. were recorded from site II, the former was also recorded from site III. *Stictogomphus* and *Gasterogomphus* were recorded only from site I. Though the odonates were site specific but their distribution or abundance was even.

Altogether 5 species of coleoptera were recorded and they were all limited to family level. Elmiidae* was recorded from all the sites except site II and site

IV. It was most abundant in site V. Similarly, Gyrinidae was recorded from site I and site IV while Dytiscidae and Psephenidae were limited to site III. Likewise Noteridae was recorded only from site V. Thus their distribution and abundance more or less resemble to odonates.

In case of Hemiptera 3 species were recorded belonging to 3 families viz; Gerridae, Nepidae and Mesovellidae. Only Nepidae (*Nepa* sp.) has been identified upto generic level and the remaining two families were limited upto family level. Gerridae was recorded from site I and siteV with even distribution. Likewise, *Nepa* sp and Mesovellidae were recorded from site V and site IV respectively.

In Neuroptera only one species was recorded belonging to family Corydalidae and genus *Corydalus*. Neuroptera was recorded from all the sites except I.

Orthoptera was also recorded from siteI and siteV but due to lack of literature it can't be identified further.

4.2. Species Richness in Sampling Sites

Out of total 4 species of Plecoptera in site I and site II highest number (3) were present which was followed by site V (2 species). Both sites III and IV had single number species of Plecoptera. The total set of Ephemeroptera (6 species) were in site V which was then followed by sites I, III and IV having similar number of species (5 species) and the remaining site II harbored 4 species of Trichoptera while each of the remaining sites harbored 3 species. The complete set of Diptera was found in site IV which was then followed by site I and site V harboring similar number of species (6 species) which were again followed by site II and site III respectively. Odonates were present in the highest number in site V (9 species) which was then followed by site I with 4 number of species and in site II and siteIII 2 number species were recorded while site IV was devoid of odonates. Species richness of Coleoptera was the highest in site III which was then followed by I, V, and IV respectively and site II was devoid of Coleoptera. Of the 3 species of Hemiptera, site V harbored 2 numbers of species and siteI and site IV harbored similar number of species (1 species) while remaining sites was deviod of Hemiptera. 1 species of Neuroptera was recorded from all the sites except site I.

From the table, among these 5 sites, the faunal richness the was highest in site V (31 species), followed by site I (25 species), site III (20 species), siteIV (19 species) and site II (17 species).

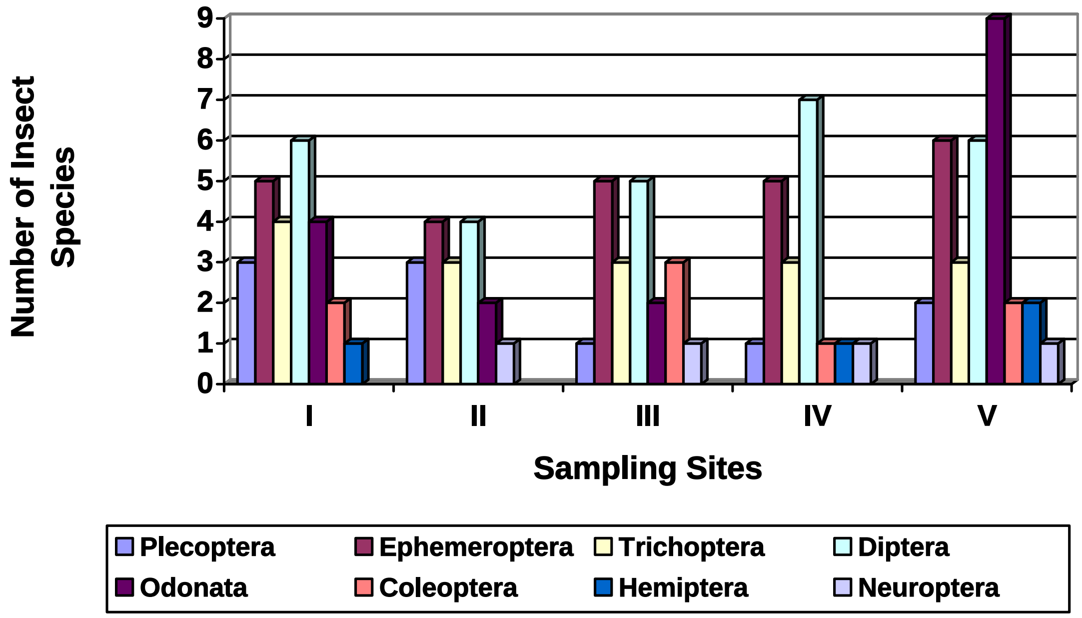

Fig. 2: Spatial Variation of different Insects Orders.

Table IV: Spatial Variation in the Number of Aquatic Insect Species.

S.N.	Orders	No. of Taxa	Sites				
			I	II	III	IV	V
	Plecoptera	4	3	3	1	1	2
2	Ephemeroptera	6	5	4	5	5	6
3	Trichoptera	6	4	3	3	3	3
4	Ditpera	7	6	4	5	7	6
5	Odonata	14	4	2	2	-	9
6	Coleoptera	5	2	-	3	1	2
7	Hemiptera	3	1	-	-	1	2
8	Neuroptera	1	-	1	1	1	1
	Total	46	25	17	20	19	31

4.3 Aquatic Insect Diversity and Evenness in Godawari Rivulets.

Diversity and evenness were calculated in different sites. Here from the table it was found that diversity and evenness were co-related because it was recorded higher the diversity higher the evenness value and vice-versa. Here, site I was recorded to have the highest diversity and evenness value and and site IV was found to have the lowest diversity and evenness value. As siteI and siteV had evenness value greater than .6 so it can be said that these 2 sites may have stable aquatic community for long periods of time. Site IV was found to be the least stable as the value is also the least.

Table V: Spatial Diversity and Evenness of Aquatic Insects

Sites	I	II	III	IV	V
$\overline{H}$	2.246	1.797	1.730	1.636	2.196
e	.68	.58	.56	.51	.62

4.4. Species Richness in Different Seasons

Species richness were recorded varied in varying seasons viz; rainy, winter, autumn and spring. In autumn season odonata was considered to be present in highest number (13 species) which was then followed by rainy (8 species) and spring (1 species) respectively and odonata were not at all recorded in winter.Total set of Plecoptera were recorded in rainy and winter season which were then followed by autumn (3 species) and spring (1 species) respectively. Likewise, the total set of Ephemeroptera were reorded in rainy season while 5 numbers of species was recorded in each of the remaining seasons. 4 number of species of Trichoptera were recorded in each rainy and winter seasons while 3 number of species each in autumn and spring seasons. The highest number of species of Diptera were recorded in autumn (7 species) which was then followed by rainy (6species), winter (5species) and spring (4speciees) respectively. Highest number of speies of Coleoptera (4 species) was found in rainy season which was then followed by winter and autumn respectively and in spring no individuals were recorded. The highest number of species of

Hemiptera were recorded in autumn which was followed by rainy and winter and spring were recorded to have similar number of species (1 species). During all the seasons only one species of Neuroptera was recorded. In total the highest number of species was recorded in autumn, which were then followed by rainy, winter and spring seasons respectively.

