Aquatic Benthic Macroinvertebrates' Biological Diversity and their Use in Habitat Quality Assessment at the Himalayan Hot Spots of Ganges River Basin

Thesis submitted in partial fulfillment of the requirements

for the degree Doctor of Philosophy (Ph.D.)

Submitted to the School of Science

Kathmandu University

By

Hasko Friedrich Nesemann, M.S. by Research

June 2009

Declaration by Student

I, Hasko Nesemann, hereby declare that the work presented herein is genuine work done originally by me and has not been published or submitted elsewhere for requirement of a degree program. Any literature data, or works done by others and cited within this thesis has been given due acknowledgement and listed in the reference section. The thesis contains eighty-eight colored figures originally drawn by me.

Signed:_____

Date:_____

Approved by:

_____ _____

Prof. Dr. Subodh Sharma
(Supervisor)
Kathmandu University
Date:

Prof. Dr. Ravindra Kumar Sinha
(Joint Supervisor)
Patna University
Date:

_____

External
Examiner:
Date:

_____

Head:
Date:

Abstract

The present study focuses on the Benthic Macroinvertebrate Fauna of natural running waters and semi-natural stagnant waters of Himalayan region and Lowlands in the Ganges River Basin. Habitat quality assessment using three different biotic scores was applied for 32 sampling sites of running waters and 26 sampling sites of stagnant waters. Benthic Macroinvertebrates were used as bio-indicators. Calculation of water quality was done based on a recently established five-class system, to describe the degree of organic pollution. Sampling localities are covering all longitudinal biocoenotic zones and lateral zones to include the traditionally well defined types of running and stagnant waters of altitudinal range from 54- to 2480 m asl. The impact of natural organic load was studied to describe the variation of Ecological quality classes within different eco-regions. Ecological quality was defined as a result of the water quality class together with the eco-morphology status of the water body. Class I (Excellent) is present only in spring-near headwaters of forested areas or in running waters coming from higher elevations between 490 to 2500 m asl. Class II (Good) and III (Moderate) is the normal reference condition for lowlands and the Gangetic plains. Wetlands, oxbow-lakes and "old" ponds have usually class II or III, independent from the grade of forests due to natural organic load accumulated during monsoon flood. Water quality undergoes seasonal changes from III (moderate) in pre-monsoon to II (good) during and after monsoon. The highest diversity with >30-42 identified taxa per sampling site (Class I) was found in the Rhithron zone of densely forested parts of Nepal, followed with >20-30 identified taxa by the Metapotamon zone (Class II, III) of large rivers in the Gangetic Plains of India. In stagnant water bodies the maximum diversity reaches >30-76 identified taxa (Class II, III) in Nepal and Maharashtra between 197-1170 m asl, whereas the floodplain wetland diversity reaches only 27 taxa (Class III). The proposed use of selected Insect-groups as bio-indicators for Lowlands and Middle Mountains includes colored illustrated catalogue of Dragonflies (Odonata) Bugs (Heteroptera), and Cockroaches (Blattodea). 12 families with 31 taxa of Odonata Nymphs, 14 families with 27 taxa of Heteroptera Nymphs and Adults, one family with two taxa of Blattodea Nymphs and Adults are described and figured with

identification characters and ecological habitat observations. This will be the first key based on material mainly from Nepal and India for the Ganges River Basin.

Acknowledgement

The work for the present study was largely supported by my supervisors Prof. Dr. Subodh Sharma, (KU) and Prof. Dr. Ravindra K. Sinha (Patna University); I like to thank for constant encouragement and all help during my study periods in Dhulikhel and Patna. Prof. Dr. Panna Thapa, Dean of School of Science (KU) and Ass. Prof. Dr. Roshan Bajracharya, Head of Department of Department of Environmental Science and Engineering (KU), are duly acknowledged for accepting me as Ph.D. Scholar, giving room facilities for my stay at KU and allowing me to work as foreign student at Aquatic Ecology Centre (AEC, KU). Thank you so much for all! At Patna Science College, my supervisor Prof. Dr. R.K. Sinha, Prof. Dr. K. Prasad and Dr. Dilip Kedia have contributed to sampling, sorting of Ganga River and all scientific literature from their own large library. Dr. P.M. Sureshan (Officer-in-charge, Z.S.I.) is thanked for using the Library and Museum specimens of the Zoological Survey of India, Lower Gangetic Plains Regional Station, Rajendranagar, Patna. Many days of extended fieldwork were done with Dr. Gopal Sharma, Dr. Dilip Kedia, Ajit Kumar Singh [in India], Ram Devi Tachamo, Deep Narayan Shah [in Nepal] who were always behind getting a most complete inventory of Macroinvertebrates. Thank you all for excellent team work throughout numerous years and especially for helping in identification of difficult aquatic insect-groups and proving some photo materials.

The concept of thesis was largely originated in Vienna, BOKU University; many thanks are due to Prof. Dr. Otto Moog, Prof. Dr. Mathias Jungwirth, Prof. Dr. Herwig Waidbacher, Dr. Berthold Janeček, Dr. Thomas Ofenböck, Dr. Wolfram Graf, Dr. Ilse Stubauer, Dr. Astrid Schmidt-Koiber, Martin Seebacher, D.I. Anne Hartmann and all members benthos group for any taxonomically support with their own excellent updated identification keys.

NHMW, the Natural History Museum in Vienna, has helped very much with identification and scientific exchange. I wish to acknowledge the always helping mood of Dr. Helmut Sattmann, Dr. Herbert Zettel and Dr. Peter Dworschak in

identification any literature. Dr. Manfred Jäch is extremely highlighted for the scientific concept to focus on invertebrates of natural water bodies.

Prof. Dr. Karl Wittmann and Dr. Emmy Wöss (University Vienna) have identified Mysida and Bryozoa; sending frequently new literature.

SMF, the Nature Museum and Research Institute Senckenberg in Frankfurt/Main have to be mentioned in great support with taxonomical literature and scientific help. Special thanks are due to Prof. Dr. Michael Türkay, Dr. Ronald Janssen, Andreas Allpach and the stuff of the "Senckenbergische Biobliothek" in University Library, 2nd floor. Andreas Dorsch (Hofheim-Lorsbach) has given always help in literature research.

Finally I wish to thank for great help during thesis writing to my supervisors Prof. Dr. Subodh Sharma, Dr. Bibhuti R. Jha from KU-side, and Prof. Dr. R.K. Sinha (Patna University) and Dr. Gopal Sharma (Z.S.I.), who have made this work possible in always in helping mood.

My parents are very much acknowledged, their support has given possibility to complete this study.

Terms and Abbrevations

AEC	Aquatic Ecology Centre, KU
Alluvial	Holocene
asl.	Above mean Sea Level
ASPT	Average Score per Taxon
BOKU	Universität für Bodenkultur Wien
Carboniferous	Coal age of Paleozoic
CNP	Chitwan National Park
Cretaceous	Chalk period of Mesozoic
Glacial	Hydrology: Glacier feed water
GRS-BIOS	Ganga River System Biotic Score
HKHBIOS	Hindu Kush Himalaya Biotic Score
Holocene	Alluvial
Jurassic	Period between Triassic and Cretaceous
KU	Kathmandu University
m asl.	meter above Mean Sea Level
m	meter
Mesozoic	Period between Paleozoic and Neozoic
mm	millimeter
Neozoic	Period after Mesozoic
NEPBIOS	Nepalese Biotic Score
NHMW	Naturhistorisches Museum in Wien
Nival	Hydrology: Snow feed water
Paleozoic	Period before Mesozoic
Permian	Period between Carboniferous and Triassic
Pliocene	Youngest Tertiary
Pluvial	Hydrology: Rain feed water
SMF	Senckenberg Museum Frankfurt/Main
Tertiary	Neozoic Period before Holocene
Triassic	Mesozoic Period between Permian and Jurassic
USA	United States of America
Z.S.I.	Zoological Survey of India
µm	1/1000 mm

Chapter Index

Figure Index

Table Index

Chapter 1: Introduction

1. 1. Introduction to Macro-Invertebrate Diversity of Ganga River System

Biological diversity is scientifically acceptable and objectively measurable parameter. It is nowadays frequently used and important gauge to decide the value of a particular habitat. Changes in diversity and taxa richness are used as indication of how a habitat is responding to any human impact and chosen kind of management (Capman 1992, Welch and Lindell 1992). Aquatic macroinvertebrates are traditionally used as bio-indicators for water quality, especially for monitoring the organic load of surface waters since more than one hundred years.

The catchments area of the river Ganges [English] or Ganga includes the Palearctic and Oriental regions with a sharp faunal boundary throughout the Central Himalayas in Nepal, especially in the rivers of Kali Gandaki/Gandak and Bhote Kosi/Kosi systems. The Indian subcontinent is a part the Oriental Realm (Menon 1990), which is covering most of south, southeast and far-east Asia. It was first figured and described by Wallace (1876). As per definition a zoogeographical Region is a geographical subdivision of the world that possesses a unique Fauna (Blachard 1870).

The benthic macroinvertebrates of running waters in Himalayan region and Ganga watershed include more than 200 families with much more the 7000 species. The knowledge of freshwater invertebrates of the Himalayan region and the northern Indian subcontinent is still very poor, only a few more popular groups like mollusks, some terrestrial insects or zooplankton crustaceans have early attracted scientific interest. Taxonomical studies are largely missing and the published results are more summarizing and listing already known geographical records. Except of few scientists who are encouraged describing new species, the literature on aquatic fauna of the last two decades is dominated rather by ‘review articles’ than by ‘research papers’. Although numerous proceedings and regular journals are released, the amount of new results is very limited; misidentifications are frequently published or presented in conferences, seminars and workshops. Many authors are using older nomenclature, although more updated identification keys with corrected genus and species name are available.

In many areas of the world the taxonomy of the organisms present is so poorly known that even diversity indices are of little scientific value, although inadequate ones may be of some political use. Even if appropriate literature exists, it is often not available to the workers in the field and laboratories. A more serious problem is that today very few people are trained to use the existing literature (Cook 1996).

Aquatic macroinvertebrates are submitting information of the environment and ecological quality not only of the actual condition, furthermore from the past: They can be used as long-time indicators for changes in environment, climate and geography, when their presence and community is related to fossil fauna.

For analyzing the present invertebrate communities the general background is required providing the following fundamental information's to answer questions:

1. What is the general present-day distribution of the Family/Genus/Species of the particular taxon? [Zoogeography]
2. What are the past distribution and possible geographical origin in geological time-scale? [Fossil range: Paleontology, Paleogeography, historical Zoogeography]
3. What is the geological "age" of the particular taxon? [Oldest fossil evidence: Paleontology]
4. Which are the ancestor groups of the particular taxon? [Fossil Morphology, Phylogeny]
5. How are the phylogenetic relationships and which are the closest living sister groups of the particular taxon? [Phylogeny, Systematic, Genetics]
6. Is the particular taxon spending the whole life cycle in freshwater or does it have terrestrial stages?
7. How and when the particular taxon has become adapted to life in freshwater habitats? [In terms of 'large-scale' taxonomical units: family, superfamily, order]
8. Is the particular taxon representing primary, secondary or peripheral freshwater fauna; marine relict or recent invader from estuaries?

9. What is the species-richness of the particular taxon [in terms of 'large-scale' taxonomical units: family, superfamily, order] of extant forms and fossil forms? When was the [estimated] highest diversification?
10. Are there morphological adaptations and modifications for aquatic life style and microhabitat, feeding and locomotion? [Significant for invertebrates of alleged terrestrial origin e.g. Insecta and Arachnida among Arthropoda, Lumbricina among Oligochaeta, Pulmonata among Gastropoda]

The answers of the questions may help in understanding the position, role and value of the invertebrates in the present-day ecosystem, giving much explanation for their suitability as bio-indicators. Recognizing relict distribution, relict fauna and distinguishing clearly from expanding zoo-benthos [= Neozoa] is an important subject in classification of living organisms. Furthermore 'living fossils' may allow looking into the biology of the past and their distributional limitation and present ecological niches can help explaining possible reasons of extinction.

