SPECIES DIVERSITY AND DISTRIBUTION PATTERN

WITH CONSERVATION THREATS OF DRAGONFLIES

(ODONATA-ANISOPTERA) IN GODAWARI, LALITPUR

A Dissertation Submitted to the Central Department of Zoology

Institute of Science and Technology

Tribhuvan University, Kirtipur, Kathmandu

for the Partial Fulfillment of Master's Degree of Science in Zoology

(Entomology)

By

Arjun Kumar Pokharel

Central Department of Zoology Institute of Science and Technology

Tribhuvan University, Kirtipur, Kathmandu

Nepal

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RECOMMENDATION

It is my great pleasure to mention here that Mr. Arjun Kumar Pokharel has completed his dissertation entitled "Species Diversity and Distribution Pattern with Conservation Threats of Dragonflies (Odonata-Anisoptera) in Godawari" under my supervision and guidance. This is the candidate's original work aiming to fulfill the information gap about dragonflies. To the best of my knowledge, his work has not been submitted to any other degree.

I recommend for the acceptance of this dissertation in partial fulfillment of the master's degree in Zoology specializing entomology.

Prof. Dr. Ananda Shova Tamrakar
Supervisor
Central Department of Zoology
T.U. Kirtipur
Kathmandu, Nepal.
Date:

LETTER OF APPROVAL

On the recommendation of supervisor Prof. Dr. Ananda Shova Tamrakar, this dissertation work of Mr. Arjun Kumar Pokharel has been accepted as a partial fulfillment of master's degree in Zoology specializing entomology.

Prof. Dr. Tej Kumar Shrestha
Head
Central Department of Zoology
Institute of Science and Technology
Tribhuvan University, Kirtipur
Kathmandu, Nepal.
Date:

CERTIFICATE OF APPROVAL

The dissertation submitted by Mr. Arjun Kumar Pokharel entitled "Species Diversity and Distribution Pattern with Conservation Threats of Dragonflies (Odonata-Anisoptera) in Godawari" has been accepted as a partial fulfillment for the Master's Degree in Zoology specializing in Entomology.

Expert Committee

Supervisor	Head of Department
Prof. Dr. Ananda Shova Tamrakar	Prof. Dr. Tej Kumar Shrestha
Central Department of Zoology	Central Department of Zoology
Institute of Science and Technology	Institute of Science and Technology
Tribhuvan University, Kirtipur	Tribhuvan University, Kirtipur
Kathmandu, Nepal.	Kathmandu, Nepal.

External Examiner

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ABSTRACT

Dragonflies of Godawari were observed during the period of 12 months (July 2005 to June 2006). Five different habitats were selected as forest land, agricultural field, grass land, flowing water bodies and stagnant water bodies. Altogether 222 specimens were collected including 4 families 15 genera and 21 species. Altogether 24 trips were done to Godawari. Main collection and observation was done at Godawari valley.

For the collection sweeping insect net was used and after collecting, killed by injecting alcohol and kept in the triangular envelop. Then they were brought to the lab and preserved in preservation box with necessary data.

Among them maximum species collected were from Libellulidae, 15 species, and only one Gomphid was collected. 2 species from cordulegasteridae and 3 from Aeshidae were collected.

Among the habitat maximum 127 specimens with 14 species was collected from the periphery of stagnant water while only 36 specimens but 14 species were collected form green open sunny grassland of Godawari.

The species diversity was found 0.87 while evenness 0.65 and community dominance 0.54). To be adjusted in 2nd paragraph of this page.

Rainfall, and R.H. showed negative effect on them while low temperature showed negative and high temperature rainy days showed positive effect on them.

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CONTENTS

1. INTRODUCTION

1.1 General Background

Dragonflies, are currently sparking great public and scientific interest and are a useful group of biological assessments for conservation planning. Because of their habitat specificity, their role as top order invertebrate predators and their conspicuous nature, along with practical number of species that are well known to science, these colorful and charismatic insects work as both indicator and flagship organisms (Corbet, 1999).

Dragonflies are often called living fossils, thus belong to palaeoptera, the most ancient group of winged insects. The ancestors of today's dragonflies, the protodonata, were on the wing above the warm carboniferous forests 300 millions years ago. They were among the largest flying insects ever to have existed. The wingspan of one group, the Meganeuridae, reached upto 70 cm, making them the largest flying beasties of their time. These monster dragonflies resembled the one we can see today however there were important differences in the structure of their wing. There was no node and no pterostigma. (Derbyshires dragonfly link with past) Now, order odonata is common order of insecta class. But less number. of species are described. In the world 5000 species are described and in Nepal only 207 species are reported in whole country. (Thapa, 1997 and Vick 1989).

Although there are not so many species reported these are one of the most common insects of the world. Because of their great adaptability and structural modifications which they exhibit have evidently contributed much to their dominance both in land and water. Apart from *Megalagrion oahcense* and few others, they are aquatic in their early ages. The adults, however, are not confined to the proximity of water and females of many

groups seldom fly there except for pairing and oviposition. They are essentially sun loving though some oriental species are only known to fly at night.(Richard and Davies, 1977) .Many are very swift on the wing and according to Tillyard, *Austrophlebia*, can fly at 60 miles per hour, other species can be easily caught except few.

Adult dragonflies and damselflies can be easily recognized; forewing is elongate, many veined and membranous; compound eyes are large and often occupy most of the head. Thorax is relatively small and compact (Prothorax is always small and other 2 thoracic segments make up most of he thorax). Autenna are very short and bristle like. Abdomen is long and slender. Cerci are unsegmented and function as clasping organs in male. Mouth parts are chewing type and metamorphosis is simple.

Fraser (1957) divided odonata into 3 suborders, namely zygoptera, anisozygoptera and anisoptera. The first suborder consists of 21 families, 2nd consist of only one family and 3rd one consists of 8 families (Richards and Davies, 1977).

All living dragonflies belong to 3 well defined suborders; the zygoptera or damselflies, anisoptera or true dragonflies and an intermediate anisozygoptera. The zygoptera is included over 2,300 species within 21 families, anisoptera over 2500 species belonging to seven families. Most anisozygoptera are known only in fossils. Only one living family Epiophlebidae, has reported with 2 species. (Davis and Tobin 1984, 1985, IUCN).

1.2 Anisoptera (True Dragonflies)

Dragonflies are one of the most successful insects of the world both in land and water. They are the great public and scientific interest and are a useful group of biological assessments for conservation planning. The guardians of watershed inhabit the riparian interface between land and water. The aquatic animals that depend on fresh water like rivers and streams are considered to be he most threatened organisms worldwide. (Allan and Hecker, 1993; Saunders et al 2002)

The life cycle of the insect complete in 3 stages as pupal stage is not found. Eggs are laid in fresh water ponds, rivers or lakes by females. They may be attached to some aquatic plants or dropped freely, except *Sympetrum* and *Tetragoncuria* where the eggs are laid in gelatinous string attached to submerged twigs. Whereas in Aeschnids and others, eggs are inserted into slits cut by their ovipositor in the stem and leaves plants or other objects near or beneath the water (Richards and Davies 1977).

True nymphs are the 2nd instar larva and first nymphs are not fully developed and are called pro-nymph. The nymphs are campodaeform and body ends in 3 small processes, a small epiproct and 2 lateral paraprocts. Respiration takes place by means of concealed rectal tracheal gills. Usually nymphs are truly aquatic living in various conditions of fresh water. Many remain hidden in sand or mud and are homogeneously coloured without any pattern. They are also able to change their colour according to changes in the environment. All species are predaceous feeding on various aquatic animals mainly Ephimeropteran nymphs and culicid larva as well as nymphs of their own. The larger Aeshnid nymph also attack tadpoles and occasionally small fish.

The number of nymphal instars ranges from10-15 according to species and whole nymphal period may last upto 2 years (Aeshna) or 3 to 5 years in others (Imm) In temperate species there may be diapause which ensures the synchronized emergence of adults in the following spring (Corbet 1959a, 1957a). The principle characters involved during metamorphosis (Snodgrass, 1954; calvert, 1934) include an increase in size of compound eyes and during last few instar ocelli becomes evident. Antennal segments increase in number and wing rudiments change so that developing hindwings overlap the anterior pair. The secondary copulatory organs of male increase largely and skeletomusular system of thorax and abdomen undergo considerable change (Maloeuf, 1935)

When other internal organs are also complete, the nymph climbs up- some suitable object out of water and fixes its legs firmly in position that the exuvie remain tightly adherent to the support long after the imago has flown away. The imago now breaks up its cuticle and withdraws its head & thorax through the hole and the insects crawl away to fly until wings and abdomen are fully extended.

Now imago comes out of exuviae. The imago has labium rather than mask of nymphs. Antennas are composed of 3 to 7 segments bearing sensilla for chemoreceptor (1972). The reduced condition of antenna is correlated with the increase power of campound eyes.the mouthparts are entirely bitting and masticatory type (mathur, 1962). 3 segments of thorax consists of 3 pairs of legs and 2 pairs of veins. They are strong flier and thus skeleton muscular system of thorax is functionally modified to enable them to move swiftly & skillfully (Clark, 1940;Hatch, 1966) Hind wings are broader basally with minor venational differences consisting of minute cells. (*Neurothemis* over

3000 cells; (Tillyard,1928) Stigma, a black spot like thickening is characteristic feature between C and R.

Abdomen is always greatly elongate in proportion to its breadth. Ten complete segments are evident and parts of 11th segments and telson are also recognizable. Secondary copulatory organs are unique, developed from 2nd and 3rd abdomenal sterna in male though true genital aperture opens on 9th segment the spermatophore must transfer from gonophores to the secondary copulatory organs. Penis is complex, jointed organ partly covered anteriorly by a sheath like ligula and two orifices. In female gonapophysis consist in 8th segment and slender ovipositor in 9th segment which is hard and may be tactile. Ovipositor is correlated with mode of oviposition.