Table VI: Seasonal Variation in the Number of Aquatic Insect Species.

S.N	Orders	Seasons			
		Rainy	Autumn	Winter	Spring
1	Plecoptera	4	3	4	1
2	Ephemeroptera	6	5	5	5
3	Trichoptera	4	3	4	3
4	Diptera	6	7	5	4
5	Odonata	8	13	-	1
6	Coleoptera	4	2	3	-
7	Hemiptera	2	3	1	1
8	Neuroptera	1	1	1	1
	Total	35	37	23	16

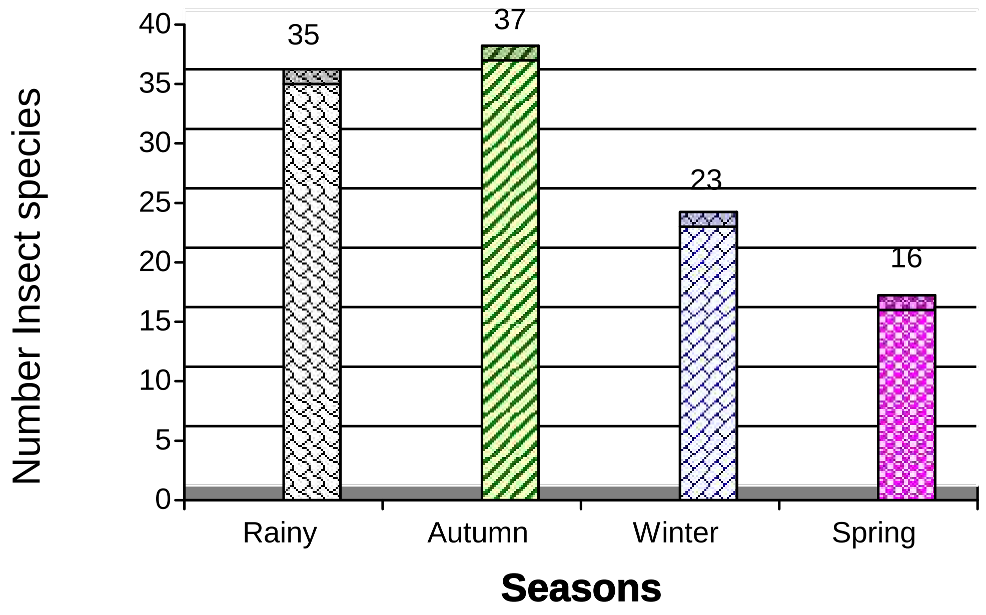

Fig. 3: Occurance of Insect Species in different Seasons.

4.5 Bioassesment of Water Quality.

4.5.1 Use of Aquatic Insect in the NEPBIOS/ASPT Values:

For the Bioassesment of water quality, NEPBIOS/ASPT values were calculated and then with help of transformation table the water quality class of Godawari Rivulets were predicted.

Table VII: Transformation of Different ASPT values Obtained to Water Quality Classes:

Sites	NEPBIOS/ASPT	Water Quality Class
I	6.43	II
II	6.76	II
III	7.21	I-II
IV	6.51	II
V	6.90	II

After calculation it was found that all rivulets water was good but site III rivulet water was found to range between good and excellent. Site III was followed by site V, site II, site IV and site I respectively. However, the water quality in all the sites weren't significantly different on the basis of biological scoring of aquatic insect recorded there in.

4.5.2 Seasonal Variation of NEPBIOS /ASPT Values.

Table VIII: ASPT values obtained to Water Quality Classes in Different Seasons.

	s e a s o n s				
Sites	Rainy	Winter	Autumn	Spring	Class
I	6.47	6.85	6.61	6.8	II
II	6.38	6.61	6.86	5.5	II
III	6.81	6.69	6.58	6.25	II
IV	6.5	6.83	6.95	6.46	II
V	6.98	6.76	6.52	dried	II

The NEPBIOS/ASPT values were slightly different in different seasons. The highest value was found in site V and in rainy season and the lowest in site II in spring season.

4.5.3 Errors in Bioassessment while Using Insect Taxa:

Biological assessment actually refers to the assessment of water quality on the basis of observations of whole biotic communities present in it. Biotic communities include all micro- and macro-invertebrates (ie, insects, molluscs, annelids, etc), however, present study is focused on only aquatic insect assemblages. The calculation of NEPBIOS/ASPT Value completely based on the available NEPBIOS values of the families/genera. Due to exclusion of non-insect fauna the assesment is affected. Thus the values obtained weren't exact as a result the water quality classes were.

4.6 Key for Identification of Aquatic-Insects.

4.6.1 Key to the Orders of Aquatic-Insects;

1.Wings or wingpads present, forewing sometimes hard and shell-like, concealing hindwings; legs present……………………..………………2

1'. Wings or wingpads entirely absent; legs present or absent………………....9

2. Wings fully developed, usually conspicuous and movable. **Adults**………....3

2'. Wings developing in fixed wing pads. **Larvae**………………………...…5

3.Forewings leathery or hard, chewing mouthparts……………………...….4

3'.Sucking mouthparts united in a jointed beaks, mandibles concealed…………………………………………………....**Hemiptera.**

4.Forewings leathery, veins distinct; femora of hind legs greatly enlarged , suited for jumping ……………………………………………....**Orthoptera.**

4'. Forewings hard (called elytra), veins indistinct; hind legs suited for walking or swimming……………………………………………….…**Coleoptera.**

5. Active insects with legs freely movable; not in cocoons or capsule-like cases; with chewing mouthparts……………..………………..……….6

5'. Sucking mouthparts united in a jointed beak with mandibles concealed………………………………………………...….**Hemiptera.**

6. Hind legs suited for jumping, hind femora greatly enlarged; abdomen with out long cerci; found in moist places and only temporarily in water…………………………………………………………..**Orthoptera.**

6'. Hind legs suited for crawling, hind femora not greatly enlarged, approximately the same size as front and middle femora; abdomen with or without conspicuous terminal appendages; usually submerged, truly aquatic……………………………………………………………….….7

7. Labium mask-like, extended into a scoop-like structure longer than head………………………………………………………………**Odonata.**

7'. Labium normal, smaller than head, not large and mask-like……………..…8

8. Tarsi with one claw; abdomen ending in 3 long filaments, less commonly with 2 filaments; gills located on sides of abdomen, may be platelike, filamentous, or feathery……………………………………..**Ephemeroptera**