The results of Paleontology and Paleogeography are not generally included and applied in Environmental Biology, although proving essential background of the former environment, its development within time that causes the present situation. Aquatic Invertebrates are especially useful as bio-indicators because of their macroscopic size, high numbers of individuals and frequent fossil occurrence often in excellent preservation. Despite from the fact that the majority of fossil organisms is in marine deposits, there are numerous estuarine, coastal, fluviatile, lacustrine and terrestrial deposits that have preserved freshwater and terrestrial Invertebrates in all continents. Previously poorly known, the fossil arthropods including insects and their aquatic stages were subject of extensive research within the last 25 years. Thus the knowledge has increased rapidly and fortunately much information is available about the origin and age of extant taxa. Walker (1993) demonstrated the importance of arthropod micro-fossils from Quaternary sediments for reconstruction of trophy and climate of the past centuries, despite the fact that traditionally mainly large-sized mollusk fossils have been used. Chironomids, Ostracods and Cladocerans are among the most favorable smaller invertebrates because their skeleton/jaws can occur in large quantities even in small amounts of sediments, whereas for mollusks much bigger samples are needed.

Plate 1: Study Area with Sampling Area (Next Page)

Fig. 1: Sampling Areas of the Present Study
Fig. 2: Zoogeographical Map

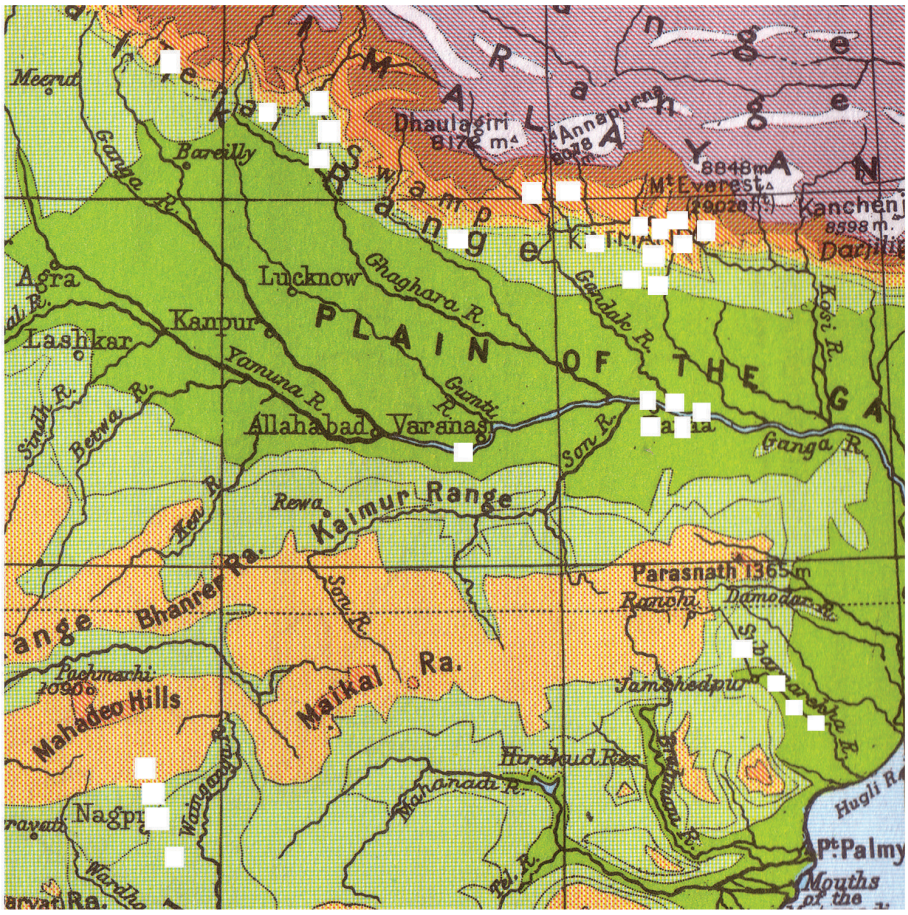
The present study focuses on more details from several groups of "old" aquatic insects that are dominating in benthic fauna of lowlands in the Ganga River System. Odonata and Heteroptera have drawn attention for the present study because of their tremendous importance in benthic communities, their esthetic, colorful appearance and [comparatively] large size.

1.2. Aim and Objectives

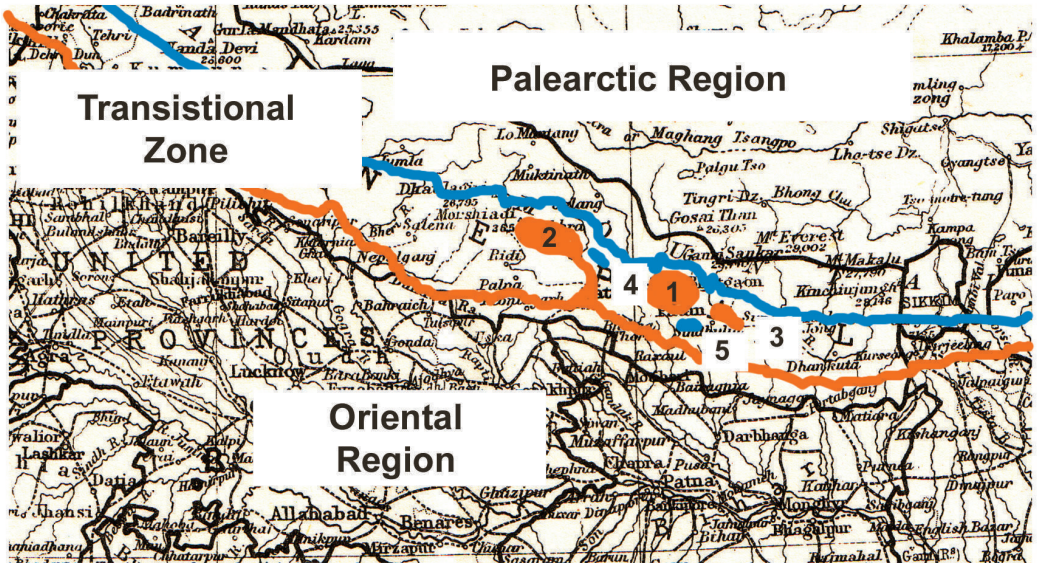
The aim of the study is to make a complete faunal list of the study sites, at least on family level for all captured aquatic macro-invertebrates. Special emphasis is given in the description of the faunal inventory of natural running waters according to respective drainage system and on stagnant waters and wetlands. Streams with less or no human impact in densely forested areas of the Himalayan Mahabharat Range and the foothills were investigated in detail for exact documentation of the benthic fauna in water bodies with low and natural organic load. Rivers were selected and their fauna was studied according to their already known "traditional" high ecological value. Another important priority is the benthic fauna of natural or semi-natural stagnant waters like lakes of the Himalayan middle mountains, wetlands and "old" ponds with extended shallow wetland connectivity to their environment.

In the past two decades studies and research using freshwater macro-invertebrates were mainly conducted in running waters to evaluate the impact of anthropogenic pollution. The requested results were more exact bio-monitoring data for the water quality classes and the status of ecological river quality of any selected particular place or area. In Nepal many sampling sites in the Middle Mountains, in Central and Eastern Terai have been investigated and worked out. That included a large number of polluted or even heavily polluted streams with reduced and poor faunal inventory. Not much time was given to find, select and study the rich and highly diversified macro-

Plate 1: Study Area with Sampling Sites



1 Samplings Area in Nepal and India from where Macro-invertebrates have been included into the present work, based on Investigations 2006 to 2009 (white rectangles).



2 Zoogeographical Map: Southern Boundary of Palearctic (blue) including Shivapuri-Nagarkot (4), Daman (5); Northern Boundary of Orientalis (red) including Pokhara Valley (2), Kathmandu Valley (1) and Kuntabesi (3) with Transistional Zone between the two realms.

invertebrate communities of pristine streams. Also stagnant water bodies and wetland have a large deficit regarding knowledge of typical benthic fauna and comparison of different altitudes within the region.

Therefore detailed survey was done in the floodplains of larger rivers and three 'Inner' Himalayan Valleys of Nepal: 1. The 'Inner' Terai of Rapti River as part of Kali Gandaki watershed in elevation of 280-286 m asl [situated "behind" the Siwalik]; The Pokhara Valley in elevation of 790-810 m asl; and the Kathmandu Valley in elevation of 1150-1300 m asl. The objective of the study is to use macro-invertebrates as bio-indicator of ecological water quality status of lentic habitats. Also the application of the presently used biotic scoring methods NEPBIOS and GRS scoring system with addition of faunal composition from unexplored stagnant water bodies is one of the important aims of the study.

The Rapid Assessment Approaches to bio-monitoring using macroinvertebrates was discussed and its need formulated more in detail by Resh and Jackson (1993). An overview the development of bio-monitoring with help of macroinvertebrates was given by Cairns and Pratt (1993).

- Application and critical Review of NEPBIOS, HKHBIOS and GRS-Biotic Score
- Finding of new Bio-Indicators
- Increasing the knowledge of the regional Fauna
- Ranking of Macro-Invertebrates according to their habitat, abundance and endemism

Furthermore some insect-orders were studied in detail with the object of developing materials for improved identification keys with data on taxa from the study area. This is the output of several years' identification experience and the use of different keys during the "Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal". Identification keys were compared and updated new data have been critically revised, showing the problems to work with the existing literature. One of the major topics is

the lack of detailed figures of aquatic insects and especially their fully aquatic larvae. The results compiled in the present work should be available for biologists to make field and laboratory identification easier and more clear on family level.

1.3. Review of Literature

The Ganga River System is famous for rich diversity of landscape, vegetation and climate because of extreme altitudinal variation. This often was brought into conclusion of existence of high biological diversity. The vertebrate fauna is relatively well known and many mammals, birds, reptiles and amphibians are directly related to wetlands and any other aquatic habitats. There is tradition of scientific interest and conservation of endangered vertebrates (Chaudhary, Singh and Sharma 2008). Fishes and some shellfishes (Crustacea, Mollusca) are valuable and favorite human food (Prabhakar and Roy 2008). The fish fauna of many rivers has been thoroughly studied, e.g. Sinha and Sharma (2003b), Jha (2006), Jha and Aava (2008). The most noticeable feature of the Ganga River System aquatic mammals is the occurrence of river dolphins *Platanista gangetica gangetica* which are highly endangered due to water pollution and habitat destruction (Sinha et al. 2001). The conservation of the dolphin populations is of great scientific interest, they are limited on river sections with high ecological integrity. Research work on river dolphins was mainly carried out in India by Sinha et al. (1992, 1993, 2000); Sinha and Sharma (2003a).

For several groups of non-insect's macroinvertebrates (Mollusca, Annelida, Crustacea) illustrated keys have been already compiled and applied within international group of taxonomists (Nesemann and Sharma 2006). Furthermore these materials were frequently used for training of students. A revised updated version with description of new species was published by Nesemann et al. (2007), including most of the taxonomically and zoo-geographically important new records of Sharma (1996), Pradhan (1998), Khanal (2001), Nesemann (2006), Shah (2007), Tachamo (2007), Sinha and Sharma (2001, 2003, 2005)

Aquatic insects of the Himalayan region have been recently covered with new identification keys used during the present study: Ephemeroptera by Soldán and Bauernfeind (2006), Plecoptera by Graf, Sivec and Schmidt-Kloiber (2006), Odonata

by Hartmann (2006), Coleoptera by Huber, Graf and Schmidt-Kloiber (2006), Heteroptera by Huber, Graf and Schmidt-Kloiber (2006), Trichoptera by Graf, Malicky and Schmidt-Kloiber (2006), and Diptera by Janeček (2006), Rozkosny and Brabec (2006)**,** Bouchard (2004).