The adults are differentiated from other insects by great development of eyes and wings.The eyes of anisoptera meet mid dorsally and composed by far the largest part of the cephalic region. Eyes are separate in archaic genera, in others more or less globular, with eyes confluent to a variable extent on vertex. Nonpetiolate wings are usually dissimilar.Hind wings are broadely dilated at the base and differ markedly in details of basal venation from forewings. Main point of identification found in wings is a triangular cell,the discoidal cell which split into 2 triangular cells, a superior (hypertrigone) and inferior (true discoidal cell) [fraser, 1983]. Unlike zygoptera they are more robust and while resting lie their wings in horizontal position, never closed over dorsum. Larva are truly aquatic thus called naids, breath by rectal gills; caudal gills are entirely absent. [Fraser 1936)

Actual data of these dragonflies is not available but according to Imm's more than 5000 species including 500 genera are reported in the world from whole odonate order. Half of these may be the true anisopterans In 1985, the

aniosoptera included over 2,500 species belonging to 7 families (Davis and Tobin 1984, 1985) They are evenly distributed throughout the world and certainly many of them are yet to be discovered.

1.3 Importance

These dragonflies are very important due to their predatory habit both in land and water, and a useful group of biological assessment and conservation planning because of their work as indicator and flagship [Corbet, 1999). These anisopterans are one of the predominant and dominant insects which are widely distributed through out the world. They attain their greatest abundance in oriental and neotropical region, and except Japan no part of palaearctic zone contains abundant dragonflies (Imm) Thus are sun loving insects and are found dancing here and there in the sky during sunny days.They are frequent in mid temperate region and less frequent in hot and cold region(imms).

The predatory behavior of these dragonflies is the most valuable and interesting topic for the world to study. The capture of prey for the feeding purpose is mainly in flight or at rest is used by their forwardly directed legs to hold and transfer it to the mouthparts. Most adult species feed during the day but some species when feeding on swarms of Culicidae, Chironomidae or other Diptera may do at dawn or dusk(ref).

Some mature males exhibit territorial behaviour establishing themselves along the stretches of water which they defend against other males in which mating and oviposition takes place (Imms'-)

This behaviour tends to control the density of species in most suitable habitats, reduces disturbances to mating and egg laying and results in the dispersal of sexually mature males to new areas (Moore; 1953, 1964)

Larvae are aquatic and also predatory in habit. It possesses a highly specialized labium, lies just beneath the head and thorax and possesses between mentum and submentum, a hinge at which it is folded in two; it can be extend at will by opening out. It is known as mask and is employed in seizing its prey by means of the powerful hooks and jaws situated at it apex. (Fraser, 1933).

These colourful, brilliant insects are also important for in another environmental points of view as they are also taken as bio-indicator of pollution in aquatic community. As the dragonflies are much valuable present study is destined to work out the distribution of anisopteran odonates in Godawari as the place is good site for odonata collection (Vick, G.S. 1989) around Kathmandu Valley. The study has tried to fulfill the information gap on dragonflies.

1.4 Rationale of the Study

Dragonflies (Gainekira in Nepali) species are predaceous insects and which is first and foremost feature of the group to mankind for centuries. In recent years another important aspect of their life history has been known to the workers namely; bio-indication, attraction of tourists and biological control agents of Chironomid and culicid larva to a far more extent. Hence the present study was selected to reveal the status of anisopteran flies, their relationship with temperature, light etc, nature of predation and role in biological control and status of bio-indication. Structure of predatory orgns varies in adult and larva and doesn't vary in species wise. Their brilliant

colour, large size and diurnal habit are the easy point of identification which may be employed in population studies by counting their number.

1.5 Limitations of the Study

The present study is a partial requirement to fulfill the M. Sc. Degree and conducted without any budgeting. The dragonflies observed and captured could not be reared in the lab because of their long life span, natural habit and unavailability of proper instruments to maintain the necessary requisites for them. Due to the politically disturbed condition of the country, I could not go deep to the forest area of Godawari up to Phulchoki and around Phulchoki hill. Due to lack of pooper instruments communication and other behaviours of them could not be detected. Though certain behaviours like mating, egg laying, territoriability was observed in the field. Proper identification was also difficult due to lack of good literatures.

1.6 Objectives

The main objective of the work was to update the information of dragonflies in Nepal. The specific objectives are:

1. To explore the species diversity, community dominance and evenness with the analysis of habitat.
2. To study the conservation threats of dragonflies
3. Know spatial and temporal variation of dragonflies in Godawari valley over a complete year cycle.

2. LITERATURE REVIEW

2.1 Works Outside Nepal

The dragonflies are found every where in the world; mainly they are distributed in oriental and Neotropical region. We got much information on works in India and around it.

The first mentioned, we find of Indian dragonflies is the description of *Neurobasis chinensis* by Linnaeus in 1958, this, however from non-Indian specimen. There after, Johannsen followed with the description of *Rhyothemis variegata* in 1768 and Drury with some half dozen descriptions in 1773. Twenty years after fabricius, the pupil of Linnaeus, published in his 'entomologia systemica' (1792-94; suppl. 1798) a further eight description After 40 yrs Rambur published his 'Histoire naturelle des insects,, Nevropteres' which contained the description of over 20 species found within Indian limits. From 1850 to 1890, Barun Edmond, de Selys Longehamps made a advanced study and published a long series of paper dealing with dragonfly. After his death in 1890, a number of workers like Dr. F. Ris and Mr. E.B. Williamson, along with Dr. F. Laidlaw worked especially on Indian fauna. In 19th century from the inspiration of laidlaw and Williamson, fraser, started to publish a number of series from 1981,, Journal of the Bombay natural history society' which have now run to forty parts. He made a extensive survey in India and around it. (Fraser, F.C., 1933)

2.2 Works in Nepal

Odonatological research in Nepal was virtually non-existent in the period to 1950; the Rana rulers closed the country to the outside world and scientific

expeditions were not permitted. However the end of British rule in India, occupation of Tibet by china and the internal revolution of 1950 produced instability which led to the restoration of Royal power and opening up of the country to tourism. Since the early 1950's here has been a tremen- dous increase in the number of foreign visitors to the country and encouragement of scientific expeditions and development of trekking holiday has enabled odonatological work to advances.

The earliest records of dragonflies form Nepal were those of 'Selys (1854) in which *Anotogaster nipalensis* and O*nychogomphus cerastic* were described from Nepalese material. The first one is still common species in hill streams of Nepalese mid land.

Hagen (In selys 1859) also described *Caliphaea confusa*, from Nepal. *Neurothemis fulvia* was reported from Nepal by Selys in 1879. A few species were mentioned in the monograph on dragonflies of British India by Fraser (1933, 1934, 1936) like *Chlorogompus preciousus*, *Aristocypha quadrimaculata*, *Calicnemia miniata*.

However, although Nepal was effectively closed to scientific workers, F.C. Fraser of Indian medical service was discovering the faunistic richness of the Himalayas. His 3 volumes (fraser, 1933, 1934, 1936) was a milestone in systematic odonatology and made the identification of most Himalayan dragonflies possible.

After the opening up of Nepal, Asahina from 1955 to 1974 produced a series of papers on the findings of the Japanese groups which laid down the foundations of Nepalese odonatology. Most interesting discovery were *Epiophlebia laidlawi* in eastern Nepal (Asahina, 1963) and also in Kathmandu valley (Tani and Miyatake, 1979).

ST. Quentin (1970) also wrote a full account of discoveries of German and Australian expeditions (1961–1970) and summarized the information on altitudinal distribution.

Sharma (1970) recorded the material in the department of Agriculture in Kathmandu and gave a comprehensive bibliography of literatuee on Nepalese fauna.

The Netherlands centre for alpine biological research sponsored expeditions in Nepal in 1972, 1973 and 1976 and the findings were included in the valuable papers published by Kiuta (1772, 1974, 1975a, 1975b, 1976, 1977, 1982, 1983, 1984) and also in Kiuta and kiuta(1976, 1980, 1982). In these papers a considerable numbers of new records were detailed and results of cytotaxonomic studies presented.

Colin Smith (1978a, 1978, 1984) recorded several new species. of Gomphidae from Nepal.

Shrestha and Mahato (1984), Mahato (1985, 1986a, 1986b, 1986c, 1987a, 1987b, 1987c, 1987d, 1988a, 1988b, 1988c) and Vick (1985, 1986a, 1986b, 1987, 1988a, 1988b) have added considerably to the Nepalese society.

Taxonomic problems of certain genera were resolved with the publication by Asahina of important revisions of *Neallogaster* (1982b), Sympetrum (1984) and Chlorogomphus (1986a) and by Liftinck (1984) on *Cialionemia*..

Important contributions by Kiuta (1974, 1975b.1976, 1982) have laid the foundations for future studies on cytotaxonomy of Nepalese fauna. A preliminary checklist of Nepalese dragonflies was produced which have been presented by Kiuta (1984).

Mahendra Mahato colleted many specimens from Kathmandu and outside the valley and kept in Natural History Museum, Kathmandu since 1976 to1984 which made easy for identification. C.Smith also helped him and Smith himself presented much collection to the museum which are still there. An odonatologists, G.S. Vick, published a book on list of dragonflies from Nepal with altitudinal variation in 1987 on opusc.zool.flumin.43 (1989) which was also a good attempt on Nepalese dragonflies,

The formation of the International odonatological society, societas Internationalis (S.I.O.) in 1971, was a crucial step forward in dragonfly research and its journals of odonatologica (Since 1972) and Notulae odonatologicae (since 1978) provide vehicles for the dissemination of research. The formation of the Indian national office of SIO (1981) has enabled odonatologists from the subcontinent to co-operate more easily and to meet and exchange view at organized symposia. (Vick, G.S. 1989)

Lastly Prof. Dr. V.K. Thapa (1997) published 3 volumes on “An inventory of Nepalese insects” where he has induded a check list of Nepalese dragonflies in 6 Families including 70 Genera and 132 species which is the best attempt up to now in the odonatological research of our country.