8'. Tarsi with 2 claws; abdomen ending in only 2 filaments; gills present, finger-like and located at base of mouthparts (inconspicuous), head or legs, or on thorax or first and/or second abdominal sterna ……….……….**Plecoptera.**

9. Three pairs of jointed legs on thorax…………………………………..……10

9'. True legs absent; fleshy leg-like protuberances or prolegs may be present on thorax; head capsule distinct or not distinct; presence of hair brushes or breathing tube at the posterior end; body maggot like or cylindrical ……………………………………………………………………….**Diptera.**

10. Middle and hind legs long and slender, extending considerably beyond the abdomen; compound eyes present (wingless Gerridae)……………**Hemiptera.**

10'. Legs not longer than the abdomen; compound eyes absent…………..….11

11. Last abdominal segment with lateral appendages bearing hooks, antennae 1-segmented, inconspicuous; gills if present, seldom confined to lateral margins of body; larvae free-living, in fixed silk retreats, or in cases made up of sand grains and/or bits of plant matter…………………………..…**Trichoptera**

11'. Last abdominal segment without anal hooks; or, if anal hooks present, antennae of more than 1-segment, and gills insertions lateral…………..…….12

12. Mandibles and maxillae united at each side to form long, straight or slightly recurved; laterally inserted, segmented gills…………………….….**Neuroptera**

12'. Mandibles and maxillae free; abdomen without lateral gills, caudal appendages paired……………………………………………………..**Coleoptera.**

4.6.2 Key to the Families and Genera of Ephemeroptera:

1. Gills consisting of 2 branches each thickly fringed with filaments along both sides…………………………………………………………………………..…2

1’. Gills not like this……………………………………………………….………3

2. Gills held over the back during life; mandibles with al long curved process that projects well beyond the front margin of the head. Fully grown nymphs upto 25mm long……………………………………………….…**Ephemeridae.**

a). Frontal process of head bifid; mandibular tusks smooth on margins; labial palpi 3-segmented…………………………………........………*Ephemera* sp.

3. Crawling nymphs living on the surface of the mud. First pair of gills reduced to tapering filaments; second pair forming a large flap which covers the rest. The body is usually covered with small particles of debris……………………………………………………………….……**Caenidae**

a)No ocellar tubercles on head; maxillary and labial palpi 3-segmented ………………………………………………………………………..…*Caenis* sp.

3'. Gills on abdominal segment 2 neither operculate nor semioperculate, either similar to those succeeding segment or absent…………………………….…..4

4. Gills absent on segment 2, gills on segment 4-7; caudal filaments with whorls of spines at apex of each segment, apical half of caudal filaments with long intersegmental setae extending laterally …………………..**Ephemerellidae** …………………..…..….. *Ephemerella* sp.

4'. Gills present on abdominal segments 1-5, 1-7 or 2-7 ……...……………….5

5. Larva distinctly flattened; head flattened; eyes and antennae dorsal; mandibles not visible in dorsal view…………..**Heptageniidae…….**…………6

5'. Larva not flattened, and is spindle shaped; abdominal gills more or less oval or heart shaped, lamellae either single, double or triple, never terminating in filaments or points; head hypognathous, claws on all legs similar usually sharp pointed, the antennae are comparatively long…………………..**Baetidae.**

a). Each gill consists of a simple, flat lamella without additional ventral or dorsal flap, lamellae never double; 3 will developed tails, median tail shorter and thinner than lateral ones; metathoracic wing pads present though they may be minute………………………………………………………………*Baetis* sp.

6. Two well-developed caudal filament, terminal filament rudimentary or absent; abdominal Terga with out paired tubercles…………...…….*Epeorus* sp.

6'. Three well developed caudal filaments; gill lamella on segment 1, two-third as long as that on segment 2, fibrilliform portion of gills usually subequal to the lamella; claws without denticle but with one basal tooth……….*Heptagenia* sp.

4.6.3 Key to the Families and Genera of Plecoptera.

1. Glossae as long as paraglossae. Labrum less than twice as wide as long; mandibles short and stout, 10th sternum reduced to a narrow strip………..…..2

1'. Glossae reduced; labrum more than twice as wide as long; mandibles elongate; 10th sternum well developed, tarsi with 2 basal segments subequal and much shorter than the 3rd segment…………………………………...….3

2. Stout nymphs with wing pads set obliquely to the body,.Hind leg when stretched back along side the abdomen greatly over-reaching its tip……………………………………………………………….**Nemouridae.**

a). Cervical gills present; gills are finely branched…………..*Amphinemura* sp.

b). Cervical gills absent; pronotum with a distinct fringe of bristles……………………………………………………….....…*Nemoura* sp.

2'. Cylindrical elongate nymphs. Hind leg when stretched back alongside the abdomen not quite reaching its tip; abdominal segments 1-4 only divided int tergum and sternum, segments 5-9 fused into complete rings; paraprocts longer than wide………………………………………………………....**Leuctridae.**

a). Membranous fold on abdominal segments 1-3……………..…….*Leuctra* sp.

3. Pleural gills present on the thorax………………………………..……**Perlidae.**

a). 3 ocelli; anal gills absent; dorsum of body without mesal row of fine hairs…………………………………………………….…………*Calineuria* sp.

4.6.4 Key to the Families and Genera of Trichoptera:

1. Three thoracic segments each covered with single dorsal plate or sclerites, sometimes divided with thin transverse sutures, or some sclerites undivided…………………………………………………………………….…2

1'. Metanotum and sometimes mesonotum entirely membranous, bearing only scattered hairs or small plates or divided into at least 2 sclerites……………...3

2. Abdomen with ventrolateral rows of branched gills and with a large fan of long hairs at base of anal claw; larvae in fixed retreat or nest; widespread in rivers and streams…………………………………………….….**Hydropsychidae**

a). Posterior ventral apotome much less than one half as long as median ecdysial line or inconspicuous; abdominal gills with upto 10 filaments arising mostly near the apex of the central stalk; fore trochantin usually forked; frontoclypeus entire; prosternal plate with a pair of detached, moderate sized, posterior sclerites; basal tooth on mandibles single, predominant in colder, larger and streams and rivers……………………………..……*Hydropsyche* sp.

2'. Abdomen without gills, and with only 2 or 3 long hairs at base of anal claw;9th abdominal tergum with sclerite…………………………………………..……..…….**Hydroptilidae.**

3. Antennae very long and prominent, at least 6 times as long as wide; and/or sclerites on mesonotum lightly pigmented except for a pair of dark curved lines on posterior half; larvae construct portable cases of various materials. Widespread in lakes and rivers……….. ………………………..**Leptoceridae.**

3'. Antennae of normal length or not apparent; mesonotum never with a pair of dark curved lines……………………………………………………………..4

4. Mesonotum largely or entirely membranous or with smalll sclerites; pronotum never with an anterolateral lobe……………………….…………5.