In many of the available identification books for aquatic invertebrates, only the larger and more popular groups are covered, whereas the often frequently sampled smaller ones are missing e.g. Nematoda, Nemertini, Hydrocarina, Hydrozoa, sessile invertebrates etc. For the Asian benthic fauna two publications are very useful, giving detailed overview about the families, genera and species. Dudegon (1999) describes the macroinvertebrates of the tropical part of Asia for the more common orders, but he includes only a selection of more popular invertebrates used for Biomonitoring. Minor or difficult orders are not covered. Yule and Hoi Sen (2004) describing the aquatic invertebrates of inland waters from Malaysia. This work covers almost the complete diversity of freshwater species including semi-aquatic, coastal and possible brackish water fauna. Nearly all orders are compiled with figures and keys, giving an excellent identification help in recognition of uncommon and relatively unknown aquatic fauna.

In addition identification book from other continents were used to gather general knowledge about ecology and distribution for (genus-) family- and order-level. The works of Bouchard (2004): North America: Minnesota, Hutchinson (1993), Merritt and Cummins (1996), Needham and Needham (1984): USA, Pennak (1978): USA, Hartmann (2007): Himalayas; Kawai (2001): Japan, Kawai and Kazumi (2005): Japan; Morse, Yang and Tian (2003): China; Chinery (2004): Europe. These books are providing highly valuable information of family characters and family definitions; they are helping in identification when the same families are present in the Asian fauna. Identification of aquatic macrophytes and surrounding vegetation was done with the help of Cook (1996): Aquatic plants; Hora (1993), Storrs and Storrs (1998): trees; Lötschert (1995): Palms.

For the taxonomical work of the present study, the author has frequently updated the literature using the Zoological Record. It is publish annually in Volumes, including all worldwide published scientific articles [living and fossil animals] in registered

journals or books (with ISSN, ISBN number) independent from their citation-index, language or geographical distribution. The Zoological Record does not include most of the 'flourishing' not registered reports, proceedings and abstract books: These publications are difficult to find, their distribution is usually only per editor/author and they are often termed as "Gray Literature". Nevertheless for completing actual information about aquatic invertebrates [if available] they also have to be considered. Publications, abstracts and extended summaries published in the internet were also collected as source used for the present study.

Odonata Literature:

For insect's phylogeny, distribution and ecology the following publications were used: Summarizing work is given by St. Quentin and Beier (1968), Pennak (1978a)Ward (1992), Trueman and Rowe (2001), and Xylander and Günther (2003). Origin and position of Odonata and other aquatic insecta is discussed by Wichard, Arens and Eisenbeis (1995) and recently in the light of new classification of Hexapoda by Gullan and Cranston (2005). The 'primitive' wingless arthropod-groups Collembola, Diplura and Protura are no longer more included into the class insecta; they are regarded as distinctly separated hexapods. A new complete inventory of all extant Odonata species was compiled by Van Tol (2008).

For the Asian Odonata Fauna there are some important publications. Mitra (2003) gave detailed information of species occurrence in the different geographical regions of India, based on records of adults. Okudaira et al. (2005) published colored photos of all known larvae and adults from Japan. Photos of living larvae from natural habitat, showing their dorsal pattern are presented by Kawai (2001). Fauna lists for Nepal were published by Vick (1989), later on an extended and updated Nepal lists is given by Sharma (1998). For Bhutan Mitra (2006) has worked out the actual knowledge of faunal inventory.

Some important studies including larvae have been conducted by Kumar (1973) and Mitra (2005, 2006, 2007). Regional faunal research in India was done by Andrew, Subramanian and Tiple (2008); the role of Odonata as bio-indicators is described by Subramanian & Ramachandra (2008). Publications on the relict dragonflies

Epiophlebiidae, related to the present study are given by Tillyard (1921), Asahina (1961a, 1961b), Sharma and Ofenböck (1996), Vick (1996), for life cycle studies were done by Inoue and Sugimura (2008). Nel and Jarzembowski (1996) described the first fossil Mesozoic Epiophlebiidae.

About history, age and origin of Odonata and ancestors the following publications are important. For the Palaeozoic numerous works has been done by Zessin (2008a, 2008b, 2008c) including a complete inventory of genera of Odonatoptera. Faunal changes caused by the Permian-Triassic crisis were described by Evans (1972), Grimaldi and Engel (2005), and Shcherbakow (2008). Mesozoic Odonata were described and discussed by Nel and Jarzembowski (1996), Bechly (1999), and fossil larvae by Zhang (2000), Zhang and Zhang (2001). An outline of Mesozoic Odonata was figured by Malz and Schröder (1979).

Heteroptera Literature:

In older literature there was often no clear distinction between the order Hemiptera and the mainly aquatic suborder Heteroptera. Thus the precise interpretation of origin and geological age of aquatic bugs remain open. General information about Heteroptera is given by Pennak (1978b): USA, Hutchinson (1993): North America, Kawai (2001): Japan; a very detailed study about Southeast Asia is done by Chen, Nieser and Zettel (2005). Worldwide updated inventory of species is recently compiled by Polhemus and Polhemus (2008). Details about respiratory organs of Aphelocheridae are found in the book of Wichard, Arens and Eisenbeis (1995).

For the Indian subcontinent most important publications are done by Thirumalai, publishing numerous local faunas: Thirumalai (2001), Thirumalai, Suresh Kumar and Sharma (2004), Thirumalai and Sharma (2005), Thirumalai, Sharma and Sreedharan Namboodiri (2006), Thirumalai and Suresh Kumar (2006), Thirumalai, Sharma and Chandra (2007). A complete inventory of all Nepomorpha found in India was given recently (Thirumalai 2007). Kment and Jindra (2008) gave a “revision” of the family Gelastocoridae in Asia. Nahar (2004) has compiled the literature and museum data for aquatic bugs of Bihar and Jharkhand. For Nepal only very few scattered records were available (Thapa 1997). There are few records of Helotrephidae from the Himalayas

attracting scientific interest: *Mixotrephes (M.) kumaonis* (Polhemus, 1990); *M. (M.) nepalensis* Papacek and Zettel, 2003, *M. (Thermotrephes) freitagi* Papacek and Zettel, 2006.

Phylogeny, fossil occurrence and history of Heteroptera are rather well represented in scientific literature. About origin of extant families detailed studies and first records are given by Popov (1971): Nepomorpha, Popov (1992, 1996a, 1996b): Belostomatidae of Germany and Poland, Nel and Waller (2006): Hydrometridae. The earliest evidence of Heteroptera is mentioned from Australia by Shelling (2009).

Blattodea Literature:

Cockroaches are well known and a number of scientific studies are published, in general: Beier (1967), Meier (1974), Bohn (2003); about phylogeny and history: Grimaldi and Engel (2005), Gullan and Cranston (2005). Very little knowledge exists about aquatic and semi-aquatic Blattodea. There are only few 'original papers' by Annandale (1900, 1907), Green (1902), Shelford (1907, 1909), Takuhashi (1921) and Bishop (1973). The terrestrial fauna of India and regional distribution is compiled by Mandal (2003, 2006). The fossil records of roaches and their ancestors from Palaeozoic (The Ohio State University 2001) and Mesozoic (www.devoniandepot,com) allows conclusions about possible origin and age of the living species.

1.4. Materials and Methods

The present study is based on fieldwork and sampling carried out from September 2006 to January 2009. In field, the samples were collected by using hand net with mesh size 1 mm and 0.5 mm from different habitats and washing aquatic plants directly into trey and sampling container for receiving smaller invertebrates from the periphyton. Samplings were done only from around the bank of the lakes and reservoir. Samples were then transferred into plastic containers and preserved in 4% formaldehyde for a week to harden the benthos. In laboratory the samples were washed carefully by using hand nets with mesh size of 0.5 mm, transferred into a white enamelled tray with water and sorted animals from sediments into different groups in Petri dishes. The remaining fine particular material (kept in bucket) was washed with standardized sieves of 150 µm mesh size and sorted under stereo-binocular. This method is especially helpful to notice the presence of smaller annelids (Naididae, Enchytraeidae), small gatropods (e.g. *Ferissia* spp.), floatoblasts of moss-animals (Bryozoa), roundworms (Nematoda), hydra's (Hydrozoa) and aquatic mites (Hydracarina).

The sorted animals were identified to the family/genus level for most insecta and genus/species level for non-insects. The specimen were kept into vials according to their particular family and filled with 70% alcohol for further preservation. Identification of the animals was done using different magnification under microscope and the keys available from different sources. Effects to the macroinvertebrates fauna were investigated in terms of the changes in faunal diversity, community composition and abundance.

Abundance:

The relative abundance of each taxon was estimated on field observations and [after sorting and identification in laboratory] than finally described in abundance five classes according to Mason (1981) and Chapman (1992).

Number of Specimens in the Qualitative Sample	Description of Abundance	Abundance Class
1-2	Present	1
3-10	Few	2
11-50	Common	3
51-100	Abundant	4
> 100	Very Abundant	5

Table 1: Abundance Classes for Aquatic Macroinvertebrates based on Five-Class-System.

Plate 2: Sampling and Identification (Next Page)

Fig. 1: Sampling of Macroinvertebrates from submerged Macrophytes (Phytal) of Pupun River at Charichak, India, Bihar, Locality No. 11.

Fig. 2: Sampling of Macroinvertebrates from submerged Macrophytes (Phytal), Fishpond north of Pahari, India, Bihar, Locality No. 15.

Fig. 3: Sampling of large Bivalves shells *Parreysia rajahensis*, *Radiatula keraudreni* and *Corbicula striatella* from Subernarekha River at Moori, India, Jharkhand.

Fig. 4: Sorted Macroinvertebrate Sample of stagnant water pond from Kumhrar, Patna, India, Bihar, Locality No. 13.

Fig. 5: Identification Work using Nikon Entomological Field-Binocular at the Zoological Survey of India, Gangetic Plains Regional Station in Rajendranagar, Patna.

Plate 2: Sampling and Identification.

1

2

3

4

5

1.5. Longitudinal Zones of Habitat Types:

The running waters are classified into longitudinal habitats and generally distinguished into three different zones [or regions] according their biocoenotic community: Crenon, → Rhithron, → Potamon. This terminology was first time proposed by Illies and Botosaneanu (1963) mainly based on fish associations but in following years applied for benthic macroinvertebrates. The following types are recognized:

A.

Crenon: Spring regions of headwaters, highest places from where running waters are originated. The spring-water is less oxygenated and with more or less constant temperature throughout the year. It is mostly near to the average annual air temperature of the particular place. Common types of springs are:

i. Rheocrenon; ground-water is directly coming up and forming a small stream from the beginning.
ii. Limnocrenon: ground-water is coming up into a small stagnant pool or even pond with a stream effluent.
iii. Helocrenon: groundwater is coming up on a large surface without any distinct visible location, forming a swamp area. Downstream from this 'spring-wetland' small streams are starting.

Spring streams are in general named as Hypocrenon; these are very small and shallow streams usually without fish population.

B.

Rhithron: Upper region of running water often in hilly or mountainous landscapes. They are characterized by high oxygen and by higher water current, often with rocks, stones and gravels of various sizes. The water temperature increases but its annual variation does not exceed < 20° Celsius. The Rhithron can be also represented by large rivers with catchments in high altitudes bringing water from Glaciers and Snow-fields. From upstream to downstream following three zones or regions are named:

i. Epirhithron: Upper region of stream, predatory fishes are present with low species diversity.
ii. Metarhithron: Middle region of stream, highest diversity of cold stenotherm species.
iii. Hyporhthron: Lower region of stream or already smaller River, high diversity of species: dominating taxa of macroinvertebrates are more similar to upstream regions.

C.