No detailed study has made about these insects in ecological point of view in Nepal. However, Borer, et. al.(1981) and Richards and Davies(1977) has written a little in their books on the Habit, Habitat, morphology and behaviours.

Moore, (1997) has published a book on Dragonflies status survey and conservation plan where some important and crucial habits and conservation status with detailed study has included.

3. MATERIALS AND METHODS

3.1 Introduction of Study Area

Godawari is situated at Lalitpur district in Bagmati Zone, which is located 16 km south east of Kathmandu City and 10Km from Satdobato Lalitpur. Godawari hill lies at 85^{o}23'E to 85^{o}27'E longitude and 27^{o}33' N to 27^{o}37' N latitude. According to Hydrology and Meteorology department, Babarmahal, area covered by it is approximately sixteen square km. It is characterized by typical monsoon type of climate with rainy summer and dry winter. Mean annual ppt. is 115.3 mm which is higher as compared to Kathmandu. Although few spells of rainfall occurs also in winter, over 80% of total annual ppt is encountered during monsoon. Annual means of minimum and maximum temperature recorded at fishery department Godawari are $13^{o}$and 26^{o}c respectively. Day temperature in summer (March-May) often rises upto 30^{o}c and drops down to 20^{o}c at night and 18^{o}c to -5^{o}c during winter (Dec.-Feb). Sometimes frost occurs in winter but snowfall is very rare. Soil is of temperate rain forest type with marked acidity, low mineral nutrients and relatively low contents of organic matter and silt loam. Soil p^{H} ranges from 5.9 to 6.3.

According to hydrology and meteorology department Babarmahal, in 2005 Maximum temperature recorded in June was 27.9^{o}C and minimum 3.4^{o}c from December to January. Maximum rainfall was recorded in August as 381.5 mm and minimum 0 from November to March 2006.

The deviation in rainfall from that of Kathmandu. Could be attributed to the favourable arrangement of the folds of Phulchoki mountain for bringing

more ppt. down to God. Valley .God valley is more humid and cooler than Kathmandu. Two perennial sources of water, Naudhara and Godawari Kunda probably have underground sources of water which get muddy in monsoon due to flood water. Besides these 2 sources of water, there are perennial rivulets scattering here and these in the valley. 2 good sources of stagnant water namely Godawarikund pond and Coronation pond inside the Botanical garden are good sites for the breeding of dragonflies. The green forest of Phulchoki and other surrounding, the valley is probably a good source of water in the valley.

Because of well protection of the place by local people and effort of the government, it is the good sources of animals as well as insect diversity. Due to suitable temperature, altitude green forest surrounding it good availability of wet land and other suitable environments, Godawari is the best place for odonata collection around Kathmandu valley (Vick, 1989).

3.2 Site Selection

The study was conducted from July 2005 to June 2006 mainly Godawari was visited for collection purpose during the field trip knowing that it is a good site for dragonflies collection.

3.3 Review of Literatures

Review of literatures was carried out before the field work. Literatures from different sources such as biological abstracts, journals, articles, books, reports, conference papers were thoroughly reviewed before and after the field work. Secondary information was collected from different sources such as climatology data (temp., rainfall and relative humidity) from department of hydrology and meteorology, Babarmahal, some records from Natural History Museum etc.

3.4 Types of Data Collection

The dragonflies were directly observed in the field during sunny days and collected by sweeping net. The field was visited once a week in breeding season from June to September and once or twice a month after September to next June. So altogether 24 times was visited to Godawari and the behaviours like duration of flight, active time, feeding habit, mating behaviour and egg laying behaviours were observed and noted down in the field. Besides this, their morphological details were also noted. Data regarding physical factors such as slope, type of land, types of habitat (like grass land, forest, water sources) were also noted down. First collection was done at 2062/318 and final on 2063/2/5.

3.5 Description of each Habitat

3.5.1 Forested land

The forest where dragonflies were collected was a true natural forest to the side of Beekeeping development section, side of picnic spot and side of Godawari kund that was directing linked with the Forest of Phulchoki Mountain. Dominant vegetation was bushes and *Schima- Castanopsis* forest.

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3.5.2 Grassland

The grass land was dominated by small herbs like Dubo, Tripholium and graminae species .Some big trees were also observed in the open areas.

3.5.3 Cultivated Land.

The land is found at the lower part of valley where mainly rice and maize cultivation was seen at that time.

3.5.4 Stagnant water bodies

These places were found to be highly populated to that of dragonflies. There are mainly 2 sources of stagnant water which are pond following Godawari Kind and coronation pond inside Botanical garden. The water was not polluted inside garden and at Godawari Kund it was little polluted.

3.5.5 Flowing water bodies

There are good sources of flowing water. There are many small rivulets flowing here and there in Godawari. The water was little polluted due to crowd of tourists and thoughtless visitors.

3.5.6 Collection and Preservation

Insects were collected once a week in the breading time i.e. From Asar to Asoj and one or twice in rest months. Every Friday was used to go there. They were collected by sweeping net and immediately killed by injecting alcohol. At first they were killed by keeping in Ethylacetate but it was not so

reliable. Some of the dragonflies didn't die immediately. And due to wriggling their wings were found to be broken. So injecting by smallest injection with alcohol was more reliable and convenient too. After killing they were kept in triangular envelope made of paper with sufficient data. It was brought to room and pinned up in insect box using naphthalene ball for protection from small mites and others.

3.5.7 Identification

It was then identified by using identification keys following. Fraser (1934) and Richards and Davies (1977) and finally taken to the Natural History Museum for confirmation. It was tallied there for some of the specimens collected and preserved in the Museum.

3.7 Data Analysis:

3.7.1 Species Diversity

Species diversity was calculated by using Shannon's diversity index and Community dominance by Simpson's index, (Odum, where

$$\overline{H} = -\Sigma\left(\frac{ni}{N}\right).\ln\left(\frac{ni}{N}\right)$$

Where $\overline{H}$ = Shannon's diversity index

ni = importance value for each species

N = Total no. of importance value

[$\therefore$ Importance value = number of individual]

3.7.2 Evenness (e) $= \frac{\overline{H}}{\log s}$

Where, S = Total no. of species

3.7.3 Dominance (C) = $\Sigma\left(\frac{ni}{N}\right)^2$

C = Simpson’s dominance index.

4. TAXONOMIC CHARACTERS OF DRAGONFLIES WITH IDENTIFICATION KEYS

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4.1 Diagnostic Characters of Anisoptera

A. Hindwings as long as front wings and wider at base, the wings are stretched at rest with mainly veins and cells in the wings.

B. Eyes prominent large and covers most of the basal portion of heads antenna short, bristle like inconspicuous.

C. Abdomen long and slender, tarsi 3 segmented, length 20- 85 mm (Richards and Davies, 1977).

D. Fore and hind wings not petiolate, dissimilar in form and venation, hind wings broadened at the base, held horizontally, discoidal cells differentiated into triangle and supratriangle

E. Eyes large, never separated by more than their dorsal diameter and often contiguous dorsally, labium variable, male with 2 superior and 1 inferior anal appendages, penis jointed

F. Female with superior appendages only and ovipositor normal or atrophied.

4.2 Keys to the Families of Anisoptera

A. Eyes separated or meeting only at a point---------- 1.1, 1.2

B. Eyes more confluent at the vertex----------2.1, 2.2

1.1 Eyes only very slightly separated or meeting at a point, discoidal cells of fore and hind wings equal in size and shape or if dissimilar then median space traversed by one or more veins.---------- Cordulegasteridae
1.2.Eyes widely separated, discoidal cells unequal, hind wings more elongate than that of forewings, median space never traversed--- Gomphidae

2.1 Discoidal cells equally of same shape of size in fore and hind wings and situated equally distant from arc, costal and subcostal autenodal nervures not coinciding, the two robust primary antenodals present, middle lobe of labium large and fissured ----------Aeshnidae
2.2Discoidal cells diffeing in size and shape in fore and hind wings, that of forewings situated far distant from arc; middle lobe of labium very small, not fissured broadly overlapped by the lateral lobes; costal and sub-costal ontenodal nervures coinciding, robust primary antenodals absent---------- ---------- Libellulidae

4.3 Keys to the Genus and Species of Gomphidae

1) Usually only 2 (rarely 3 or4) transverse nervures between sectors of arc in forewing from arc to bifurcation of Rs, superior anal appendages as long as branches of inferior appendages and furnished beneath with a black robust spine or process----------*Anisogomphus* (Selys)

1.1 An incomplete basal antenodal nervure very rarely present nearly always

Nervures in the forewing ----------1.2

1.2. Only an upper humeral spot present, antehumeral stripes confluent with the middles of each half of mesothoracic collar so as to form the inverted T shaped figures---------- *occipitalis* (Selys)

4.4 Keys to the Genera of Aeshnidae

1. Base of hind wing without a notch; tornus (Postero-basal angle) of hind wing rounded in both sexes, anal triangle absent----------2

2. Segments 4 to 8 of abdomen with longitudinal supplementary ridges on the sides; superior anal appendages of male obtuse at apex; only 2 rows of cells between the origin of Cuii and IA of hind wing----------. *Anax* (Leach)

3. Membrane large extending upto base of wing; base of wing nearly as broad as the broadest part of wing; base of discoidal cell in forewing nearer level of arc than its own length----------4

4. Dentigerous plate of female specialized, produced posteriorly and ending in a number of robust spines; arc distal, promimal ontenodal nervure for a distance equal to one third the length between two primary antenodal nervures, hind femora armed with very closely set serrated spines, discoidal cells of same shape and size with 5 cells----------*Polycanthagyna*

5. Membrane not extending to the base of wing, base of hindwing much narrower than broadest part of wing; base of discoidal cell of forewing as far from level of arc as its own length----------6

6. Pterostigma long and narrow without any opaque cells beneath it, dentigerous plate of female ending in 2 long curved divariate spines, segment 3 of abdomen nearly always markedly constricted------ *Gynacantha*