4'. Mesonotum largely covered by sclerotised plates, various subdivided and pigmented; 1st abdominal segment always with a lateral hump on each side although not always prominent, with or without dorsal hump; metanotal Sa1 present and represented by single seta; labrum with transverse row of approximately 5–16 or more long setae across central part; foretrochantin fused completely with episternum forming a sharp, curved projection, antennae clearly between head margin and eye; case of leaves and twigs; anal hooks with 2 accessory teeth, but not forming comb………...............……**Calamoceratidae**

a). Anterolateral corners of pronotum produced into prominent lobes; gills each with 2 or 3 branches; hind tibia usually divided; case of 2 leaf pieces, dorsal piece overlapping ventral one…………………………….…*Anisocentropus* sp.

5. Metanotum Sa3 consisting of a cluster of setae arising from a small rounded sclerite; prosternal horns present; abdomen broad and fat; simple filiform gills attached to the sides of abdominal segments; one dorsal and 2 lateral protuberances or humps are present on first abdominal segment; larvae construct tubular cases of plant materials ………………...…….**Phryganeidae**

5'. Basal half of anal pro-legs broadly jointed with 9th abdominal segment; anal claw small, retractile with at least one dorsal accessory hook; fore-trochantin difficult to distinguish; gills on abdominal segments absent; case of tortoise shell like, portable, made of small stones……………………….**Glossomatidae**

4.6.5 Key to the Families and Genera of Diptera.

1. Head capsule usually well developed, complete and fully exposed (may be reduced and/or retracted in Tipulidae); mandibles usually toothed and moving

in horizontal or oblique plane ……………………..…. ……………………………………….**Nematocera**……………………………2

1'. Head capsule absent or variously reduced posteriorly, partially or almost completely retracted within thorax, with retracted portion consisting of a few slender rods; mandibles usually hook or sickle-shaped and moving in vertical plane…………………………….**Brachycera**……………………………..…..5

2. Head capsule partially or fully retracted within thorax, cranium with longitudinal incisions posteriorly , sometimes leaving only a series of longitudinal rods and plates; respiratory system usually metapneustic with posterior spiracles bordered by 1-3 pairs of short, fringed lobes……………………………………………………………….**Tipulidae.**

a).Spiracular disc surrounded by 6 (rarely 8) lobes; head capsule broad and massive…………………………………………………….subfamily **Tipulinae**

i). Anal gills not branched; usually 6 in numbers, directed lateral or ventral; spiracles separated by more than diameter of a spiracle, lobes around spiracular disc highly variable, from short and rounded to elongate and sub-conical, rarely branching with secondary lobes, spiracular lobes with developed border of setae, all spiracular lobes usually similar in shape and size……………………………………………………………….*Tipula* sp.

2'. Head capsule usually fully exposed, complete, without longitudinal incisions; respiratory system variable, posterior spiracles, if present, not bordered by fringed lobes; prolegs generally absent, but if present, on thoracic segments only…………………………………………………………...…3

3. Pseudopods lacking; thoracic segments fused into an enlarged complex which is distinctly broader than the abdomen, the spiracles either sessile or at the end of a long or short respiratory siphon; antennae not prehensile, with only short apical setae; prominent mouth brushes on either side of labrum…………………………..**Culicidae**.………………………...….*Culex* sp.

3'. Pseudopods present, either at one or both ends of body, or on the intermediate sements;thoracic segments usually indivisible, about as wide or not as wide as abdomen………………………………………………………..….4

4. Pseudopods present on the anal and on the prothoracic segment or lacking; pseudopods paired; head capsule without labral fans, abdominal segments neither swollen nor terminated in hook rows; caudal end of body lacking long filaments……………………………………………………...**Chironomiidae**

a).Antennae not retractile , frontoclypeus narrowed behind, paralabial plates present and radially striated; 3rd antennal segment not annulated; antennae shorter, 5-segmented , bifid, plumose bristle laterally on abdomen lacking; 5th abdominal segment with finger like ventral gills……....………*Chironomus* sp.

4'. Pseudopods present on the intermediate body segment or confined to the prothorax, the apex of abdomen with an adhesive disc; head capsule with a pair of conspicuous labral fans dorsolaterally; abdominal segments 5-8 swollen, terminating in circles of radiating rows of minute hooks……………………..**Simuliidae**………………..…………..….*Simulium* sp.

5. Body not compressed, cylindrical; posterior spiracles present at apex of short respiratory siphon or a slighly domed area on terminal segment , each abdominal segment encircled by 3 or 4 pairs of fleshy welts or prolegs, each sometimes bearing apical spines…………………………………....**Tabanidae.**

a). Anal segment usually tapering into extensible siphon……..……*Tabanus* sp.

5'. Posterior spiracles absent or with in a small terminal cavity; abdomen without prolegs or with only 1 pair of ventral prolegs on each segment (long filaments may be present on last 1-3 segments)…………………………..……6

6. Abdominal segments each with a pair of ventral prolegs bearing apical hooks; slender tubercles of progressively increasing size laterally and dorsolaterally on abdominal segments; posterior spiracles not in a vertical cleft; apex of abdomen with a pair of caudal processess which are obviously longer than the pseudopods……………………………………………..**Athericidae**

a.Lateral sides of each abdominal segment armed with a pair of slender tubercles or pseudopods ………………….… ……….………….*Atherix* sp.

6'. Posterior spiracular plates fused or closely appoximated, usually at apex of telescopic siphon; anterior spiracles, if present, with openings, near apex of a simple stalk; cephalopharyngeal skeleton without mouth hooks, replaced by ribed filter chamber; caudal respiratory tube when extended, about 1/2 the length of the body……………..…..**Syrphidae………….**……*Chrysogaster* sp.