Potamon: Lower region of running water often in smooth hilly lowlands or flat plains. They are characterized by lower oxygen and often with low current velocity, sedimentation of sand, silt and mud in various forms. The water temperature is high in summer and its annual variation always exceeds > 20° Celsius. The Potamon can be also represented by small rivers and streams with catchments in lowlands bringing water from natural swamps, ponds and paddy-fields. Even in higher altitudes of Himalayan Middle Mountains Potamon can be found in effluents of mesotrophic or eutrophic Lakes and ponds. From upstream to downstream following three zones or regions are named:

i. Epipotamon: Upper region of river, species diversity can reach maximum due to presence of Potamo-fauna, rheophilic species with high oxygen demand and still existing species of Rhithron in lotic habitats. Epipotamon usually has higher gradient than Metapotamon; the river bed is structured into riffles and pools. Deposited sediment- [substrate-] types can be small stones, gravels and coarse-grained sand of Microlithal, Akal and Psammal.
ii. Metapotamon: Middle and Lower region of rivers and longest biocoenotic zone of all large rivers, high diversity of warm stenotherm species and filter-feeders. Deposited sediment- [substrate-] types can be coarse-grained sand, fine sand, silt and mud of Psammal, Pelal, Detrial and Debris.
iii. Hypopotamon: Lower region of river with tidal impact and mixture with sea water, high turbidity and changing salinity, high sedimentation of silt and mud: dominating taxa of macroinvertebrates are in part related to

marine fauna. This biocoenotic zone can have extension over more than one hundred kilometres length of river coarse like in Hugli and numerous branches of the Gangetic delta.

1.6. Lateral Zones of Habitat Types:

Larger rivers and lowland rivers can have extended floodplains creating a network of water bodies with different lateral connectivity. In the original longitudinal concept of running waters the importance of the adjacent landscape and the interaction between the different water bodies were not sufficiently involved. This has created the development of the River Continuum Concept by Vannote et al. (1980) and a wider definition of the Potamon biocoenotic zone by Amoros and Roux (1988). Within large rivers the following habitat types are distinguished:

1. Eupotamon: The main channel of river with highest discharge is usually the largest water body of the system.
2. Parapotamon: Large water bodies; side-arms and branches with permanent open connection to the main channel. Their hydrological regime is prescribed by the main river, but they differ markedly in current velocity, sedimentation, substrate types, and annual range of water temperature. Water can have high turbidity and load of inorganic sediments. Parapotamon habitats might be linked upstream and downstream allowing some discharge or they are connected only downstream after the inlet is filled up with sediment.
3. Plesiopotamon: Large water bodies; oxbow-lakes and old river beds without direct [open] connection to the main channel. Their hydrological regime largely depends on the groundwater level in the floodplain. Plesiopotamon is mainly a lentic habitat, but surface water and groundwater is flowing through small channels, providing a continuous discharge and water exchange throughout the whole year. Water has low turbidity; the sedimentation is low and dominated by biogenic deposits from aquatic, animals and floodplain vegetation. In Plesiopotamon habitats there is no measurable or visible current velocity during low water saison; except of passages under bridges.
4. Palaeopotamon: Various sized permanent or temporary water bodies in old river beds which are largely filled up with sediments; they are situated in

greater distance to the main channel of river. Palaeopotamon habitats have no direct discharge and no direct connection to the drainage system of the floodplain. They can be pond-like water bodies or shallow temporary flooded swamps with reeds. They are often with high natural organic load and have thick biogenetic sediment layers of decaying plant material. Paleopotamon habitats have interaction with other water bodies only during high flood periods.

Littoral of running water systems: The Littoral zone is an important ecotone habitat; forming the linkage between aquatic and terrestrial realms. The term is used in different ways for inland waters and marine waters, a fact that makes some further explanations necessary.

In marine habitats, the Littoral is the seashore under the tidal influence which is periodically flooded, called Eulittoral. Adjacent are the shallow zones which are always under water, called Sublittoral. The splash zone above the highest water level, flooded during spring tide is called Supralittoral.

In classical Limnology, originally limited on (Freshwater-) Lakes only, Littoral is the shallow water zone with enough light intensity for growing aquatic macrophytes; mostly from 0-3 m depth.

In modern Hydrobiology running water systems are fully included and terms are used in synthesis to describe the banks of rivers and streams. The Littoral is the regularly flooded zone where no terrestrial plant cover can grow up. It is characterized by unique invertebrate fauna distinguished into amphibious, semi-aquatic or semi-terrestrial species depending on their origin. This habitat is more recently named as Eulittoral, its definition is borrowed from the traditional marine ecology.

1.7. Choriotopes – Biotic + Abiotic Microhabitats including Sediments Types:

The terminology of sediment types and biotic substrates follows the international applied system described by Chapman (1992), Moog (1995, 2002) and Aschauer et al. (2006). The following types are distinguished:

1. Pelal: < 0.063 mm, silt, loam and sludge.
2. Psammal: 0.063 mm - ≤ 2 mm, sand.
3. Akal: 2 mm - ≤ 2 cm, medium to fine gravel.
4. Microlithal: 2 cm – ≤ 6.3 cm, coarse gravel with mixture of medium to fine gravel.
5. Mesolithal: 6.3 cm – ≤ 20 cm, fist to hand-sized cobbles with a mixture of medium to fine gravel.
6. Macrolithal: 20 cm - ≤ 40 cm, coarse blocks, head-sized cobbles, mix of cobbles, gravel and sand.
7. Megalithal: ≥ 40 cm, large cobbles, blocks.
8. Gigalithal: Bedrock.
9. Saprobel: Organic sludge.
10. Detrial: Deposits of particulate organic matter. Different types are CPOM = coarse particulate organic matter (e.g. fallen leaves) and FPOM (= fine particulate organic matter).
11. Debris: Organic and inorganic matter deposited within the splash zone area by wave motion and changing water levels (e.g. mussel and snail beds).
12. Phytal: Submerged plants, floating stands or mats, lawns of bacteria or fungi, and tufts, often with aggregation of detritus, moss or algal mats; Interphytal = Habitat within a vegetation stand or plant mat.
13. Xylal: Tree trunks, roots, branches or other dead wood.

Embedded ness Definitions:

Loose (L): River bottom materials can be dislodged easily when stepped or kicked (e.g. sand gravel, detritus).
Embedded (E): River bottom materials are firmly in place and only dislodged with great effort: → typical result of stream armouring.

Solid (S): River section is flowing over exposed bedrock slabs of rock, or an artificial surface.

1.8. Study area and Sampling Sites

Out of more than one hundred investigated sampling sites, fifty seven were included in the present study, covering an altitudinal range from the Gangetic Plains [54 m asl] to the Himalayan Middle Mountains [2470 m asl]. Altogether thirty-three sampling sites were sampled for whole benthic fauna analysis in Nepal and twenty four in India. An overview of the study area is given in Plate .

Nepal:

Seven sampling sites are in the Nepal Terai, including three wetlands and the Karnali River as the uppermost distributional border of the migrating River dolphin. Four sampling sites from streams with catchments in naturally forested foothills of Hetauda and Chitwan were investigated. The Khageri Khola was sampled because it is the main supplier of Bishazari Tal. The upper Khageri Khola watershed has no human settlement. In the Nepalese Himalayan Middle Mountains stagnant waters of the large valleys of Pokhara and Kathmandu were sampled numerously in different seasons to gather information about the pre-monsoon and monsoon aspect of their fauna. Two watersheds of the Daman hills were studied thoroughly, because they are the most vulnerable habitats of the Himalayan Relict Dragonfly *Epiophlebia*. Numerous material of several insect-orders sampled during May to November 2006 is included into the thesis, especially collections from three surveys of the Lower Gangetic Plains at the southernmost part of Rautahat district, which allows direct comparison with similar habitats of Patna district, Bihar, in the same eco-region of moist deciduous forests. Excluded were samples from the Helumbo region in altitude from 2500-3900 meters above mean sea-level, because they are not in any context to the present study and they include mainly aquatic insect-orders in which the author is not taxonomically trained.

India:

The Ganga River as largest running water of the Indian subcontinent was investigated at ten sampling sites. Two sites in Uttar Pradesh upstream from urban area of Varanasi were studied as reference. Here is one of the unique places with natural stone substratum and bedrocks where the Himalayan-originated river meets with Palaeozoic sediment stones of the Gondwanaland. Eight sites were investigated in Bihar at Patna to include different choriotopes such as Phytal, Pelal, artificial Lithal, and natural Helocrenon- (Spring-) habitats. The Punpun River south of Patna City was sampled at two locations to include true lowland water (Eupotamon) with pluvial hydrological regime that is not under any mountainous impact. It also can be regarded as reference, since there is no discharge of waste water upstream. Six stagnant waters of the floodplain of Ganga River were sampled (Plesiopotamon, Palaeopotamon), some without any agricultural impact for documenting the natural organic load. Although far away from main rivers all are linked during monsoon flood for several weeks. Attending Symposium and Workshop on Odonatology in Nagpur, Maharashtra, there was the possibility to study forest water bodies of Tahoba and Pench Tiger Reserves which are free from any human disturbance. This is giving additional reference sites for the natural degree of organic pollution in deciduous forests from two streams and three wetlands. Numerous further locations in Bihar, Jharkhand and West Bengal could be studied with special aut-ecological research on insect-orders included into this thesis.

List of Study-Sites

Rivers of the Gangetic Plains:
Ganga River:

1. Ganga River at Chunar (Chunarghat), lenthic, Pelal, 10.March 2008
2. Ganga River at Chunar (Chunarghat), lotic, Lithal, 10.March 2008
3. Ganga River, Patna, upstream Krishnaghat, 13 March 2008
4. Ganga Springs at Mahendrughat, Patna, 18.+23. March 2008
5. Ganga River downstream from Mahendrughat, Patna, 18.March 2008
6. Ganga River at Adalat-Ghat, Patna, Periphyton, 20.March 2008
7. Ganga River at Adalat Ghat, Patna, 28. March 2008
8. Ganga River at Gandhi Ghat, Patna, 31. March 2008
9. Ganga River at Old Royal Palace, Patna, Lithal, 2.April 2008
10. Ganga River at Old Royal Palace, Patna, Phytal, 2.April 2008

Punpun River:

11. Punpun River at Gaurichak (Patna), Phytal, 4.April 2008
12. Punpun River at Gaurichak (Patna), Psammal, Pelal, 4.April 2008

Stagnant Water bodies and Wetlands of the Gangetic Plains:

13. Patna, Kumhrar, large Bivalvia pond, 25. March 2008
14. Patna, Kumhrar, central *Phoenix sylvestris* pond, 25. March 2008
15. Patna, Fishpond north of Pahari, 4. April 2008
16. Patna, Wetland-Channel at Pahari south of Fishpond, 4. April 2008
17. Patna, Bairia, *Eichhornia crassipes* Pond, 4. April 2008
18. Patna, Bairia, *Trapa natans* Pond, 4. April 2008

Wetlands and Forest Streams of Nagpur, Maharashtra:

19. Pench, forest spring stream (Tiger Reserve) 13. November 2008

20. Pench, Ambakhori-Totladoah forest stream, waterfalls (Tiger Reserve), 13. 11. 2008
21. Kamthi River north of Nagpur, Changaghat, 14.November 2008
22. Large shallow pond in grassland, Ghorpad northwest of Nagpur, 7. November 2008
23. Small and shallow forest-pond, Ghorpad northwest of Nagpur, 7. November 2008
24. Large shallow pond and wetlands at Tahoba (Tiger Reserve) 11. November 2008

Karnali River of the Nepal Terai:

25. Karnali River, Khote Ghat, Dothadi-9, Bardia District, 10.January 2008
26. Karnali River, Manau Ghat, Dothadi-9, Bardia District, 10.January 2008
27. Karnali River, Chisapani, Dothadi-9, Bardia District, 10.January 2008

Wetlands of the Nepal Terai:

28. Bishazari Tal, Chitwan District, November 2004, September 2006
29. Ghodaghori Tal, Kailali District, January + April 2007
30. Jagadishpur Reservoir, Kapilvastu District, January 2007+2008
31. Hetauda Fish-Pond, Makwampur District, September 2006