4.4.1 Key to the Species of *Anax*

1. Frons with a black T shaped spot---------- *nigrolineatus.*

4.4.2 Keys to the Species of *Gynacantha*

1. Larger species with abdomen 45 cm or more and hind wing about 40 mm or more---------- 2

2. Upper surface of frons marked with thick black T----------3

3. Inferior anal appendages less than half the length of superiors, thorax without dark stripes---------- --4

4. Wings never tipped with dark brown---------- -5

5. Wings unmarked at base----------6

6. Superior anal appendage with a deep incision near its base in the inner posterior side----------*incisura* (Fraser)

4.5 Keys to the Genus of Cordulegasteridae

1. Basal space entire; tibia of male without a keel, ovipositor of female enormously produced----------–2

2. Base of hind wing of male rounded anal triangle absent---------- ---------- *Anotogaster* (selys)

4.5.1 Keys to the Species of *Anotogaster*

1. Abdomen with 52 – 58 mm hind wing 42 – 46 mm, females proportionally larger----------2

2. Costal, first antenodal nervures, arc, costal and distal sides of discoidal cells and basal portion of IA and MA bright yellow --------*nepalensis* (Selys)

3. Costal and all other nervures of wings black---------- 4

4.7 Abdominal segments marked yellow, frons bordered with black below and for its basal half above---------- *basalis* (selys)

4.6 Keys to the Genera of Libellulidae:

1. Tibiae of male without a membrane keel on flexor surface; base of hind wing in both sexes always rounded, thorax rarely metallic in colour, eyes without a projection at posterior border----------2

2. Lobe of prothorax large and fringed with long hairs----------3

3. Frons non metallic above---------- 4

4. Never less than 12 antenodal nervures in forewing, shape of abdomen variable----------*Orthretrum*(Newman)

5. Borders of discoidal field in forewing diverging widely at wing border-- 6

6. Eyes more broadly contiguous, discoidal cell in hindwing traversed, costal border of forwing sinous near base frons metallic above, discoidal field beginning with at least 3 rows of cells----------*Palpopleura* (Rambur)

7. Discoidal field with borders converging strongly at wing margin ----------8

8. Discoidal cell in forewing very narrow, its costal side only about 1/4th to one third the length of basal, a conspicuous suplementory nervure (IRii) present between Rii and Riii----------*Pantala* (Hagen)

9. Discoidal field with borders parallel or widely diverging at wing margin. ----------10

10. Discoidal cell in forewing broader, its costal side about ½ the length of basal; no supplementary nervures (IRii) between Rii and Riii---------- ---------- *Trithemis* (Brauer)

11. One row of cells between IRiii and Rspl----------12

12. Riii evenly curved not undulated, pterostigma smaller in hindwing than in forewing, apical angle of anal loop much more acute than distal ---------- ----------*Tramea* (Hagen)

13. Pterostigma unicolour, 1 or rarely 2 rows of cells between I Riii and Rspl ----------14

14. Wings coloured amber yellow at base or more broadly dark reddish brown, and often with a development of close second reticulation especially proximal to node, more than 1 cubital nervures in all wings----------*Neurothemis* (Brauer)

15. Wings usually uncoloured or with a small basal yellow marking in hind wings; no secondary reticulation in wings only one cubital nervure in all wings----------16

16. Red or ochreous species with basal or median yellow markings in wings----------17

17. Wings with small basal yellow marking eyes but slightly contiguous, face and from red, 91/2 to 10 ½ autenadal nerrures in forewing ---- ----------*Crocothemis* (Brauer)

18. Variably colored and dark species ,never or only partly red or ochreous----------19

19. Arc situated between the first and second antenodal nervures; 2 rows of cells between IRii and Rspl----------*Potamarcha* (Karsch)

4.7 Keys to the Species of *Orthretrum*

1. Males colored some shades of red ----------2

2. Males violaceous red due to a thin overlying pruinescence, frons blue-back anteriorly---------- *pruinosum neglectum* (Rambur)

3. Males colored brown or black with yellow markings, often pruinosed -- 4

4. Abdomen enormously swollen at base and then abruptly slimmed and compressed laterally to the end, black marked with greenish yellow, not pruinosed ----------*sabina* (Drury)

5. Abdomen variable but never very slim nor compressed laterally, mostly with pruinosed abdomen and thorax ---------- 6

6. Base of hind wing with a large black triangular marking ----------*triangulare triangulare* (Selys)

7. Base of hind wing without triangular marking---------- 8

8. Cuii of hind wing arising from the distal side of discoidal cell well away from its posterior angle ----------*luzonicum*

9. Costal border of wings and antenodal nervures black---------- 10

10 Abdomen long and rather narrow, often blue with pruinescence, thorax with very narrow whitish or creamy stripes---------- 11

11. Moderately large species with face black or frons blackish anteriorly; membrane black---------- *glaucum* (Braur)

4.8 Key to the Species of *Palpopleura*

1. Small dragonflies with robust build, coloured yellow with dark markings, abdomen blue with more or less colored and marked with black brown and yellow ----------2

2. Abdomen 14-16 mm and hind wing 15-21 mm in male and 13-14 mm and 18-21 mm in female respectively----------3

3. Male and female differ, a black spot in forewing of male, abdomen pruinosed light blue, sides of segment 1,2 and base of 3 yellow, anal appendages black----------*sexmaculata sexmaculata*

4.9 Key to the Species of *Crocothemis*

1. Male; abdomen 24-35 mm, Hind wing 27 – 38 mm, labrum blood red, eyes blood red above during life----------– 2

2. Thorax blood red, abdomen and anal appendages blood red ------- *servillia*

3. Length of abdomen 25-27 mm, hind wing 27-35 mm---------- 4

4. Differ from *servillia* by segment 8 and 9 of abdomen without black markings on mid dorsal carina, wings without brown suffusion apex---------- ---------- ----------– *erythraea*

4.10 Key to the Species of *Neurothemis*

1. Wings broadly dark reddish brown with neuration very close ----------2

2. Wings dark reddish brown from base to about middle of pterostigmata, apex of wings also narrowly opaque, brown to partly enclose, a clear window in each wing at apex ---------- *fulvia*

3. Base of wings golden yellow to as far distal as outer border of discoidal cell or a few cells beyond ---------- --4

4. Yellow area at base of wing not very sharply defined and rather pale in color, costal border of wings pale yellow to as far as pterostigma, a pale brown humeral stripe on thorax---------- *intermedia intermedia* (Rambur)

5. Yellow area at base of wing very well defined and deep amber – yellow, often enfumed with brawn, costal border of wings not tinted with yellow as a rule, humeral stripe absent on thorax---------- *intermedia atlanta* (Ris)

4.11 Key to the Species of *Trithemis*

1. Legs of ordinary length, pterostigma unicolour, body colour variable--- 2

2. Thorax and abdomen violaceous black, base of hind wing with a small dark brown spot, neuration black---------- *festiva*

4. Thorax and abdomen viollaceous crimson, base of hind wing with small redish brown spot, neuration crimson---------- *auroa* (Burmeister)

4.12 Key to the Species of *Tramea*

1. Wings coloured and marked at the base---------- -----2

2. Two large black spots at base of hind wing surrounded by a golden yellow areola, one in cubital space and other lying obliquely in anal area of wing, the 2 narrowly confluent near base of discoidal cell in base---------- ---------- *basillaris burmeisteri* (Kirby)

4.13 Key to the Species of *Pantala*

1. Head large, eyes broadly contiguous abdomen robust and dilated at basal segment---------- 2

2. Eyes reddish brown above, base of hind wing pale golden yellow as far distal as anal loop, anal appendages changing to black towards apex ---------- ----------*flavecens*

4.14 Key to the Species of *Potamarcha*

1. Thorax black in adult, wings with extreme apices tipped brown, anal appendages black---------- *obscura*.

5. RESULTS

5.1 Habitat analysis of Study Area

5.1.1 Vegetation

As the area is good and rich in wild fauna, the vegetation of Godawari is also rich. The valley is surrounded by dense forest in Phulchoki side. The forest mainly consists of *Schima-Castanopsis* plants. It is also filled up of *Dalbergia sisso*, *Alnus nipalensis*, Rhododendron and other temperate trees. In the study area, main vegetation was bushy with small herbs like *Berberis aristata*. Godawari Garden consists of variety of trees. In the side of Godawari Kund, there is dense *Schima-Castanopsis* forest. On the upper side and inside of Herbarium laboratory, *Schima-Castanopsis* and *Sisso* is found. There is a lot of good green pasture with variety of herbs here and there is Godawai valley. Lower part of valley consist of cultivated or agriculture land which mainly consist of rice and maize field. On the side of field there is a naked green hill with herbs.

At last, it could be concluded that the areas is rich in vegetation variety and thus variation is great in the case of vegetation.

5.1.2 Water resources:

Godawari is rich in water resources. There are 2 perennial sources of water namely Naudhara and Godawarikund. After Naudhara, Phulchoki forest starts and in the side of Godawari Kund also there is dense forest. Except these 2, there are other many small rivulets scattered here and there in Godawari. All these mix up and come out as a small river from Nahar.

5.1.3 Temperature:

The place is not so hot and not so cool. But the study period was little drier than previous one. The temperature ranges from 3.4^{o}c to 27.9^{o}c in the year according to Hydrology and Meteorology department Babarmahal, maximum 27.9^{o} temperature was recorded in June 2005 and minimum 3.4^{o}c in December and January 2005. Very less insects was observed in winter sunny days.

5.1.4 Rainfall:

The monsoon was little delayed in the study period. Due to this emergence of insect was little delayed in the year. Rainfall is frequent on Godawari. In the period maximum 381.5 mm rainfall was recorded in August 2005 and minimum or almost zero from November to March 2006. .

5.1.5 Relative Humidity

It is mostly variable in Godawari. There is variation of R.H. in the morning and evening in each month. It was 75-90 in morning while 65 to 85 in the evening. In the morning average R.H. was 85% and 80% in the evening.