4.6.6 Key to Families and Genera of Odonata:

1. External gills present in the form of 3 or rarely 2 flat and vertical caudal lamellae; abdomen cylindrical, not wider posteriorly than at base……………………………………………………..….Suborder **Zygoptera**

1'. External gills absent; the longest caudal appendages less than 1/3 the length of the abdomen; abdomen more or less flattened dorsoventrally and widened posteriorly from base to mid-length or beyond …………………………..Suborder **- Anisopter**a ……………….. ……………..….4

2. Apex of abdomen with 2 lateral gills which are long, triangular in cross-section, with spines along the ridges of the gills …………………………………………………………...**Chlorocyphidae.**

2’. Apex of abdomen with 3 gills either laminate or saccoid…………….…..……3

3. Caudal abdominal gills saccoid, fleshy; body depressed; abdomen ventrally with lateral gills …………………………………………………....**Euphaeidae**

3'. Body cylindrical or depressed, without lateral abdominal gills; tarsi 3-segmented; lateral lobes with 3 sharp distal teeth, the middle one being the longest………………………………………………….…..**Amphiterygidae.**

4. Prementum and palpal lobes of labium forming a spoon-shaped structure, usually with dorsal premental setae and always with palpal setae…………..…6

4'. Prementum and palpal lobes of labium flat, without dorsal premental and usually without palpal setae………………………………………...…..5

5. Antennae 4-segmented; fore and middle tarsi 2-segmented; ligula without a median cleft……………………………..**Gomphidae**…………………….....11

5'. Antennae 6- or 7- segmented; fore and middle tarsi 3-segmented; ligula with a median cleft…………………………..…Aeshnidae…………………..….10

6. Distal edge of each palpal lobe deeply cut into large irregular dentations, without asssociated groups of setae; ligula represented by a tooth-like process, which is cleft……………………………………….....**Cordulegasteridae.**.9

6'. Distal edge of each palpal lobe evenly crenulate, each crenulation bearing one or more setae; ligula not so often indistinct…………….…………………7

7. Head with a prominent, suberect horn between the bases of the antennae, legs very long, premental setae 16-17 on each side of median line; palpal setae 9; abdominal segments without dorsal hooks; segment 9 with short lateral spines, segment 10^{th} very short, less than 1/4 as long as 9^{th} …………………………………………..…**Macromiidae**……..…*Macromia* sp.

7'. Head without a prominent median horn; metasternum without a median tubercle; legs shorter, the apex of each hind femur usually not reaching to the hind margin of abdominal segment 8^{th} ……………………………….…………..8

8. Crenations (rounded projections) on distal lobes of labium separated by deep notches, crenations usually one-fourth to one-half as high as they are broad; cerci more than one-half as long as paraprocts; abdomen without dorsal hooks and lateral spines……………………… **Corduliidae……….**.*Somatochiora* sp

8'. Crenations on distal margins of palpal lobes of labium generally separated by shallow notches, crenations usually one-tenth to one-sixth as high as they are broad, each cercus as long as the epiproct, spines small, absent on segment 3, and only a rudiment on 5……………**Libellulidae** ….……*Somatochlora* sp.

9. Anterior margin of ligula straight, medially with a pair of processess; palpal lobes of labium each with 4 setae, rarely 5; …………..… *Chlorogomphus* sp.

9'. Anterior margin of ligula medially protruded, with 4 dentations at its apex………………………………………………………...*Anotogaster* sp.

10. Abdominal segments 8 and 9 with middorsal hooks...….*Aeschnophlebia* sp.

10'. No abdominal segments with middorsal hooks; abdominal segments 7-9 with lateral spines…………………………………………………….*Anax* sp.

11. Tarsal segments 2-2-2 ; abdomen distinctly longer than wide, abndominal sgments 1-7 more or less trapezoid , widest at apical margin of 7 which bears elongate lateral spines ; prementum longer than wide……..*Sinictogomphus* sp.

11'. Body thick, not especially flat; 3rd segment of antennae of various shapes, mostly elongate or finger-like or slightly flattened, if thin and broad, decidedly longer than broad, tarsal segments 2-2-3……………………………..…….12

12. Wing cases divergent; anterior margin of prementum straight; palpal lobe with its margin slightly curving mesad; apically round, not sharply pointed ……………………………………………………………..*Leptogomphus* sp.

12’. Wing cases parallel…………………………………………….……13

13. Anterior margin of prementum armed with about 23 quadrate teeth……………………………………………………..*Heliogomphus* sp.

13'. Anterior margin of prementum with at most (20) teeth; 3rd antennal segment slender; generally more than 3 times as long as wide; anterior margin of prementum produced in a double curve; abdominal segments without dorsal hooks, segments with 9 lateral spines……………………*Gastrogomphus* sp.

4.6.7 Key to Suborder and Families of Coleoptera:

Adults:

1. Hind coxae immovably fixed to the metasternum completely dividing the basal abdominal sternite………………………Suborder **Adephaga**…………2

1'. Hind coxae are rarely fused to the metasternum; prothorax without notopleural sutures; apex of wing not spirally rolled in repose……………………………..………..**Polyphaga**………..…………..3

2. Compound eyes divided into separate dorsal and ventral pairs; antennae short and clavate; middle and hind legs much shorter than the front legs, and highly flattened……………………………………………….……..**Gyrinidae.**

2'.Compound eyes normal, undivided; antennae long, filiform or moniliform; middle and hind legs not shorter than the front legs; elytra without lateral groove; body without long and slender, erect hairs; metathoracic episternum widely separated from the intermediate coxal cavities; body flattened ventrally ………………………………………………………………………..**Noteridae**

3. Maxillary palpi shorter than antennae; head without a median longitudinal line; elytra covering entire abdomen or exposing only one abdominal tergite; tarsal formula 5-5-5 or 4-4--4, 4th segment clearly visible, abdomen with 5 or 6 visible segments, pronotum and elytra without scales; posterior edge of pronotum and the opposed basal edge of the elytra not crenulated; fore, mid and hind coxae widely separated, fore coxae gobular; prosternum small, much narrower than head; antennae slender or short , but never with a pectinate club; body size 2mm ……………………………………………………..…**Elmiidae**

Larvae (Suborder- Adephaga)

1. Abdomen without hooks on terminal segments, thorax and abdomen not strongly flattened; legs long and slender, adapted for swimming; tarsi with 2 claws; thorax and abdomen without ventral gills; abdominal segments 1-7 not sub-equal in shape and size, 8th segment usually with a pair of large terminal spiracles; mandibles slender, channeled…………………………….……**Dytiscidae.**

Larvae (Suborder-Polyphaga)

1. Body cylindrical, sub-cylindrical; head and legs visible in dorsal aspect, 9th abdominal segment with a ventral movable operculum closing or caudal chamber containing extrudable gills; terminal abdominal segment bifid or slightly emarginated posteriorly and with lateral ridges; head capsule with 1 or 5 stemmata on each side…………………...…………………………..**Elmiidae.**

1'. Body form greatly flattened, discoidal; the segments much expanded laterally as thin laminae concealing head and legs from above…………………………………………………………..….**Psephenida4**

.6.8 Key to the Families and Genera of Hemiptera.

1. Apex of abdomen with elongate tail-like respiratory appendage, one-fouth to one-half of abdominal length………………………**Nepidae**…………*Nepa* sp.