Wetlands of Pokhara Valley, Phewa Tal:

[A-32] Faunal Inventory of Phewa Tal, including all Collections 2005-2007
32. Phewa Tal at Khapaudi, northernmost shore of the open lake, March 2007
33. Phewa Tal, Old Harpan Khola Branch southwest of Khapaudi, March 2007
34. Phewa Tal southern shore, forest bank at Rani Ban, March 2007
35. Phewa Tal Forest bank + Rocks, southwest of Tal Barahi Temple, March 2007

Wetlands of Kathmandu Valley, Ponds:

36. Nagdaha, Lalitpur district, Premonsoon, 2. March 2007
37. Nagdaha, Lalitpur district, Monsoon, 3. July 2007
38. Nagdaha Outlet Stream, Lalitpur district, Monsoon, 3.July 2007

39. Nagdaha, Lalitpur district, Monsoon, 19. August 2007
40. Nagdaha, East, Lithal Substrate, 9. September 2008
41. Nagdaha, Northwest, Psammal Substrate, 9. September 2008
42. Nagdaha Southwest, *Nelumbo nucifera* habitat, 9. September 2008
43. Taudaha Lake, Kirtipur, 12.August 2007

Small Inner Terai Foothill Streams, Hetauda:

44. Ghatte Khola, Hetauda, Makwanpur District, September 2006
45. Trichaudi Khola north of Hetauda Makwanpur District, September 2006
46. Khageri Khola at Ratnanahar, upstream, Chitwan district, September 2006
47. Khageri Khola at Ratnanahar, downstream, Chitwan district, September 2006

Mahabharat Forest Streams, Makwanpur District:

48. Daman, Sim Bhanjyan Khola between Daman and Sim Bhanjyan, 21 Sep. 2006
49. Daman, Lower Sim Bhanjyang Khola, 21 September, 2006
50. Daman, Middle Sim Bhanjyan Khola, 11. November 2007
51. Daman, Left Tributary of Sim Bhanjyan Khola, 11. November 2007
52. Daman, Right Tributary of Sim Bhanjyan Khola, 11. November 2007
53. Daman, Sim Khola (upstream), 11. November 2007
54. Daman, Sim Khola (midstream), 10. November 2007
55. Daman, First Tributary of Sim Khola, 10. November 2007
56. Daman, Third Tributary of Sim Khola, 11. November 2007
57. Daman, Sim Khola below Sim Bhanjyan, 10. November 2007

Chapter 2 Ecological Integrity Assessment Methodology

2.1. Ecological Status and Water Quality

The proposed biotic scores for Nepal (NEPBIOS: Sharma 1996), for the Ganga River System and (GRS-BIOS: Nesemann, 2006) and for the Himalayan region (HKHBIOS: Ofenböck, Moog and Sharma 2008) are applied for the assessment of ecological status of the studied water bodies. It has to be mentioned that every existing scoring system covers only superficially the more important, abundant or visible aquatic invertebrates. Only counting on family level, there are much more than two hundred (estimated up to three hundred) aquatic, amphibious and semi-aquatic invertebrates of macroscopic size; living in the watershed of Ganga River.

The original NEPBIOS is commonly used in field; it includes 92 taxa as indicators mainly on family level. The purpose is to make a rapid field bio-screening possible that can be applied by taxonomically well trained and experienced scientists. The GRS-BIOS contains 376 taxa as indicators mainly on species level for important groups of non-insect's macroinvertebrates. It is specially developed for the use in lowlands and middle mountains below 2000 meter above sea-level. It also focuses on the stagnant water fauna of wetlands, lakes and ponds. GRS-BIOS are only applicable after thorough sorting and identification of the benthic samples in laboratory. Recently the HKHBIOS was established to cover all benthic macroinvertebrates-taxa of the whole Himalayan region and river systems originating from here. There are in total scores to 199 taxa assigned and the weight of indicative important fauna is taken into consideration with a three class system.

Ecological Quality Class

At present five (six) different water quality classes are distinguished and defined by macroinvertebrates and their communities. Together with the ecological integrity, e.g. lateral connectivity, riverbed morphology, the distinct water quality is used to describe the River Quality Class of running water bodies. For including stagnant

waters like in GRS-BIOS the term is modified and changed into Ecological Quality Class; that includes all surface waters either permanent, periodically, connected to running water system or isolated. The water quality classes and revised transformation are given in Table 2 from Sharma et al. (2009).

BIOS/ASPT	Quality Class	Quality Description	Mapping Colour
6.00-10.00	I	Excellent	Blue
5.00-5.99	II	Good	Green
4.00-4.99	III	Moderate	Yellow
2.50-3.99	IV	Poor	Orange
1.01-2.49	V	Bad	Red
No Macroinvertebrates	[VI]	Severe	Black

Table 2: Transformation of Biotic Scores to Water Quality Classes based on extended Five-Scales.

2. 2. Calculation of Average Score per Taxon (ASPT) - Value:

In detail the calculation procedure using ASPT value is described by Ofenböck, Moog and Sharma (2008) and Sharma et al. (2009). Here only a short explanation is given, using three different score lists mentioned above.

NEPBIOS:

ASPT Value = ∑individual Score value/∑taxa

GRS-BIOS:

ASPT Value = ∑individual Score value/∑taxa

HKHBIOS:

ASPT Value = ∑individual Score value · weight*/∑weight*

The weight* of each indicator taxon is given in the score list with a three class system as one-, three- or five.

All three biotic scores were applied for the different sampling sites since they have different qualities. NEPBIOS was especially created for running waters of the mountainous regions with dominance of coldwater fauna and insect families. Similarly is the HKHBIOS with more precise distinction of remarkable insects that can be recognized and identified in the field up to genus level, whereas species-rich groups of non-insect macroinvertebrates are included only on family level. The GRS-BIOS appears to be a compromise to fill the gap, but it requires much more identification work; it is more time-consuming and not applicable in field. The question which biotic score system is more suitable can not be answered generally. It is largely depending on objectives of the studies and on the altitudinal location of the study area.

Chapter 3. Gangetic Plains and Lowlands in India

3.1. Macro-invertebrate Communities of Rivers in the Gangetic Plains

Locality No. 1:		Ganga River, Chunar, lentic, Pelal	April 2004, 10. March 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		2
Heteroptera	Nepidae: Nepinae	*Laccothrephes spec.*	1
	Notonectidae	*Anisops sp.*	1
	Micronectidae	*Micronecta sp.*	4
	Corixidae		2
Diptera	Culicidae		1
	Chironomidae		3
Veneroida	Corbiculidae	*Corbicula striatella*	2
		Corbicula bensoni	3
		Corbicula aurea	1
Arcoida	Arcidae	*Scaphula celox*	1
Unionoida	Unionidae	*Lamellidens narainporensis*	1
	Amblemidae	*Radiatula caerulea*	3
		Radiatula shurtleffiana	1
		Parreysia favidens chrysis	3
		Parreysia corrugata laevirostris	2
		Parreysia viridula	1
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	3
		Mekongia crassa	3
	Thiaridae	*Melanoides tuberculatus*	2
		Melanoides pyramis	1
		Thiara scabra	3
		Thiara lineata	2
		Thiara granifera	1
Errantia	Nereididae	*Namalycastis indica*	3
	Nephthydae	*Nephthys oligobranchia*	2
Hirudinida	Glossiphoniidae	*Alboglossiphonia weberi*	1
		Placobdelloides fulvus	1
Total Number of Taxa			28

Table 3: Macroinvertebrate Taxa-List of Locality No.1; Ganga River.

\

Number of scored Indicator taxa from NEPBIOS: 10; from GRS-BIOS: 24

For original NEPBIOS = ∑individual Score value/number of taxa scores

40/10 = 4.00 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

126/24 = 5.25 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

68/15 = 4.54 Water quality class- **III**

Locality No. 2:		Ganga River, Chunar, lotic, Lithal	April 2004, 10. March 2008
Order	Family	Genus species	Abundance
Coleoptera	Dytiscidae		1
	Hydrophilidae		1
Heteroptera	Micronectidae	*Micronecta sp.*	2
	Corixidae		4
Diptera	Culicidae		1
	Chironomidae		2
Decapoda	Parathelphusidae	*Barythelphusa lugubris*	2
Veneroida	Corbiculidae	*Corbicula striatella*	2
		Corbicula bensoni	1
Arcoida	Arcidae	*Scaphula celox*	1
Unionoida	Amblemidae	*Radiatula caerulea*	3
		Radiatula shurtleffiana	1
		Parreysia favidens chrysis	3
		Parreysia corrugata laevirostris	1
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	1
		Mekongia crassa	3
	Thiaridae	*Thiara scabra*	2
		Thiara lineata	2
Basommatophora	Physidae	*Haitia mexicana*	1
Errantia	Nereididae	*Namalycastis indica*	1
	Nephthydae	*Nephthys oligobranchia*	2
Hirudinida	Glossiphoniidae	*Alboglossiphonia weberi*	1
Total Number of Taxa			22

Table 4: Macroinvertebrate Taxa-List of Locality No.2; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 18

For original NEPBIOS = ∑individual Score value/number of taxa scores

48/11 = 4.36 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

97/18 = 5.39 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

55/13 = 4.23 Water quality class- **III**

The Ganga River upstream of Chunar has natural stone substrate because the main channel is eroding exposed Palaeozoic rocks at the right (southern) bank. Hard substrate Macrolithal together with fine sand, silt and mud Psammal/Psammopelal was sampled to compare the benthic faunal composition with similar artificially created habitats at Patna. Both are lotic habitats with full exposition to the main current during monsoon, but often with low current velocity and fine sediment cover during late winter to summer in April/May. Additional lentic zones downstream were sampled; this locality is in a larger bay-like reach with thick silt deposits and numerous macrophytes.

Large freshwater mussels were more abundant in the soft bottom of the lotic habitat between the fixed bedrocks and Megalithal substrate. In or near the thick mats of submerged macrophytes and green algae Corixidae were more common than Micronectidae.

The biological water quality ranges between different results. The original NEPBIOS calculation confirms moderate organic pollution of Class III, but maximum only 50 % of the identified taxa are covered. Ganga River is moderately polluted using GRS-BIOS with Class II in both localities.