5.1.6 Habitat wise Distribution of Dragonflies in Godawari

Table-1

Family/Species	Grass land	Forest land	Stagnant water bodies	Flowing water bodies	Agricultural land	Total
Family-Gomphidae						
Anisogomphus Occipitalis	-	-	2	-	-	2
Family-Cordulegastridae						
-*Anotagaster nipalensis*	-	1	2	1	-	4
A. basalis	-	-	2	-	-	2
Family-Aeshnidae						
Anax nigrolineatus	1	-	1	-	-	2
Gynacantha incisura	1	-	-	-	-	1
Polycanthagyna erythromelasa	1	-	-	-	-	1
Family-Libellulidae						
Orthretrum	2	2	19	3	5	31

triangulare						
O. pruinosum neglectum	5	-	26	-	7	38
O. sabina	3	-	14	-	-	17
O. luzinicum	-	-	1	-	-	1
O. glaucum	1	-	-	-	-	1
Crocothemis Servillia	5	-	20	-	-	25
Crocothemis species.	-	-	3	-	-	3
Trithemis festiva	1	-	8	-	-	9
T. aurora	2	-	21	2	2	27
Neurothemis fulvia	-	15	-	-	8	23
N. intermedia	-	-	-	-	2	2
Pantalla flavescens	9	-	-	-	2	11
Tramea basilaris burmeisteri	1	-	-	-	-	1
Potamarcha obscura	1	-	7	-	1	9
Palpopleura sexmaculata	2	2	1	-	6	11

5.1.7 Seasonal Variation of Dragonflies

Table-2

Family/Species	Rainy	Autumn	Winter	Spring
Family-Gomphidae				
Anisogomphus Occipitalis	+	-	-	-
Family-Cordulegasteridae				
Anotagaster nepalensis	+	+	+	+
A. basalis	+	+	+	+
Family-Aeshnidae				
Anax nigrolineatus	+	+	-	-
Gynacantha incisura	+	+	-	-
Polycanthagyna erythromelasa	+	-	-	-
Family-Libellulidae				
Orthretrum triangulare	+ + +	+ +	-	+ +

O.pruinosum neglectum	+ + +	+ + +	+ +	+ + +
O. sabina	+ + +	+ +	+	+ +
O. luzinicum	+	-	-	-
O. glaucum	+	-	-	-
Crocothemis Servillia	+ + +	+ + +	+ +	+ +
Crocothemis species.	+ +	-	-	-
Trithemis festiva	+ + +	+ +	+ +	+ +
T. aurora	+ +	+	-	-
Neurothemis fulvia	+ +	+ +	-	-
N. intermedia	+ +	-	-	-
Pantalla flavescens	+ +	+	-	-
Tramea basilaris burmeisteri	+	-	-	-
Potamarcha obscura	+	-	-	-
Palpopleura sexmaculata	+ +	+	-	-

Godwari was encountered with abundant number of dragonflies as it is a good preferred habitat for dragonflies (Vick G.S. 1989). Thousands of speciemens might have observed and hundred, might have captured but only 222 specimens within 4 families was brought for further study. Among them maximum no. of specimens were collected form the family Libellulidae and minimum Gomphidae. A total of 1300 specimens were collected form stagnant water and minimum 6 from flowing water. Form Libellulidae 15 species were captured among which 4 species were seen all other the year (in winter also). The species from cordulegesteridae was also seen the whole year but due to their strong flying habit very less was collected. As a whole from Gomphidae only 1 species was found and 2,3 and 15 species from Cordulegasteridae, Aeshridae and Libellulidae respectively.

Figure: 2 Habitatwise Distribution Among Different Families

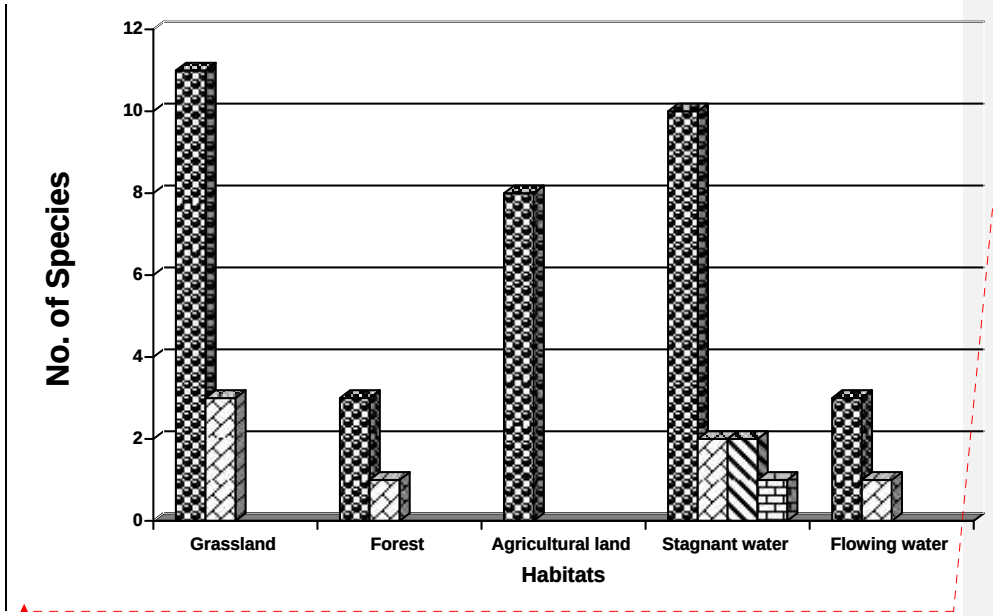

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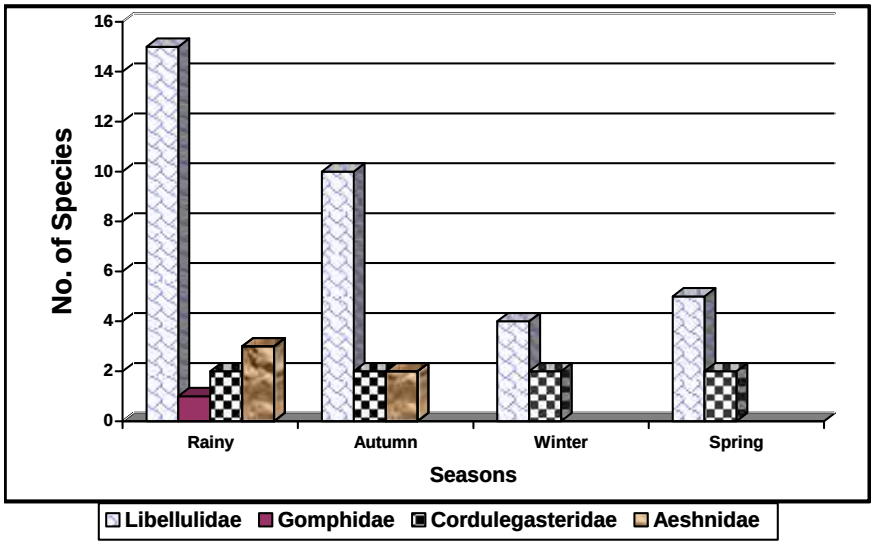
Figure-3 Seasonal Variation among Different Families



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5.1.8 Species Diversity of Dragonflies:

To determine the diversity of individual species, Shannon's diversity index was applied. It was based upon the relationship between total number of species and individual species within a family.

Table-3 Shannon's index for species diversity:

Family	(Pi). ln (Pi)	Evenness (e = $\frac{\overline{H}}{\log S}$)
Gomphidae	-0.14	0.65
Cordulegateridae	-0.22	
Aeshnidae	-0.27	
Libellulidae	-0.24	
	$\overline{H} = \Sigma(Pi).\ln(Pi) = 0.87$	

The four families showed not very many considerable differences in the diversity. The species diversity in Godawari was recorded 0.87. Evenness recorded is 0.65.

5.1.9 Community Dominance

It was recorded or calculated within each family and within each habitat and found as below:

Table 4 Simpson's community dominance within each family

Families	$\left(\frac{ni}{N}\right)^2$
Gomhidae	0.002
Cordelegasteridae	0.009
Aeschnidae	0.02
Libellulidae	0.51
	$C = \Sigma\left(\frac{ni}{N}\right)^2 = 0.54$

Community dominance within the families was found to be average as 0.54. Among the families, Libellulidae was found to be dominant as its value was 0.51 while Gomphidae was least as 0.002.

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6. DISCUSSION

———This is the first complete year cycle in the history of dragonflies collection in Nepal. Although the study has done in limited land, comparatively large number of species has collected in the comparison of whole Country. Previously 132 species within 60 genus and 6 families, has been reported from Nepal (Thapa, 1997). According to Vick(1989), 113 species are reported in Nepal. Present study has reported 21 species in the lower belt of Godawari alone. They were recorded in Nepal and they are found preserved in Natural History Museum, Kathmandu. According to Prasad and Varshney (1995), in India 139 Genus with 499 species has recorded. In the same way in Bangladesh 114 species, in Bhutan 6, in Pakistan 13 and in Srilanka 111 species has reported. This study projected the possibility of discovering more dragonflies in Nepal. Most of the individuals were collected form late may to October i.e. pre-monsoon, monsoon and post- monsoon period. These 6 months was found more active for dragonflies.

———Among these species; *Orthretrum pruinosum neglectum, Crocothemis servillia, Trithemis aurora, and Orthretrum sabina* were found throughout the year. They were less common in winter but their total no. never disappeared.

———Another common one *Anotogaster species* was also seen throughout the year but due to their strong and high flying habit, very less number was collected.

———Another common species was *Orthretrum triangulare triangulare* whose density or distribution was found variable in the year. It started to

seem from pre-monsoon i.e. from June to post monsoon i.e. upto September. During this period their distribution was so high that they seem every where

———Other species were also found common from June to September mainly.

———After September their number goes on decreasing and in winter only few species were abundant and *Orthretrum sabina* was also found in less number. This (0. *Sabina*) was appeared at late monsoon and less common at pre-monsoon i.e. from late August to early may it was not so common. It might have hibernating due to warm temperature and heavy rain. So from late may to early august it was not seen abundantly.