1’. Apex of abdomen not as above…………………………………………...2

2. Tarsi each 3-segmented; ventral side of head and thorax without deep groove……………………………………………………………..…**Mesovelliidae**

2'. Head without median sulcus or stripe; femora of hind legs greatly surpassing apex of abdomen.…………………………………………………..…**Gerridae.**

4.6.9 Key to the Family and a Genus of Neuroptera.

1. Abdomen with a pair of anal prolegs, each bearing 2 strong hooks; paired lateral 2 - segmented appendages on abdominal segments 1-8 and 10; tufts of gills sometimes present, bodylength 40mm ………….………….**Corydalidae.**

a). Abdomen with tufts of tracheal gills at bases of lateral appendages on segments 1-7; 8th abdominal segment without dorsal respiratory tubules, spiracles close to lateral appendages……………………………...*Corydalus* sp.

5. Discussion

The aquatic insects were collected monthly for the whole year. Altogether, 47 taxa were collected belonging to 9 orders, 40 families and 33 genera. Among them the highest number of species (14 species) belong to the order Odonata belonging to 9 families and 11 genera, Neuroptera had single family with single genus. 7 species of Diptera belonging to 7 families and 7 genera; 6 species of each of Ephemeroptera and Trichoptera belonging to 5 and 6 families respectively and again 6 and 3 genera respectively; 5 species of Coleoptera belonging to 5 families; 4 species of Plecoptera belonging to 3 families and 4 genera and 3 species of Hemiptera belonging to 3 families and one genus were reported from Godavari Rivulets. Malla *et.al.* (1978) reported 61 species from Kathmandu valley, among them the taxa reported from Godavari running and stagnant water were *Apobaetis* sp., *Orthemis ferruginea* (Libellulidae), *Sympetrum* sp., *Macromia* sp., *Chromagrion* sp. (Agrionidae), *Lestes* sp. (Lestidae), *Paragnetin*a sp.(Perlidae), *Macronecta lineata* (Corixidae), *Fabatus servus*, *Metrocoris illustranius*, *Anisops niveus* (Notonectidae), *Tendepes* sp., *Tipula* sp., *Atherix* sp., *Amphizoa* sp., *Haemonia* sp., Dytiscidae and Haliplidae.

Yadav *et.al.* (1980) on similar kind of exploration reported 25 taxa of macrofauna from Godavari Khola of which Oligochaetes and Molluscs were the dominant groups. Yadav and Rajbhandari (1982) studied on the benthic macrofauna of Bansbari Khola and Dhobi Khola in Kathmandu and the major fauna were Tipulidae, Dolichopidae and Chironomidae. Yadav (1987) in similar type of investigation in Palung Khola (the mountain stream) reported 7 different orders including 8 species of Ephemeroptera, one species from each of the families Chrysomelidae, Hydrophilidae, Dytiscidae and Hydropsychidae and 2 species of Rhyacophilidae.

In the presently conducted work in Godavari rivulets the insects collected were arranged in the descending order as Odonata, Diptera, Trichoptera and Ephemeroptera, Coleoptera, Plecoptera, Hemiptera and Neuroptera respectively. Likewise, Shakya (1992) arranged the orders in terms of their dominance in descending order of Oligochaeta, Diptera, Ephemeroptera, Trichoptera and so on. Khadka (1983) reported dominant benthos in the descending order of Trichoptera, Plecoptera, Ephemeroptera and other fauna. Roy (2006) on similar kind of study reported 66 taxa and on the basis of species richness the orders arranged in descending orders were as Trichoptera, Ephemeroptera, Diptera, Plecoptera, Odonata, Coleoptera, Hemiptera and Neuroptera respectively. Number of taxa were reported more by Roy (2006) in Sundarijal Drinking Water Supply though the method of collection were same, it may be due to difference in water quality of Sundarijal and Godavari. The quality of water was better of Sundarijal Rivulets than that of Godavari Rivulets so species richness were high in Sundarijal Drinking Water Supply.

At site I, the substratum was composed of rocks, stones, gravel and fine sand with partially decomposed leaves. The good abiotic conditions support a widely diverse insect. Out of 47 taxa, 25 species were recorded from the site. Ephemeroptera was most abundant and it was then followed by Diptera, Plecoptera, Trichoptera, Hemiptera, Coleoptera and Odonata respectively. Neuroptera wasn't at all recorded in this site. Though the source of this rivulet was pure (drinking water was the source) but this site was made somewhat polluted by the people nearby using it as a mini-dumping site, the very sensitive aquatic insect as Plecoptera and Odonata were also recorded from this site has been due to flowing water due to which the pollutants were washed away contineously.

At site II, though the area was devoid of human settlements but the site and area was frequently disturbed by visitors and locals nearby. This site consists of 17 species i.e., lowest number of species compared to other sites. As substrate is also an important factor for the insects present in the water, here the bottom substrates differ than that of site I.The substratum at this site was composed of sand, silt and gravel with little scattered vegetation. Here the Trichoptera has been found most abundant and followed by Ephemeroptera, Diptera, Neuroptera, Hemiptera, Plecoptera, Coleoptera and Odonata respectively. Here the low number of species has been due to poor substrate and different human activities and using the site as dumping site especially by the visitors. Illies (1957), Miller (1956), Petr (1970) and Philipson (1954) observed running water with faster current velocity (75 to 140 cms-1) supports higher density of Trichoptera where as there is absence in those areas where water current is below 45cms-1, likewise here, in this site the width of the rivulet was small but the velocity of water current was high, it has been the reason for the most abundance of Trichoptera than compared to other sites.

In site III 20 taxa were recorded thus occupied 3^{rd} position in species richness compared to other sites. Here the substrate consists of small stones and sand. Here the most abundant was Ephemeroptera, followed by Diptera, Trichoptera, Coleoptera, Neuroptera and Odonata respectively. Here in this site was found complete absence of Hemiptera.

Site IV constituted 19 speceis i.e., apporximately equal to that of site III. It is probably due to similar nature of microhabitats. Sharma (2000) and Shakya (1992) observed similar results but their sampling procedures were quite different. It is obvious that sampling techniques affect the types of insect fauna collected and outcome of the study. Here, the highest number of species (7 species) belonged to the order Diptera, which was then followed by Ephemeroptera and Trichoptera having 5 species and 3 species respectively. Remaining orders each with 1 number of species. In terms of abundance Ephemeroptera and Diptera were the top most. Among all the five sites, it is the site harboring highest number of Chironomiids. Here sensitive insects as Plecoptera, Trichoptera, Odonata were replaced by pollution tolerant as chironomiids. The reason for the abundance of Chironomiids has been due to enough organic matter present there. This site was used as toilet for pigs and dogs, swimming pool for ducks and cleaning basins by locals nearby.

Site V constituted 32 number of species i.e., highest number of species. It means it can been said that this site was the most suitable site for aquatic insects. Here highest number of Odonata species were recorded i.e., 9 species. It may be due to presence of abundant vegetaion in the margin of the stream as well as in around. Mainly small stones constituted the substratum and may be this is the reason for the presence of highest abundance of *Simuliium* sp.