Locality No. 3:		Ganga River, Patna, upstream Krishnaghat	13. March 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		2
Diptera	Culicidae		4
	Chironomidae		2
Coleoptera	Gyrinidae		3
Veneroida	Corbiculidae	*Corbicula striatella*	2
		Corbicula bensoni	1
		Corbicula aurea	1
	Psammobiidae	*Novaculina gangetica*	1
Unionoida	Amblemidae	*Radiatula occata*	5
		Radiatula caerulea	5
		Radiatula lima	2
Mesogastropoda	Viviparidae	*Mekongia crassa*	5
	Thiaridae	*Melanoides tuberculatus*	3
		Thiara scabra	2
		Thiara lineata	1
	Pleuroceridae	*Brotia costula*	2
Errantia	Nereididae	*Namalycastis indica*	1
Haplotaxida	Tubificidae	*Limnodrilus hoffmeisteri*	1
Total Number of Taxa			18

Table 5: Macroinvertebrate Taxa-List of Locality No.3; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 9; from GRS-BIOS: 15

For original NEPBIOS = ∑individual Score value/number of taxa scores

39/9 = 4.33 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

83/15 = 5.53 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

52/12 = 4.34 Water quality class- **III**

Locality No. 4:		Ganga Springs at Mahendrughat	18. +23. March 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		2
Diptera	Culicidae		4
	Chironomidae		2
	Psychodidae		1
Coleoptera	Gyrinidae		3
	Dytiscidae		2
	Hydrophilidae		1
Veneroida	Corbiculidae	*Corbicula striatella*	1
Basommatophora	Physidae	*Haitia mexicana*	3
	Planorbidae	*Ferissia verruca*	Shell
Stylomatophora	Succineidae	*Quickia bensoni*	2
Hirudinida	Salifidae	*Salifa biharensis*	3
	Glossiphoniidae	*Alboglossiphonia weberi*	2
Haplotaxida	Tubificidae	*Limnodrilus hoffmeisteri*	3
		Aulodrilus pigueti	1
	Naididae	*Nais spec.*	2
Suborder: Lumbricina	Megascolecidae	*Perionyx excavatus*	1
	Microchaetidae	*Glyphidrilus gangeticus*	2
Nematoda			2
Total Number of Taxa			19

Table 6: Macroinvertebrate Taxa-List of Locality No.4; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

40/11 = 3.64 Water quality class- **IV**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

65/14 = 4.64 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

56/17 = 3.30 Water quality class- **IV**

Locality No. 5:		Ganga River downstream from Mahendrughat	18. March 2008
Order	Family	Genus species	Abundance
Diptera	Chironomidae		3
	Culicidae		2
Trichoptera	Hydropsychidae		1
Heteroptera	Micronectidae		2
Basommatophora	Lymnaeidae	*Radix persica*	2
	Physidae	*Haitia mexicana*	2
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	1
		Mekongia crassa	3
	Pleuroceridae	*Brotia costula*	2
	Thiaridae	*Thiara lineta*	2
		Thiara scabra	2
		Melanoides tuberculatus	2
Arcoida	Arcidae	*Scaphula celox*	1
Veneroida	Psammobiidae	*Novaculina gangetica*	2
Unionoida	Unionidae	*Lamellidens corrianus*	Shells
Haplotaxida	Tubificidae	*Limnodrilus hoffmeisteri*	3
Total Number of Taxa			16

Table 7: Macroinvertebrate Taxa-List of Locality No.5; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 10; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

42/10 = 4.20 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

67/14 = 4.78 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

57/13 = 4.39 Water quality class- **III**

Locality No. 6:		Ganga River at Adalat-Ghat, Periphyton	20. March 2008
Order	Family	Genus species	Abundance
Heteroptera	Micronectidae	*Micronecta sp.*	4
Diptera	Culicidae		1
	Chironomidae		1
Mysida	Mysidae	*Gangemysis sp. cf.*	2
Basommatophora	Physidae	*Haitia mexicana*	2
	Lymnaeidae	*Radix persica*	1
Mesogastropoda	Thiaridae	*Melanoides tuberculatus*	2
Haplotaxida	Naididae	*Nais spec.*	2
Total Number of Taxa			8

Table 8: Macroinvertebrate Taxa-List of Locality No.6; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 5; from GRS-BIOS: 6

For original NEPBIOS = ∑individual Score value/number of taxa scores

17/5 = 3.40 Water quality class- **IV**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

27/6 = 4.50 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

22/8 = 2.75 Water quality class- **IV**

Locality No. 7:		Ganga River at Adalat Ghat	28. March 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		1
Coleoptera	Gyrinidae		3
	Dytiscidae		2
Heteroptera	Nepidae: Ranatrinae	*Ranatra sp.*	1
	Micronectidae	*Micronecta sp.*	5
	Corixidae		3
Trichoptera	Hydropsychidae		3
Diptera	Chironomidae		2
	Culicidae		2
Diptera (Pupa)			1
Mysida	Mysidae	*Gangemysis sp.*	2
Mesogastropoda	Pleuroceridae	*Brotia costula*	1
	Thiaridae	*Melanoides tuberculatus*	3
		Thiara lineata	2
		Thiara scabra	1
	Viviparidae	*Bellamya bengalensis*	1
		Mekongia crassa	3
Basommatophora	Physidae	*Haitia mexicana*	3
	Lymnaeidae	*Radix persica*	2
	Planorbidae	*Ferrissia verruca*	1
Total Number of Taxa			20

Table 9: Macroinvertebrate Taxa-List of Locality No.7; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 15

For original NEPBIOS = ∑individual Score value/number of taxa scores

58/13 = 4.46 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

68/15 = 4.60 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

59/13 = 4.54 Water quality class- **III**

Locality No. 8:		Ganga River at Ghandi Ghat	31. March 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		3
Coleoptera	Gyrinidae		2
Diptera	Culicidae		4
	Chironomidae		1
Heteroptera	Micronectidae	*Micronecta sp.*	2
Unionoida	Amblemidae	*Radiatula occata*	4
		Radiatula caerulea	4
Veneroida	Psammobiidae	*Novaculina gangetica*	1
	Corbiculidae	*Corbicula striatella*	1
		Corbicula bensoni	1
	Sphaeriidae	*Pisidium clarkeanum*	3
Mesogastropoda	Pleuroceridae	*Brotia costula*	3
	Thiaridae	*Thiara lineata*	1
		Thiara scabra	1
		Melanoides tuberculatus	2
	Viviparidae	*Bellamya bengalensis*	1
		Mekongia crassa	3
Basommatophora	Lymnaeidae	*Radix persica*	2
	Physidae	*Haitia mexicana*	2
Haplotaxida	Tubificidae	*Branchiura sowerbyi*	1
	Naididae	*Branchiodrilus semperi*	1
Total Number of Taxa			21

Table 10: Macroinvertebrate Taxa-List of Locality No.8; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 18

For original NEPBIOS = ∑individual Score value/number of taxa scores

57/13 = 4.38 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

92/18 = 5.11 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

61/15 = 4.07 Water quality class- **III**

Locality No. 9:		Ganga River at Old Royal Palace, Lithal	2. April 2008
Order	Family	Genus species	Abundance
Coleoptera	Gyrinidae		3
Heteroptera	Micronectidae	*Micronecta sp.*	1
	Nepidae: Nepinae	*Laccotrephes sp.*	2
Diptera	Chironomidae		2
Mesogastropda	Viviparidae	*Bellamya bengalensis*	1
		Mekongia crassa	5
	Pleuroceridae	*Brotia costula*	2
	Thiaridae	*Thiara lineata*	2
		Thiara scabra	2
		Melanoides tuberculatus	2
Basommatophora	Lymnaeidae	*Radix persica*	3
	Physidae	*Haitia mexicana*	2
Arcoida	Arcidae	*Scaphula celox*	3
		Scaphula deltae	2
Veneroida	Psammobiidae	*Novaculina gangetica*	2
Unionoida	Unionidae	*Lamellidens corrianus*	3
		Lamellidens consorbrinus	3
	Amblemidae	*Radiatula caerulea*	3
		Radiatula lima	1
		Radiatula occata	3
		Parreysia favidens	3
		Parreysia corrugata	3
Errantia	Nereididae	*Namalycastis indica*	1
Haplotaxida	Tubificidae		2
Lumbricina	Microchaetidae	*Glyphidrilus gangeticus*	1
Hirudinida	Glossiphoniidae	*Alboglossiphonia weberi*	3
Total Number of Taxa			26

Table 11: Macroinvertebrate Taxa-List of Locality No.9; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 24

For original NEPBIOS = ∑individual Score value/number of taxa scores

48/11 = 4.36 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

139/24 = 5.79 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

85/18 = 4.73 Water quality class- **III**

Locality No. 10:		Ganga River at Old Royal Palace, Phytal, *Potamogeton crispus*	2. April 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		3
	Protoneuridae		1
Heteroptera	Belostomatidae	*Diplonychus sp.*	2
	Nepidae: Nepinae	*Laccotrephes sp.*	1
	Nepidae: Ranatrinae	*Ranatra sp.*	1
	Micronectidae	*Micronecta*	4
	Corixidae		2
	Pleidae	*Paraplea sp.cf.*	3
	Mesoveliidae		1
Coleoptera	Dytiscidae		2
	Hydrophilidae		1
Lepidoptera	Pyralidae		2
Diptera	Culicidae		1
Decapoda	Atyidae		3
	Glossiphoniidae	*Alboglossiphonia weberi*	1
	Viviparidae	*Bellamya bengalensis*	1
	Pleuroceridae	*Brotia costula*	2
	Physidae	*Haitia mexicana*	3
	Thiaridae	*Melanoides tuberculatus*	2
		Thiara scabra	1
		Thiara lineata	1
	Lymnaeidae	*Radix persica*	2
	Bithyniidae	*Digoniostoma pulchella*	1
Total Number of Taxa			23

Table 12: Macroinvertebrate Taxa-List of Locality No.10; Ganga River.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 17

For original NEPBIOS = ∑individual Score value/number of taxa scores

62/14 = 4.43 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

8217 = 4.82 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

67/13 = 5.16 Water quality class- **II**

The Macroinvertebrate community of the Ganga River is characterized by high number of filterfeeders and dominance of molluscs especially the large bivalves of the genera *Parreysia*, *Radiatula* and *Lamellidens*. They are concentrated along the fixed erosion banks and forming large 'mussel-beds' with millions of individuals. The animals are almost completely burrowed into the upper layer of thick silt-deposits. Only their siphons and sometimes part of the posterior shell are hold above the sediment surface. Thus the dense mussel-colonies are virtually invisible, except a few migrating specimens crawling on the bottom. It is noteworthy that the Amblemidae and Unionidae populations in Ganga River are well adapted to the hydrology and seasonal changing water level. Almost no death individuals are normally seen along the river banks except of some specimens in sediment catches brought up by local fishermen during net-fishing. All large freshwater mussels are moving down with the decreasing water level. The most striking on the bottom surface is the abundance of Prosobranchia, dominated by Viviparidae and Thiaridae. Three species *Mekongia crassa*, *Thiara scabra*, and *Thiara lineata* are common along the main channel. Crustacea are represented mainly by crabs *Barythelphusa lugubris*, prawns *Macrobrachium* spp., and shrimps of *Caridina* group. Since the year 2008 the Mysidae (*Gangemysis assimilis*) were found for the first time in the Ganga River at Patna, whereas they could not be collected in the same stretch from 2001-2004. Hymenosomatidae crabs (*Hymenicoides carteri*, *Neorhynchoplax nasalis*) are present in shallow zones only during winter season. Large Oligochaeta, the endemic *Glyphidrlus gangeticus* and the widespread *Perionyx excavatus* are confined to seeping springs along the erosion bank where groundwater and plant cover are providing a structural rich variation of microhabitats. The particular spring type where groundwater comes out over a large surface is termed as Helocrenal. These habitats are rare and have a very limited extension. They were observed along high erosion banks at Patna and Bhagalpur only.

The fauna of Macrophytes (Phytal) was investigated separately at locality No.10. A dense undisturbed colony of *Potamogeton cripsus* in 0.1-0.25 m water depth (Plate 3, Fig. 3) is Microhabitat of 23 taxa. Numerous Macroinvertebrates inhabit the Interphytal, which are not found in the open water of zones lacking plant cover. Among them there are interesting taxa of typical lentic zones, especially the

Heteroptera *Diplonychus annulatus*, *Ranatra* spec., Mesoveliidae and damselfly larva of Protoneuridae.

The fauna of artificial hard substrate with stones and bricks is represented with locality No.9 for the Patna section that can be compared with natural hard substrate at locality No.2 at Chunar upstream Varanasi. The localities have a very similar benthic community with some less common bivalves attached to surface with byssus: *Scaphula celox* and *Scaphula deltae*. The two species are usually found on Macrolithal and Megalithal (Plate 5, Fig. 2) but they also occur on CPOM like fallen leafs of *Ficus bengalensis* (Plate 5, Fig. 3). Occasionally *Scaphula celox* is fixed on the posterior shell of living *Parreysia* spp. and *Radiatula* spp. at places where the large bivalves are not fully burrowed into the sediment. According to earlier observations in 2003/2004 the Lithal substrate of locality No.9 is preferred by small crabs (Hymenosomatidae) and prosobranch Gastropods (Stenothyridae: *Gangetia miliacea*) during winter saison of year 2002/2003.