———Dragonflies were found quite abundant in sunny and warm rainy season mainly.

———Gomphids were less common and found only in rainy season. Only one species *Anisogompus occipitalis* was collected at rainy season and in other days it was not observed.

———Aeschnids were also found rare in the year and collected only during rainy season. 3 genera of this family were collected in rainy season around stagnant water bodies and in green pastures.

———Smith (1978 – 1981) has collected 21 species from Godawari in which 4 Gomphids, 14 Libellulids 1 cordulegasteridae and 3 Aeschnids are found to be registered in Natural History Museum. Among them *Anotogaster basalis, Polycanthagyna erythromelase Potamarcha obscura, Tramea basilaris burmesteri, Pantala flavescens* and sub-species of *Neurothemis intermedia* are not registered. But present study reported the presence of

these species also. It means there is the possibility of getting more new species. Other few species which he collected were from higher altitude.

———Vick (1989) has reported 113 species form the whole country with their altitudinal variation which include 25 Gomphida, 20 Aesunides, 1.3 cordulegaster, 7 cordallidae 48 libellulids

————The calculated species diversity 0.87 shows a good diversity of dragonflies in Godawari and community dominance 0.54 shows dominancy is also satisfactory, the evenness 0.65 shows they are not evenly distributed.

———Out of 21 species, 15 species were collected from a single family. Among these 4 species are the most common species found every where which was detected. 4 species (name already mentioned) were seen throughout the year. One species triangular was dominant except winter.

———Among 5 habitats, the number of dragonflies was found more around stagnant water bodies. The open and green ground near by the sources of stagnant water was found more suitable place for them to dance.

———Altogether 222 specimens collected, 127 specimens were found near by stagnant water bodies of Godawarikunda Pond and Coronation pond. The mating and ovipositing of them was also seen in the ponds. So these 2 ponds are found more suitable for dragonflies. A little far from the source of water, was also collected 36 specimens. They were mostly males and less females were observed in this area.

———In agricultural land very few species was observed. Only *Neurothemis fulvia* and *Palpopleura sexmaculata* was found permanently or abundantly in the rice field. *N. fulvia* was also found in the bushy forest in large number

but at that area trees were not so high and small herbs and shrubs was found. There were also some flowering plants.

———Around the flowing water no any permanent specimens was observed. They were collected just accidentally.

———Just around stagnant water bodies many dominant species was found always. They were; *Orthretrcem triangularge triangulare*, *Orthretrum Sabina*, *O.pruinosum neglectum*, *Crocothemis servillia*, *Trithemis festiva*, *Trithemis aurora* and *Potamarcha obscura*. They were maily seen around coronation pond and Godawari Kund . In other areas also they were found but the number was very less.

———Their flying period started from the bright sunny morning to evening up to sunset. If there is rainfall suddenly their flying number was zero. They were found hiding in the trees and under the leaves.

———In winter their flight period was found very short. It was just about 4-5 hours when the sun shines brightly. When there was warm noon only, they appeared at that time. In early evening and late morning too, they were not observed.

———It was observed by field trip that the dragonflies mate and lay eggs throughout the year. Few most common species like *Orthretrum pruinosum neglectum* was found in tandem during winter days also. After tandem, the female starts to lay eggs in water. In most Libellulids female laid eggs by flying above water and just touching water surface many times. At that time male was also found guiding if another male come there that was attacked by previous one(imms).

———But in cordulegasteridae females and males were found separately. Egg laying habit was also little different than Libellulids. The female rest to the plants near by water surface and kept her abdomen down to the water little deeper than Libellulids (borer Delong) At that time only it was captured. In other time it was very difficult to collect them.

The egg laying habit of Gomphids was also same to that of Libellulids. But the egg laying habit of Aeschnids was not observed in the field. According to Borer, Delong and Triplehorn they oviposit their eggs in plant tissues due to their strong and well developed ovipositor by the help of which eggs are inserted inside the soft tissue of the plants near by water source so that after hatching they can easily reach to the water. (Smith 1978)

———Talking about habitat, stagnant water was found most preferable for *Orthretrum triangulare triaugulare*, O. *pruinosum neglectum*, *Potamarcha obscura*,O. *sabina*, *Crocothemis servillia*, *Trithemis aurora* and T. *festiva* while agricultural land and forested land was found to be preferred by *Palpopleura sexmaculata sexmaculata* and *Neurothemis fulvia*. Others were found here and there. But at the evening just before or after sunset it was found mostly flying in the sky, can be assumed for food in sky.

———The exuvie of them was also found scattered here and there near the ponds.

———Dominance was found to be highest in open ground and grass land as 0.51. Almost all species was observed in the grass land and stagnant water and so relative density is also high in these two habitats. Density was low in and around flowing water, moist places and polluted environment as they are also regarded as the flagship for detecting pollution (IUCN)

———In heterogeneous environmental the distribution of a species depends upon the way it experience the area. Specialist species discriminate between resources and thus select only habitat patches suitable for them whereas generalist species are able to utilize several resources and use them in the proportion they occur. Thus the way the animals perceive their environment is species specific and the way the animals respond to their environment is also scale dependent. (Wiens 1989)

———Preferred temperature is an important physiological character of species and one that can be determined experimentally with good reproducibility. This preferred temperature is very narrow in case of dragonflies. Rising temperature after winter accelerates their activities and lowering after autumn retard the activities.

———Rainfall has direct influence on them. Their number increases after the commencement of rainy season and decreases at the end. In rainy days only one specimen was also not observed.

———R.H. also influences as less dragonflies can be observed in the early morning and late evening when it is high.

———Solar light intensity increases their activities while aquatic environment is also essential.

———Pollution has the most negative effect on them. Water pollution, mostly has more negative effect. Sewage or factory effluents, pesticide spray on agricultural land are other factors that affect them negatively. (IUCN 1999)

———Dragonflies are found to be most important species and their conservation is of great importance for the agricultural industry. However in

our country they are under a lot of threats form the rampart use of chemical fertilizers and pesticides. This useful group needs to be integrated into the manifold of integrated pest management (IPM).

———Various conservation measures should have done to conserve these important and valuable insects. The first need is to run the biological diversity. Secondly, they all are connected with the fact that dragonflies are exceptionally large, day flying insects. Like butterflies they are also beautiful creatures of terrestrial world. Their size and colour has brought them to the attention of people throughout the world so they have become part of the folk of many countries, notably in china and Japan, where they are the subject of poetry and paintings(Moore,1997) Their size make them suitable subject for biological research, as they can be observed and counted as birds.

———Some species are characteristic of particular habitats and so can be used for rapid mapping of the habitat where they represent. They vary in their sensitivity to different sorts of pollution. Although they are less sensitive than other aquatic insects their conspicuousness makes them valuable for quick assessment of water quality. The number of species present on lakes or rivers can be compared with that of an unpolluted site of same type. A count of dragonflies would provide a quick and therefore low cost of the indication of health and sickness of lake or river. (IUCN odonata specialist group).

———Dragonflies eat vast quantities of insects which are harmful to human beings. Recently it was proved that the larva of Libellulid dragonfly can be used deliberately to control the insect vectors of dengue fever, which breed in water (Sebastian. et. al. 1990)

———Finally it can be said without any hesitation dragonflies have very much importance on health and economic value. And thus they should be conserved.

———Comparison between past and present record shows that dragonflies have disappeared form numerous water bodies throughout the world. e.g. 42 species which were bred in the British Islets have become extinct there since 1950 (Moore 1999).

———The causes of declines are obvious. The most important cause is the destruction of habitat on which they depend. Forest clearance is the main cause of habitat loss which eventually causes the forest streams and pools to dry up or become clogged with silt. Forest clearance also causes the loss of habitat of dragonflies preys. Since most of them depend upon the tropical rain forest, the clearance of tropical rain forest for whatever purpose imposes the greatest threats to dragonflies (Moore, 1997)

———The damming of rivers for hydroelectric purpose and drainage has exterminated populations of species which depend on fast running streams in the USA and other its neighbouring countries (Vick, 1989)

———Pollution from sewage and industrial wastes, fertilizer run off and pesticide drift have greatly reduced dragonflies' populations throughout the industrial world. The wash of fast moving boats harms them by sweeping away newly emerging larva from their suitable habitat and by making water turbid and thus reducing the amount of submerged vegetation on which larva depend. This is the problem in tourist area.

———Thus it can be concludes that dragonflies are threatened throughout the world through habitat loss and pollution (Moore, 1999). Therefore action to conserve them is urgent.

~~6.1 A Strategy for Conserving Dragonflies~~

———Any strategy for conserving dragonflies must contain 3 basics

1. Establishing protected areas
2. Conserving habitats outside protected areas by modifying agricultural forestry and industrial procedures.
3. Carrying out supports to (1) and (2) as

a. Doing research works in protected areas to know their diversity

b. Controlling pollution in protected areas and around it.

c. Legislative approach to control pollution and to control unwanted destruction of their habitat.

d. Education and raising public awareness.

Protected areas are the places where conservation is the primary land-use although many tourism, research and some forms of agricultural and forestry may secondary land-use.

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———In Japan not less than 24 protected areas has been established primarily for dragonflies (Eda, 1995). Particularly important are the dragonflies kingdom at Nakamure established in 1987, Honmoku Citizens Park in Yokohama established in 1985 and rebuilt the pond in 1986, and conservation area at Okegayanuma to protect very few populations of *Libellula angelina* and others.

———In Great Britain 3 to four reserves have been set up like Ashton water dragonfly sanctuary designed principally to promote interest in dragonflies (Corbet, 1993).

———Other protected areas are the Wilson promontory National park in Australia (Sant and New, 1988), the Tambopata-candamo reserved zone in Peru in which 150 species. Of dragonflies have recorded (Paulson, 1985; Butt 1995)

———In our country also we can establish the protected areas for these important and beautiful species.

Not only conserving habitat inside protected areas is sufficient for their protection but outside the protected areas is also important necessity.