Baetis sp. and *Hydropsyche* sp. were found most abundant or bountiful from all the sites but the latter was present in less abundance in site IV. Likewise, *Chironomus* sp. and *Simuliium* sp. were plentiful in all sites but the former was almost absent in site V.

Individual numbers of species were counted for each species in every sampling effort as the study is conducted for qualitative and quantitative analysis. Hence, species diversity and evenness were calculated of different sites. Highest species diversity and evenness were calculated for site I and the lowest in site IV. This shows that species diversity is directly related with evenness i.e., higher the species diversity value higher is the evenness and vice-versa. It was found that site I and site V to be most stable community as the evenness value exceeds 0.6 and site IV to be the least stable with lowest evenness value.

V.C. Kapoor *et.al*. reported 22 species of Syrphids from Kathmandu valley but in the presently conducted research only one species has been recorded from Godavari it may be because of the absence of very polluted water as it is considered to be pollution tolerant in NEPBIOS/ASPT Values.

Benthic macroinvertebrates density varied considerably between seasons and in months (Brewin et. al. 2000). Strong seasonal variation was confined to streams at low altitude. Highest number of species were recorde in autumn (37 species) season which was the followed by rainy (35 species), winter (23 species) and spring (16 species) respectively. The highest number of Plecoptera species were recorded in rainy and winter (4 species each) followed by autumn (3 species) and spring (1 species). The lowest number of Plecoptera species in spring is probably due to decrease in sampling event because most of the sites were found deviod of water. For Ephemeroptera there has not been found much variation in the number of species in different season but *Baetis* sp.and

Caneis sp. were most abundant in autumn. *Heptagenia* sp. was most abundant in winter and least in spring. *Ephemera* sp. was least abundant (1 individual) among the Ephemeroptera and was collected only in rainy season. The less number of individual might has been due to absence of efficient sampling techniques ie, grab sampling for burrowing insect. Trichoptera were most abundant in rainy season followed by autumn, winter and spring season respectively. As already discussed, higher velocity of water current favours the Trichoptera, similar results were obtained in the presently conducted study also. Similarly, *Hydropsyche* sp. and *Lepdostoma* sp. were most abundant in rainy season. *Hydropsyche* sp. was abundant also in autumn. Phryganeidae and Leptoceridae were very rare and were recorded only in winter in siteI and siteIII respectively. Glossomatidae was also rare and was recorded in autumn only from site I. *Anisocentropus* sp. was also rare and was recorded only in rainy and spring season. The highest number of Diptera (7 species) was recorded in autumn and the least (4 species) in spring. Rainy and winter seasons constituted 6 species of Diptera.Chironomiids were most abundant in winter in site IV. *Tabanus* sp. wasn't recorded in winter may be it has gone to inactive or dormant stage.

Coleoptera also showed seasonal fluctuation in abundnce as well as in diversity. In rainy their highest number of species (6 species) as well as highest abundance were recorded. This kind of result was also studied by Macan's (1976) in a moorland fish pond. In the present investigation, the maximum abundance of Dytiscidae was recorded in winter season but Zimmerman (1960) working on Dytiscidae reported maximum abundance of these species during rainy season. It was also suggested by Boughey (1968) and Fernando (1958). The variation is may be due to difference in collecting time and collecting methods.

Neuroptera was recorded most abundant in autumn and least in spring. Hemiptera had highest number of species (3 species) in autumn and lowest in spring (1 species) and winter. Only one individual of *Nepa* sp. was collected in autumn in site V in the margin of the rivulet with vegetation of the rivulet. Thus there occur seasonal variation of the insects.

Chemical tests aren't always reliable for detecting pollultion. Forbes (1913) remarked that biological observations are more dependable in certain ways than chemical determination since they show cumulative effects of the present and past conditions, while chemical tests apply to the moment of sampling. The biotic in the aquatic ecosystem positively reflects the conditions existing in the environment and the data can be utilized for biological monitoring of water level (Sharkar and Krishnamurti, 1977). Plecopterans, Ephemeropterans and Trichopterans are generally taken as pollution intolerant fauna. WHO (1976) excluded Baetids and Caenids from pollution intolerent fauna, though they were abundantly recorde from all the sites. Selwin (1974) concluded that Ephemeroptera, Trichoptera, Coleoptera, Diptera and Odonata are tolerant to pollution and found in wide range of water quality thouth odonates were completely absent from the site where the most abundant individual was Chirnomiid i.e., site IV while Plecoptera and Planaria were considered to be pollution intoerant fauna. Likewise, Coleopterns were most abnundant in site IV in which Chironomiids were also the most abundant, also *Chrysogaster* sp. was found in the same site i.e., site IV which shows gathering of pollution tolerant insects.

The concept of using invertebrates (both micro- and macroinvertebrates) to determine the health of aquatic systems isn't now. They have been commonly referred as indicators by several researchers e.g., Ellis (1937), Hellwell (1978), Tarzwell and Grafin (1953). Site V has been found to harbour the highest number of species which was then followed by site I, site III, site IV and site II respectively. Thus site V was found to be most favourable habitat for aquatic insects. The biological analysis happened with in the benthic macroinvertebrates community. The main factors responsible for this situation are: the change of the composition of the substratum and the alternation of environment due to human activities.

Indigenous biotic scoring system was used to calculate the water quality class of the stream water at different sites. According to Sharma (1996), a suitable biological method, to identify the pollution level of a country with different fauna, based on indices of score system is possible only when local reference communities are properly scored. Nepalese taxa were scored for Nepal with the name Nepalese Biotic Score (NEPBIOS). NEPBIOS/ ASPT values were calculated which were then transformed into water quality class II for all the sites except site III for which, class I-II was calculated.

There were slight variations in NEPBIOS/ASPT Values obtained for all the sites. Water quality class assigned to all these sites was II except for site III for which class I-II was calculated. It revealed the water of all the sites except site III was good but not enough hygienic for human use for different purposes as drinking, washing face and utensils, etc. Highest diversity and evenness value were claculated for site I which means there the aquatic community will be stable for long term but NEPBIOS/ASPT Value was the least for this site and previously it has been discussed that decrease in water quality cause decrease in habitat for aquatic insects. This error has been probably due to error in bio-assesment i.e., exclusion of non-insect fauna and limitations of insects in NEPBIOS list.

6. Conclusion and Recommendations

In the present study on aquatic insects of Godawari Rivulets, 47 taxa were collected belonging to 9 orders, 40 families and 33 genera. The highest species richness was found to be of Odonata which was then followed by Diptera, Trichoptera and coleoptera, Ephemeroptera, Plecoptera, Hemiptera and Neuroptera. Species diversity and evenness values were highest in site I, which was then followed by siteV, siteII, site III and site IV respectively. Thus, it can be said that site I aquatic community to be most stable and site IV to be least stable. Site V was also considered to be stable aquatic community because it's value also exceeds 0.6. Species richness also varied in different season. Highest species richness was found in autumn, which was then followed by rainy, winter and spring seasons respectively.