Along the river bank of the historical cities the fauna of artificial hard substrate appears to be well established and can not be distinguished from natural stone and rock substrates. The bank fixation and presence of Lithal over centuries has created equal Microhabitats as demonstrated with Figs 1 and 2 on Plate 3.

Plate 3: Habitats of Large Water Bodies.

Fig. 1: Ganga River at Chunarghat with natural Rock Substrate, India, Uttar Pradesh, Locality No. 2.

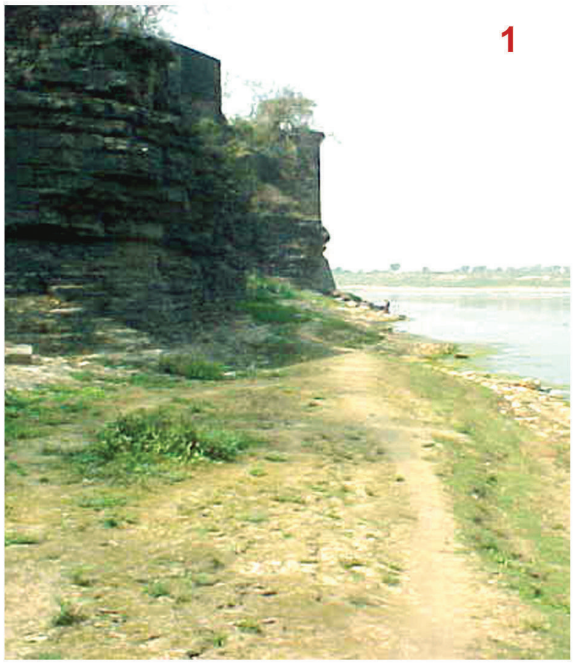
Fig. 2: Ganga River at Old Palace, Patna, with artificial Rock Substrate, India, Bihar, Locality No. 9.

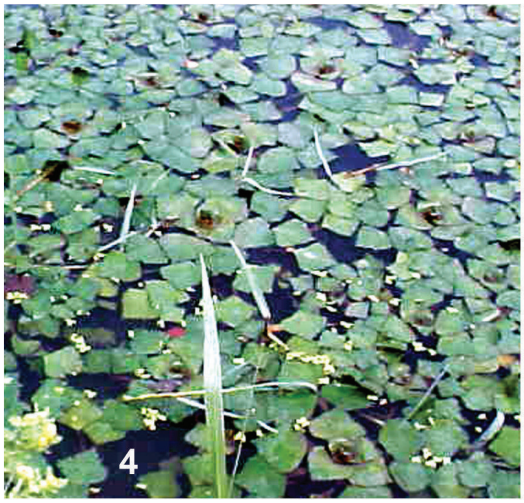
Fig. 3: Ganga River at Old Palace, Patna, with *Potamogeton crispus*, Phytal Choriotope, India, Bihar, Locality No. 10.

Fig. 4: Small floodplain pond with *Trapa natans*, Phytal Choriotope, India, Bihar, Locality No. 18.

Fig. 5: Phewa Tal, shoreline Macrolithal Choriotope with dense population of aquatic mites Arachnida: *Hydracarina* spp., Nepal, Pokhara Valley, Locality No. 34.

Plate 3: Habitats of Large Water Bodies.





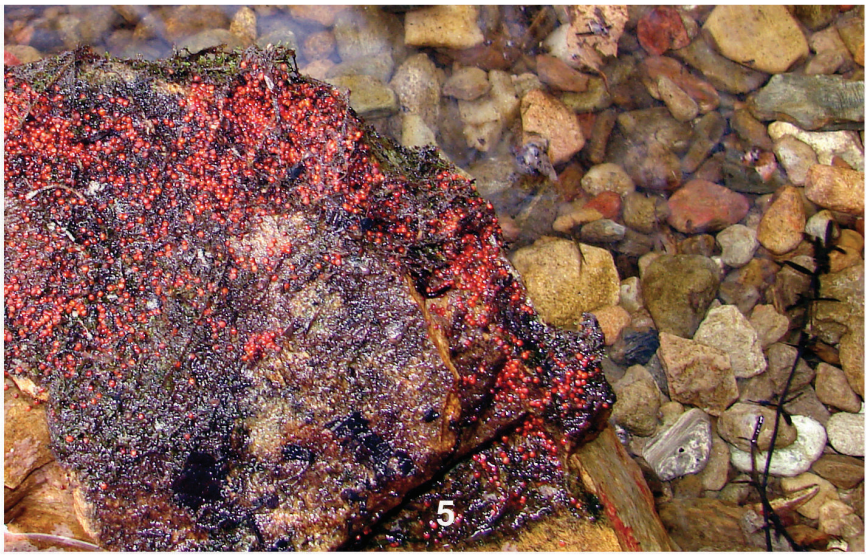


Plate 4: Helocrenon Habitats at the Bank of Ganga River.

Fig. 1: Ganga River at Mahendrughat, Patna, India, Bihar, Locality No. 4.

Fig. 2: Right Bank of Ganga River at Mahendrughat, Patna, with spring area.

Fig. 3: Helocrenon (seeping springs) at Mahendrughat, Patna.

Fig. 4: Helocrenon spring effluent at Mahendrughat, Patna.

Plate 4: Helocrenon Habitats at the Bank of Ganga River.

1

2

3

4

Plate 5: Non-insects Macroinvertebrates of Large Water Bodies.

Fig. 1: Gastropoda: Succineidae: *Quickia bensoni* at the bank of Kumhrar Pond, Hard Substrate, India, Locality No. 14.

Fig. 2: Bivalvia: Arcidae: *Scaphula celox* and *Scaphula deltae* attached on Macrolithal in the Ganga River at Old Palace, Patna, India, Bihar, Locality No. 9.

Fig. 3: Bivalvia: Arcidae: *Scaphula celox* attached on leaf of *Ficus bengalensis* in the Ganga River at Old Palace, India, Bihar, Locality No. 9.

Plate 5: Non-insects Macroinvertebrates of Large Water Bodies.

Plate 6: Non-insects Macroinvertebrates from Helocrenon Habitats at the Bank of Ganga River.

Fig. 1-3: Annelida: Hirudinida: Salifidae: *Salifa biharensis* at Ganga River at Mahendrughat, Patna, India, Bihar, Locality No. 4.

Fig. 4: Microhabitat of *Salifa biharensis*, Ganga River at Mahendrughat, Patna, India, Bihar, Locality No. 4.

Fig. 5: Annelida: Lumbricina: Microchaetidae: *Glyphidrilus gangeticus*, Ganga River at Mahendrughat, Patna, India, Bihar, Locality No. 4.

Fig. 6: Annelida: Lumbricina: Megascolecidae: *Perionyx excavatus*, Ganga River at Mahendrughat, Patna, India, Bihar, Locality No. 4.

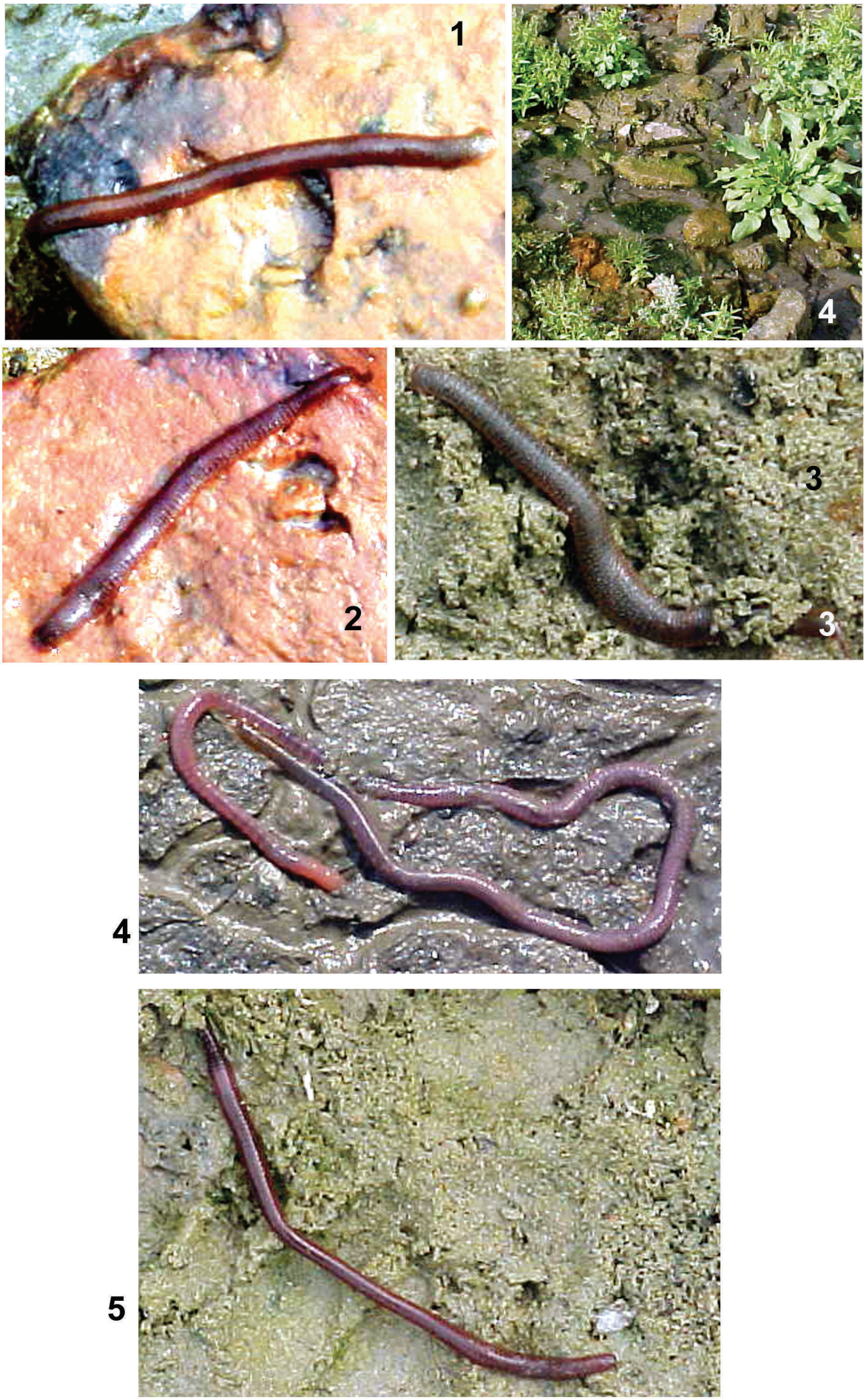


Plate 6: Non-insects Macroinvertebrates from Helocrenon Habitats at the Bank of Ganga River.

Punpun River

Locality No. 11:		Punpun River at Gaurichak, Phytal, *Potamogeton crispus, P. pectinatus, Najas tenuis*	4. April 2008
Order	Family	Genus species	Abundance
Odonata	Coenagrionidae		3
	Protoneuridae		2
	Libellulidae		3
	Gomphidae		1
	Aeshnidae	*Anax sp.*	2
Ephemeroptera	Baetidae		1
Heteroptera	Belostomatidae	*Diplonychus sp.*	1
	Pleidae	*Paraplea sp.*	4
	Corixidae		1
	Micronectidae	*Micronecta sp.*	1
	Nepidae: Ranatrinae	*Ranatra sp.*	1
	Nepinae	*Laccotrephes sp.*	2
Coleoptera	Dytiscidae		3
	Hydrophilidae		2
Lepidoptera	Pyralidae		1
Diptera	Chironomidae		1
Decapoda	Atyidae	*Caridina-group*	4
Veneroida	Corbiculidae	*Corbicula striatella*	2
Unionoida	Unionidae	*Lamellidens spec. juvenil*	1
	Amblemidae	*Radiatula spec. juvenil*	3
Mesogastropoda	Pleuroceridae	*Brotia costula*	2
	Thiaridae	*Melanoides tuberculatus*	2
	Bithyniidae	*Digoniostoma pulchella*	1
	Viviparidae	*Bellamya bengalensis*	2
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	1
	Planorbidae	*Gyraulus convexiusculus*	1
Hirudinida	Hirudinidae	*Hirudinaria manillensis*	1
Total Number of Taxa			27

Table 13: Macroinvertebrate Taxa-List of Locality No.11; Punpun River.