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———Supporting measures like research works primarily on taxonomy, mapping of distribution building database, habitat requirements are necessary.

———Pollution control mainly in waters, agricultural land and industrial belts are also most essential. It is also necessary to design the conserving of protected areas through legislation on endangered species is required.

———Unless public awareness and education all the conservation measures are incomplete. So the importance and value of these insects are how necessary to know the people of rural areas and interested pupils.

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7. CONCLUSION

——This study thus raises many more questions than it answers. How many more species of dragonflies could be there in Katmandu valley and in Nepal? What roles do they play in the environment? How do the urbanization, population growth and industrialization affect them? How can these insects be utilized for agricultural ecosystem? How can we conserve them and how could their microhabitats be established? How can they be used for the indication of pollution and biological water assessment? and many more.

——In conclusion, dragonflies are abundant and rich in Godawari as well as in the surrounding of Kathmandu. Valley. The species diversity was observed as 0.87 while their evenness was calculated as 0.65. Community dominance was found to be 0.54. Their thorough study can yield a wealth of knowledge in conservation, biodiversity, agriculture, taxonomy, ecology and numerous other fields. Species assemblages are very specific to their microhabitat. Wetland sunny habitat is the suitable place for them while their richness was very low in forest area far from water sources. Their abundance and richness is also affected by variation of temperature in different season and by the effect of many other environmental factors like rainfall, humidity, pollution etc. However, they are not directly disturbed by human brings but seriously affected by the foolish activities like pollution of breeding areas by thoughtless visitors.

8. SUMMARY AND RECOMMENDATIONS

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8. 1 Summary

———This study was started in July 2005 and continued up to June 2006. The study was carried mainly in Godawari but observation was done in many places in Kathmandu. Valley and outside valley. Godawari was represented by 5 different habitats viz. grassland habitat, forest land, running water, stagnant water and agricultural land, altogether 24 times was visited to Godawari in a year at different months. The data was collected and labeled with specific date and collecting place with altitude. Monthly variation of abiotic factors like rainfall, temperature and R.H. was taken from meteorological department Babarmahal. Similarly possible impact of pollution, habitat loss reproductive behaviour climatic effects and effects of other disturbances was also studied as far as possible.

———A total of 222 specimens were collected but about thrice of them may have captured. They belong to 4 families with 14 genera and 21 species. Among them about 55% specimens were collected from the periphery of stagnant water sources of Godawari Kund and coronation pond. Least specimens were collected from the periphery of fast flowing water.

———Among a total of 21 species, 15 species were recorded from Libellulidae alone while 1, 2 and 3 from Gomphidae, cordulegasteridae and Aeshnidae respectively.

———Shannon's species diversity index was obtained as $\overline{H}$ =0.87 while Simpson's community dominance was obtained as 0.54. Evenness was just 0.65.

———Among 5 habitats, highest no. of species were collected from grass land where 15 species was observed. In forest, stagnant water, Flowing water and agricultural land were 4,13,3 and 8 species were collected respectively.

———Temporal distributional study revealed that maximum species was observed and collected during summer days. Mainly sunny days of premonsoon, monsoon and post monsoon was found more suitable for them. Their number was maximum from June to early October. In winter their number decreases and few numbers of species were observed.

———Rainfall showed total hiding of them while R.H. and temperature also had negative effect.

———Study of their number in the microhabitats showed that they can not remain in polluted environment and their naiads were not observed in polluted water.

———The most serious problem faced was mainly climate of Godwari. The climatic variation mainly occurrence of rainfall in short interval without a day also made the study difficult.

———Another problem was lack of relevant literatures in Nepal and lack of experts. The identification was very difficult due to this fact.

The political disturbance of the country made difficult to enter into the depth of forest of Phulchoki.

8.2 Recommendations

Since these are very important insects their through study in the country in different microhabitats is urgent and immediate need because rapid loss of habitat in the country is leading to the extinction of these important and beautiful creatures.

1. Like foreign countries dragonflies protected areas is necessary to be established in order to conserve them mainly in Godawari because species diversity is high in that place.
2. Proper education and public awareness is most essential as many people of Nepal do not know the importance and value of the dragonflies.
3. They are the useful means of bio-control in agricultural environment. So they need to be integrated with IPM mainly as biological controlling agent.
4. Pollution, urbanization and chemical insecticides or pesticides in field has negative role for their conservation. So, the use of chemicals needs to be avoided.
5. They can be used as flagship organisms for the assessment of water quality. Therefore further study on this topic is necessary.
6. Mainly larva can be used for organic farming so that hazards of chemical fertilizer can be reduced.

REFERENCE

Asahina, (1982b). The larval stage of *Neallogaster hermionate* (Fraser) (Anisoptera-cordulegasteridae). Odonatologica 11 (4): 309-315, Figs 1-17.

- (1984a). The himaleyan dragonflies of genus *Sympetrum libellulides* Bull. Nat. Hist. Museus, Tokyo (a) 10 (3): 212-133. Figs. 1-40.

- (1986a). Revisional notes on Nepalese and Assamese dragonflies of genus *Chlorogmphus* (cordulegasteridae). Cho-chog (1): 11-26, Figs. 1-51

Asahina, S. in Moore (1994). Report of the 8th meeting of IUCN Odonata specialist groups, species survey Commission, International Union for the conservation of nature and natural resources (IUCN), 100: 9-12.

Allan, J.D. and Flecker, A.S. (1993). Biodiversity conservation in running water, Bioscience 43.

Borror, D.J., De Long, D.M., and Triplehorn, C.A. (1981). An Introduciton to the study of insects. 5th Ed. CBS Publishers, New York 197-212

Butt, M. (1995). Odonata collected from Tambopata-Candamo Reserved zones southeasters Peru, August 1992-January 1993, Notulae Odonatologicae **4**: 93-97.

Calvert, p.p. (1934). The rates of growth, larval development and seasonal distribution of genus *Anax* (Odonata-Aeshnidae*) proc. Am. Phil. Soc.*, **73**, 1-70.

Clark, H.W. (1940). The adult muscualature of anisopterous dragonfly thorax. Morph, **67**, 52 3-565.

Corbet, P.S. (1956a). Environmental factors influencing the induction and termination of diapause in the emperor dragonly, *Anax imperator* leach (Odonata-Aeshnide), exp. Biol., 33. 1-44.

- 1957 (a). The life history of the emperor dragonly *Anax imperotor* Leach. (Odonata-Aeshnidae). F. Anim. Ecol; 26, 1-69.

- (1999). Dragonflies behaviour and ecology of Odonata, Cornell University Press, Ithaca, NY.

Davis, D.A.L. and Tobin. P. 1985. The dragonflies of the world; a systematic list of the extinct species of Odonata Anisoptera, **2**.

Eda, S. (1995). The Conservation of dragonflies including endangered or vulnerable species in Japan. 19-22 in Corbet P.S. Dunkle, S.W. and Ubukata, H. (eds); proceedings of the international symposium on the conservation of dragonflies and their habitat, Khusiro, Hokkaido, Japan, 13-15 August 1993. Japanese society for preservation of birds, Khusiro.

Fraser, F.C. (1933). The fauna of British India including Ceylon and Burma; odonata **1.**, Taylor and Francis, London xiv + 424; 1folded map

- (1934), the fauna of British India including Ceylon and Burma: Odonata, Vol. II., Taylor and Francis, London xxiv + 398 pp. 120 text figs., 4 col.pls.

- (1936), The fauna of British India including Ceylon and Burma: Odonata. Vol.3 Taylor and Francis, London. Xii + 461 pp, 125 text figs; 2 pls.

Fraser, F.C. (1957a). A reclassification of order Odonata. R. Zool. Soc. N.S.W., Sydney. 133.

Hatch, G. (1966). Structure and Mechanics of dragonfly pterothorax. Annent. Soc. Am, **59**, 702-714.

IUCN (1966). IUCN red list of threatened animals IUCN. Gland, Switzerland, 368.

Kiuta, B. (1984b). Preliminary checklist of Odonata taxa published from Nepal (1954-1984).

Kiuta, B., (1975b). Cytotaxonomy of dragonflies with special reference to Nepalese fauna, lectures delivered at the Tribhuvan University, Kathmandu, vol. 2, Nepal research center, Kathmnadu, xii+78 pp. **5** text figs. 3 pls (Data for 42 species.)

Mahato M. (1988c), Dragonfly inventory of the survey of eastern and Mid western Nepal, with records of 5 species new to the fauna of Nepal Opusc. Zool. Flumin. **29**: (1-9) (45 species. in duling data from Pokhara and Dharan).

- (1964). Intra and inter specific competition among dragonflies Anim. Ecol. **33**, 49-71.

- (1985). Nepaka Gainekirako Yak Chhoto Parichaya, New Bull. Nat. Hist. Mus. **8** (114): 23-27- (19 species).

- (1987a). Barsat aghi paine Nepalka Kehi Gainekira, News Bull. Nat. list Mus. Kathmandu. **2** (1/4): 22-23 (17 species with localities)

- (1987b). Dragonfly and its economic importance Bull. Tribhuvan University, Kathmandu. **20,** (6) 4-5.

Maloeuf, N.S. (1935). The postembryonic history of the somatic musculature of the dragonfly thorax, morph; **58**, 87-115.

Mathur, K.C. (1962). The musculature of the head capsule and month parts of adult *Pantala flavescens* (Fabricius) (Odonata, Anisoptera, Libellulidae *libellulinae,*), F. Anim. Morph; **58**, 87-115 .

Moore, N.W. (1953). Population density in adult dragonflies. Anim. Ecol., **22**, 344-359.

Moore, N.W. (1997). Dragonflies status, survey and conservation action plan, IUCN/SSC. Odonata specialist group IUCN, Gland Switzerland and Cambridge, U.K., V+28.

Odum, E.P.(1996). Fundamentals of Ecology. Gayatri Offset Press. New Delhi. 574

Paulson, D.R. (1985), Odonata of the Tambopata reserved zone, Madre de Dios, Peru. Review of peruvion entomology. **27**: 9-14.