The bio-assessment of the water quality by using the NEPBIOS list determined the water quality classes of the study area. The water quality of Godawari Rivulets were classified as good. But from the value it was clear that the quality of the rivulets was degrading from site III to site I. As the quality of the rivulets weren't enough good, hence the water should be avoided from drinking, washing face and utensil, etc. directly, it needs treatment before use. Though bioassesment is a reliable means for catagorizing the water quality of the rivulets, but in this result (i.e, present study) there are errors due to exclusion of all non-insect fauna and limitations of insect-fauna in the NEPBIOS list.

A safe environment is essential for a quality of life and there is no real development if the natural process is destroyed. So in order to preserve and protect our fresh nature following recommendation have been made:

1. Extensive study needs to be conducted for complete and exact survey of aquatic insects in different streams at different water quality level.
2. There should be promotion of researchers on aquatic health effects of environmental pollution.
3. There should be implementing monitoring and surveillance programmes of the soures, levels and effect of water pollution.

4. NEPBIOS list should include majority of aquatic fauna.

5. Local people and visitors need some awareness programs so that they can know about the aquatic ecosystem.

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ANNEX-1

SPATIOTEMPORAL VARIATION IN AQUATIC INSECTS DIVERSITY.

Aquatic Insects	**Seasons**																			
	Rainy					Winter					Autumn					Spring				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Order-Ephemeroptera																				
Heptagenia sp.	+ +	-	+	+	++	++	+++	++	+	-	-	+	+	+	+	-	-	-	+	-
Baetis sp.	++	+	++++	+++	++	++	++	+++	++	+	++++	++	++++	+++++	+++	+	+	+++	++	-
Caenis sp.	+	+	++	++	-	-	-	+	+	-	+	+	+++	++	-	+	+	++	+	-
Epeorus sp.	+	-	-	-	-	+++	-	+	+	-	+	-	-	+	+	+	-	-	-	-
Ephemerella sp.	+	+	++	+	+	-	+	+	-	+	+	+	-	++	-	+	-	-	+	_
Ephemera sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Order-Plecoptera																				
calineura sp.	-	-	-	-	+	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-
Amphinemoura sp.	+++	+	-	-	-	+	-	-	-	-	+	+	-	-	+	-	-	-	-	-
Nemoura sp.	+	+	-	-	-	-	+	-	-	-	+	-	-	-	+	+	-	-	-	-
Leuctra sp.	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Order-Trichoptera																				
Leptoceridae	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydropsyche sp.	+	++++	++	+	+++	++	+	+	+	++	++	+++++	+	-	++	++	-	-	+	-
Lepidostoma sp.	+	+++	+	+	++++	++	-	+	+	+	+	+	+	++	++	-	-	-	+	-
Glossomatidae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Anisocentropus sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Phragynidae	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Order-Diptera																				
Tabanus sp.	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Tipula sp.	+	+	-	+	+	+	-	-	+	-	+++	-	+	++	+	-	+	-	-	-
Atherix sp.	+	+	+	-	+	++	-	-	-	+	+	++	+	+	+	-	-	-	-	-
Simulium sp.	-	++	++	+	++++	++	+	+	+	-	++	+	+	+	+	-	-	+	++++	-
Culex	+	+	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-
Chironomus sp.	++	+	++	+++++	-	+	+++	+++++	+++	-	+	-	++	++++	+	+	-	-	+	-

Chrysogaster sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Order-Coleoptera																				
Psephenidae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Elmiidae*	+	+	+	-	++++	-	-	+	-	-	+	+	+	-	+	-	-	-	-	-
Gyrinidae	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
Dytiscidae	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Noteridae	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Order-Neuroptera																				
Corydalus sp.	-	+	+	+	+	-	+	+	+	+	-	+	+	+	+	-	+	+	+	+
Order-Hemiptera																				
Gerridae*	+	+	-	-	+	++	++	-	-	+	+	-	-	-	+	+	-	-	-	-
Mesovellidae	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Nepa sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Order-Odonata																				
Euphaedae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Amphiterygidae	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-
Chlorocyphydae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Anax	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Aeschnphlebia sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Gasterogomphus sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sinictogomphus sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Leptogomphus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Heliogomphus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Somatochlora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Chlorogomphus sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Anatogaster sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Somatochiora sp.	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Order-Orthoptera	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-

ANNEX-2

NEPBIOS Original List

Name of the Taxa	Value
Athericidae, Capniidae, Epiophlebiidae, Helicopsychidae, Helodidae, Heptageniidae (*Epeorus rhithralis*), Heptageniidae (*Rhithrogena nepalensis*), Hydrobiosidae, Lepidostomatidae, Leuctridae, Peltroperlidae, Perlidae (*Acroneuria* sp.), Siphlonuridae, Taeniopterygidae, Uenoidae.	10
Chloroperlidae, Goeridae, Limnephilidae, Limnocentropodidae, Nemouridae, Neoephemeridae, Perlodidae	9
Elmiidae, Euphaeridae, Heptageniidae (*Rhithrogena* sp.), Limoniidae, Perlidae, Rhyacophiliae, Stenopsychidae, Tipulidae.	8
Aphelocheiridae, Baetidae (*Baetiella* sp.), Baetidae (*Baetis* sp.), Brachycentridae, Ephemerellidae, Gammaridae, Glossomatidae, Heptageniidae, Hydraenidae, Leptophlebiidae, Philoptamidae, Polycentropidae, Potamidae, Psephenidae, Simuliidae.	7
Aeshnidae, Caenidae, Corydalidae, Ecnomidae, Ephemerellidae (*Torleya* sp.), Ephemeridae, Gyrinidae, Hydraenidae (*Ochthebius* sp.), Hydrophilidae, Hydropsychidae, Hydroptilidae, Libelluliidae, Lymnaedae, Psychomyiidae, Scirtidae, Viviparidae.	6
Bithyniidae, Chlorocyphidae, Coenagrionidae, Corduliidae, Dryoprdae, Leptophlebiidae (*Elthraulus* sp.), Odontoceridae, Protoneuridae, Sphaeriidae, Unionidae.	5
Calopterygidae, Corbiculidae, Corixidae, Dytiscidae, Gerridae, Glossiphoniidae, Gomphidae, Naucoridae, Nepidae, Noteridae, Palaemonidae, Planorbidae, Pleuroceridae, Ranatridae, Thiaridae.	4
Notonectidae, Salifidae.	3
Culicidae, Physidae.	2
Chironomidae (*Chironomus* group *riparius*(=thummi) and group *plumosus*), Tubificidae.	1