Prasad, M.and Varshney, R.K.(1995), A checklist of the order odonata of India including data on larval studies, Oriental insects, **29,** 385 - 428

Richards, O.W., and Davies, R.G. (1977). Imm's general textbook of entomology. 10th ed. Chapman and Hall, London **2**.l 494-520

Smith, C. (1978). Dragonflies of Nepal with particular reference to Kathmandu valley, part 2 – Gomphidae, J. Nat. Hist. Mus. Kathmandu **2.** (114): 67-71.

- (1981). Dragonflies of Nepal with particular reference to Kathmandu. Valley, Part 3, Agriidae and Gomphidae. J. Nat. Hist. mus. Kathmandu. **5** no. 3. 78-83

Sant, G. J. and New, T.E. (1988). The biology and conservation of *Hemiphlebia mirabilis* Selys. (Odonata-Hemiphlebidae) in southern

Victoria. Arthur Rylah Institute for environmental research Technical report 82.

Saunders, D.C. Meeuwing, J.J., and Kincent, A.C. J (2002). Freshwater protected areas: strategy for conservation, conservation biology 16 (I): 30-41.

Sebastion, A., Sein, M.M., Thu, M.H. and Corbet, P.S. (1990). Suppression of *Aedes aegypti* (Diptera-Culicida) using augmentative release of dragonflies larva (Odonata-Libellulidae) with community participation in Yongon, Myanmer, Bulletin of entomological research 80: 223-232.

Selys – Longchamps, E.de (1859). Additions au synopsis des calopterygnies. Bull. Acad. R. Belg (II) 7 (holotype le Nepal. 102-103)

Shrestha, R.L. and Mahato. M (1983), Some Odonates of Nepal. Jour. Of Nat. Hist. Mus. **7.** No. 4, . 82-91.

Slifer, E.H. and Sekhen, S.S. (1972). Sense organs on the antennal flagella of damselflies and dragonflies (Oodonata), intl. F. Insect morphol. And embryol; I, 289-300

Snodgrass, R.E. (1954). The dragonfly larva, Smithson. Misc. collns, 123 (2), 1-38 pp.

ST Quention. D., (1970). Odonata aus Nepal, Khumbu Himal. **3** (3): 389-411 pp. figs. 1-7.

Thapa, V.K. (1997). An inventory of Nepal's insect. (Protura-odonata) vol. 1, Biodiversity publication series 1, IUCN, Nepal, Kathmandu, 98

Tillyard, R.J. (1928). The evolution of order Odonata. Part I. Introduction and early history of the order. ibid. 30. 151-172

Vick, G.S. 1989. List of the dragonflies recorded from Nepal with a summary of their altitudinal distribution, *opuscula zoologica fluminensia* (43), 1-21 pp.

Whitig, P., Tiwari, K.N. and Subba, K.J. 1986. Land Resources Mapping Project: Land Utilization Report Appendix one; Government of Nepal and Government of Canada, Kenting Earth Science Ltd. 483 pp.

Wienus, J.A. (1989). Spatial Scaling in Ecology Functional Ecology. **3**. 358-397.

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ANNEX 1

List of Plants Recorded from Godawari

1. *Alnus nepalensis* – Utis
2. *Artemisia japonica* – Titepati
3. *Barleria cristata* – Bhende kuro
4. *Berberis aristata* – chutro
5. *Castanopsis indica* – musure katus
6. *Castanopsis tribuloids* – Dhale katus
7. *Cedrus deodara* – Devdar
8. *Celtis australis* – Khari
9. *Centella asiatica* – Gholtapre
10. *Cinammomum camphora* – Kapur
11. *Duranta repens* – Nilkanda
12. *Euatorium adenophorum* – Banmara
13. *Eugelhardia spicata* – Mauwa
14. *Fraxinus Floribunda* – Lankuri
15. *Girardinia Palmata* – Sisnu
16. *Jatropha curcas* – Sajiwan
17. *Juglans regia* – Okhar
18. *Lyonia orlifolia* – Angeri
19. *Mimosa rubicaulis* – Boksighans

20.*Myric esculenta* – Kafal

21.*Oryza sativa* – Rice

22.*Oxalis corniculta* – Chariamilo

23.*Pinus roxburghi* – Rani Salla

24.*Pinus wallichiana* – Salla

25.*Rhododendron arboretum* – Laligurans

26. *Rubus ellipticus* – Aiselu

27.*Rubus folious* – Kalo aiselu

28.*schima wallichii* – Chilaune

29.*Smiler menispermoidea* – Kukur daino

30.*Trifolium ripens* – Herb

31.*Vitex nigundo* – Simali

32.*Zanthoxylum* sps. – Timur

33.*Zea mays* – Maize

34.*Zizyphus incurva* – Hade bayer

Source: Botanical Garden, Godawari.

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ANNEX- 2

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List of Species Collected by Smith in Godawari

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1. *Orthretrum triangulare*
2. *Anisogomphus occipitalis*
3. *Anotogaster nepalensis*
4. *Neurothemis intermedia*
5. *Orthretrum sabina*
6. *O.glaucum*
7. *O. pruinosum neglectum*
8. *O. taeniolatum*
9. *O.luzonicum*
10. *Neurothemis fulvia*
11. *Trithemis festiva*
12. *Palpoleura sexmaculata*
13. *Crocothemis erythrea*
14. *Trithemis aurora*
15. *Anax nigrofaseiatus*
16. *Onycogomphus flavum*
17. *Anax nigrolineatus*
18. *Diploeodes trivialis*
19. *Gynacantha incisura*
20. *Nepagomphus modistes*
21. *Lamellogomphus biforups*

Source: Natural history museum, Swayambhu)

ANNEX-3

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Meteorological Data of Climatic factors

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Months	Rainfall (mm)	Temp. Max (^{o}c)	Temp. Min. (^{o}c)	R.H. (Morning)	R.H. (Evening)
January	72.6	15	3.4	86.4	90.4
February	14.5	19.7	5.1	81.2	87.9
March	39.6	22.4	9.1	88.6	82.4
April	88	26.5	10.9	78.4	79.8
May	89.1	26.1	13.2	75.6	65.2
June	221.9	27.9	17.7	80.6	65.4
July	272.7	25.4	18.8	88.6	79.6
August	381.5	25.4	18.9	89.5	84
September	141.6	26.7	17.5	87.6	83.7
October	117.5	23.7	12.3	85.3	81.1
November	0	20.2	7.2	88.7	82.6
December	0	18.4	3.4	85.1	81.2

Source: Hydrology and Meterology Department

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ABSTRACT

Dragonflies of Godawari were observed during the period of 12 months (July 2005 to June 2006). Five different habitats were selected as forest land, agricultural field, grass land, flowing water bodies and stagnant water bodies. Altogether 222 specimens were collected including 4 families 15 genera and 21 species. Altogether 24 trips were done to Godawari. Main collection and observation was done at Godawari valley.

For the collection sweeping insect net was used and after collecting, killed by injecting alcohol and kept in the triangular envelop. Then they were brought to the lab and preserved in preservation box with necessary data.

Among them maximum species collected were from Libellulidae, 15 species, and only one Gomphid was collected. 2 species from cordulegasteridae and 3 from Aeshidae were collected.

Among the habitat maximum 127 specimens with 14 species was collected from the periphery of stagnant water while only 36 specimens but 14 species were collected form green open sunny grassland of Godawari.

The species diversity was found 0.87 while evenness 0.65 and community dominance 0.54). To be adjusted in 2nd paragraph of this page.

Rainfall, and R.H. showed negative effect on them while low temperature showed negative and high temperature rainy days showed positive effect on them.

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It's my great pleasure to express immense gratitude to my respected supervisor Prof. Dr. Anand Shova Tamrakar for her continuous guidance, encouragement and help for my dissertation work. Without her help my dissertation would be incomplete.

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Finally, I would like to thank all the staffs of CDZ, my friends and other persons who are directly or indirectly related to my dissertation work.

SPECIES DIVERSITY AND DISTRIBUTION PATTERN WITH CONSERVATION THREATS OF DRAGONFLIES (ODONATA: ANISOPTERA) IN GODAWARI, LALITPUR

A Dissertation Submitted to the Central Department of Zoology Tribhuvan University, Kirtipur, Kathmandu

for the Partial Fulfillment of Master's Degree of Science in Zoology (Entomology)

By

Arjun Kumar Pokharel

Central Department of Zoology Tribhuvan University

Kirtipur, Kathmandu

Nepal

November 2006

RECOMMENDATION

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It is my great pleasure to mention here that Mr. Arjun Kumar Pokharel has completed his dissertation entitled "Species Diversity and Distribution Pattern with Conservation Threats of Dragonflies (Odonata-Anisoptera) in Godawari" under my supervision and guidance. This is the candidate's original work aiming to fulfill the information gap about dragonflies. To the best of my knowledge, his work has not been submitted to any other degree.

I recommend for the acceptance of this dissertation in partial fulfillment of the master's degree in Zoology specializing entomology.

Prof. Dr. Ananda Shova Tamrakar

Supervisor

Central Department of Zoology

T.U. Kirtipur

Kathmandu, Nepal.

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APPROVAL

On the recommendation of supervisor Prof. Dr. Ananda Shova Tamrakar, this dissertation work of Mr. Arjun Kumar Pokharel has been accepted as a partial fulfillment of master's degree in Zoology specializing entomology.

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Prof. Dr. Tej Kumar Shrestha

Head, Central Department of Zoology

Tribhuvan University, Kirtipur

Kathmandu, Nepal

Date:

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CERTIFICATE OF APPROVAL

The dissertation submitted by Mr. Arjun Kumar Pokharel entitled "Species Diversity and Distribution Pattern with Conservation Threats of Dragonflies (Odonata-Anisoptera) in Godawari" has been accepted as a partial fulfillment for the Master's Degree in Zoology specializing in Entomology.

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Expert Committee

Supervisor Head of Department

External Examiner

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~~Annex~~

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