Number of scored Indicator taxa from NEPBIOS: 17; from GRS-BIOS: 21

For original NEPBIOS = ∑individual Score value/number of taxa scores

84/17 = 4.94 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

114/21 = 5.43 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

103/21 = 4.91 Water quality class- **III**

Locality No. 12:		Punpun River at Gaurichak, Psammal, Pelal, shallow water	4. April 2008
Order	Family	Genus species	Abundance
Odonata	Gomphidae		1
	Coenagrionidae		1
Heteroptera	Micronectidae	*Micronecta sp..*	1
	Corixidae		2
	Pleidae	*Paraplea sp.*	1
Coleoptera	Hydrophilidae		2
	Dytiscidae		2
	Chironomidae		1
Decapoda	Palaemonidae	*Macrobrachium sp.*	1
	Atyidae	*Caridina-group*	2
Veneroida	Corbiculidae	*Corbicula striatella*	3
	Sphaeriidae	*Pisidium clarkeanum*	2
		Pisidium nevillianum	1
Unionoida	Amblemidae	*Parreysia favidens*	3
		Radiatula occata	3
Mesogastropoda	Pleuroceridae	*Brotia costula*	2
	Thiaridae	*Melanoides tuberculatus*	2
		Thiara lineata	2
		Thiara scabra	1
	Viviparidae	*Bellamya bengalensis*	3
	Bithyniidae	*Digoniostoma cerameopoma*	Shells
		Digoniostoma pulchella	Shells
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	1
	Planorbidae	*Gyraulus convexiusculus*	Shells
Hirudinida	Hirudinidae	*Hirudinaria manillensis*	1
Total Number of Taxa			25

Table 14: Macroinvertebrate Taxa-List of Locality No.12; Punpun River.

Number of scored Indicator taxa from NEPBIOS: 15; from GRS-BIOS: 20

For original NEPBIOS = ∑individual Score value/number of taxa scores

72/15 = 4.80 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

104/20 = 5.20 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

68/15 = 4.54 Water quality class- **III**

The Punpun River is a right tributary of Ganga, forming a confluence with South Branch of Ganga at Fatuha downstream [east] of Patna. The Punpun River represents a rain-feed and groundwater-feed lowland river type, which is common elsewhere in the Gangetic Plains. One of the mains characteristics is absence of hilly or mountainous landscape in the watershed. The origin of river is in lowlands. These rivers do not transport high quantities of coarse-grained sand, gravel and pebbles; naturally stone substrates (Akal, Micro-, Meso- and Macrolithal) are lacking; the river bed is surrounded by alluvial floodplains only. The water has less turbidity than rivers coming from High-Altitude Himalayan range. Due to absence of frequent shifting of the main channel as in parts of Ganga, lower Kosi and Gandak, the river bottom is stable. It forms together with moderate current velocity an ideal substrate for dense aquatic vegetation. Frequently observed species were *Potamogeton crispus*, *Potamogeton pectinatus*, *Ceratophyllum demersum* and *Najas tenius*. The benthic fauna is accordingly rich because of the variety of numerous Microhabitats for lotic and lentic species.

The macroinvertebrate fauna includes typical river species but the characteristically Ganga-inhabiting species are not present at the localities No.11 and 12, e.g. Polychaeta, Arcidae, Psammobiidae, *Mekongia crassa*, several Corbiculidae and Isopoda of the family Cirolanidae. Some of them were found between November 1999 and May 2004 at Fatuha, where they colonize the mouth of river and move only several hundreds meters upstream.

Lentic and wetland species are well represented with *Diplonychus* spec., *Ranatra* spec., *Paraplea* spec., Protoneuridae and Pyralidae. Among the leeches the occurrence of *Hirudinaria manillensis* in the main channel of the river is noteworthy, since it is an endangered pollution- and disturbance-sensitive species.

3.2. Stagnant Water Bodies and Wetlands of the Gangetic Plains

Locality No. 13:		Kumhrar, large pond	25. March 2008
Order	Family	Genus species	Abundance
Spongillina	Spongillidae		3
Ephemeroptera	Baetidae		2
Odonata	Libellulidae		3
	Coenagrionidae		4
Heteroptera	Nepidae: Ranatrinae	*Ranatra sp.*	1
	Pleidae	*Paraplea sp. cf*	3
	Micronectidae	*Micronecta sp.*	2
	Belostomatidae	*Diplonychus sp.*	4
Coleoptera	Hydrophilidae		2
	Dytiscidae		3
Diptera	Chironomidae		3
	Culicidae		1
	Muscidae		1
Decapoda	Parathelphusidae	*Sartoriana spinigera*	1
Haplotaxida	Tubificidae	*Branchiura sowerbyi*	2
		Aulodrilus sp.	1
Hiridinida	Glossiphoniidae	*Alboglossiphonia heteroclita*	2
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	3
	Thiaridae	*Melanoides tuberculatus*	4
	Bithyniidae	*Digoniostoma pulchella*	2
	Ampullariidae	*Pila globosa*	Shells
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	1
		Radix persica	1
	Planorbidae	*Gyraulus euphraticus*	2
		Gyraulus convexiusculus	1
Unionoida	Amblemidae	*Radiatula caerulea*	4
		Radiatula occata	2
Total Number of Taxa			27

Table 15: Macroinvertebrate Taxa-List of Locality No.13; Kumhrar.

Number of scored Indicator taxa from NEPBIOS: 16; from GRS-BIOS: 21

For original NEPBIOS = ∑individual Score value/number of taxa scores

72/16 = 4.50 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

98/21 = 4.66 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

88/20 = 4.40 Water quality class- **III**

Locality No. 14:		Kumhrar, central *Phoenix sylvestris* pond	25. March 2008
Order	Family	Genus species	Abundance
Odonata	Libellulidae		3
	Coenagrionidae		2
Ephereroptera	Baetidae		1
Heteroptera	Pleidae	*Paraplea sp. cf.*	2
	Micronectidae	*Micronecta sp.*	2
	Ranatrinae	*Ranatra sp.*	1
	Belostomatidae	*Diplonychus sp.*	3
	Veliidae		2
Coleoptera	Dytiscidae A		4
	Dytiscidae B		1
	Hydrophilidae		1
	Staphylinidae		1
Diptera	Culicidae		1
	Chironomidae		2
	Limoniidae		2
Haplotaxida	Naididae	*Branchiodrilus hortensis*	3
Lumbricina	Megascolecidae	*Perionyx excavatus*	4
Hirudinida	Glossiphoniidae	*Placobdelloides fulvus*	2
Mesogastropoda	Ampullariidae	*Pila globosa*	Shells
	Viviparidae	*Bellamya bengalensis*	2
	Bithyniidae	*Lymnaea acuminata*	2
Basommatophora	Lymnaeidae	*Radix luteola*	1
	Planorbidae	*Gyraulus euphraticus*	3
		Gyraulus convexiusculus	1
		Segmentina calatha	1
		Hippeutis umbilicalis	3
Stylommatophora	Succineidae	*Quickia bensoni*	3
Total Number of Taxa			27

Table 16: Macroinvertebrate Taxa-List of Locality No.14; Kumhrar.

Number of scored Indicator taxa from NEPBIOS: 12; from GRS-BIOS: 21

For original NEPBIOS = ∑individual Score value/number of taxa scores

58/12 = 4.83 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

102/21 = 4.86 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

77/17 = 4.53 Water quality class- **III**

Locality No. 15:		Fishpond north of Pahari	April 2003 + 4. April 2008
Order	Family	Genus species	Abundance
Odonata	Coenagrionidae		3
Ephemeroptera	Baetidae		2
Heteroptera	Nepidae	*Ranatra sp.*	2
	Belostomatidae:	*Diplonychus sp.*	4
		Diplonychus cf. rusticus	1
	Pleidae	*Paraplea sp. cf.*	2
	Micronectidae	*Micronecta sp.*	2
	Notonectidae	*Anisops sp.*	2
Coleoptera	Hydrophilidae		2
	Dytiscidae		4
Diptera	Chironomidae		3
Mesogastropoda		*Bellamya bengalensis*	1
		Pila globosa	1
		Digoniostoma cerameopoma	1
Basommatophora		*Gyraulus convexiusculus*	Shells
		Indoplanorbis exustus	Shells
Haplotaxida	Tubificidae		1
Hirudinida	Glossiphoniidae	*Alboglossiphonia pahariensis*	2
	Salifidae	*Salifa lateroculata*	2
Total Number of Taxa			19

Table 17: Macroinvertebrate Taxa-List of Locality No.15; Pahari.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 13

For original NEPBIOS = ∑individual Score value/number of taxa scores

48/11 = 4.36 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

62/13 = 4.77 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

59/15 = 3.94 Water quality class- **IV**

Locality No. 16:		Wetland-Channel at Pahari south of Fishpond, *Eichhornia crassipes*	April 2003 + 4. April 2008
Order	Family	Genus species	Abundance
Heteroptera	Belostomatidae	*Diplonychus sp.*	3
	Hydrometridae		1
	Pleidae	*Paraplea sp. cf.*	1
Coleoptera	Hydrophilidae		1
	Dytiscidae		3
Diptera	Chironomidae		2
	Culicidae		1
	Stratomyidae		2
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	2
		Idiopoma dissimilis	3
	Bithyniidae	*Digoniostoma cerameopoma*	2
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	2
	Planorbidae	*Indoplanorbis exustus*	1
Stylommatophora	Succineidae	*Quickia bensoni*	1
Haplotaxida	Tubificidae		1
	Naididae	*Chaetogaster lymnaei lymnaei*	2
Hirudinida	Glossiphoniidae	*Placobdelloides fulvus*	1
	Salifidae	*Salifa lateroculata*	1
Total Number of Taxa			18

Table 18: Macroinvertebrate Taxa-List of Locality No.16; Pahari.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 15

For original NEPBIOS = ∑individual Score value/number of taxa scores

42/11 = 3.82 Water quality class- **IV**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

69/15 = 4.60 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

46/13 = 3.54 Water quality class- **IV**

Locality No. 17:		Bairia, *Eichhornia crassipes* Pond	4. April 2008
Order	Family	Genus species	Abundance
Odonata	Coenagrionidae		2
Heteroptera	Nepidae: Ranatrinae	*Ranatra sp.*	1
	Pleidae	*Paraplea sp. cf.*	2
	Belostomatidae	*Diplonychus sp.*	3
Coleoptera	Hydrophilidae		2
	Dytiscidae		2
Diptera	Muscidae		2
	Stratiomyidae		2
	Chironomidae		3
	Culicidae		2
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	2
		Idiopoma dissimilis	1
	Bithyniidae	*Digoniostoma cerameopoma*	3
Basommatophora	Lymnaeidae	*Radix luteola*	2
	Planorbidae	*Gyraulus convexiusculus*	3
		Gyraulus euphraticus	2
		Segmentina calatha	1
Haplotaxida	Naididae	*Branchiodrilus hortensis*	1
Total Number of Taxa			18

Table 19: Macroinvertebrate Taxa-List of Locality No.17; Bairia.

Number of scored Indicator taxa from NEPBIOS: 9; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

41/9 = 4.55 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

64/14 = 4.57 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

45/12 = 3.75 Water quality class- **IV**

Locality No. 18:		Bairia, *Trapa natans* Pond	4. April 2008
Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		2
Heteroptera	Pleidae	*Paraplea sp. cf.*	1
Diptera	Chironomidae		2
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	3
		Idiopoma dissimilis	3
	Bithyniidae	*Digoniostoma cerameopoma*	4
		Indoplanorbis exustus	Shells
Basommatophora	Lymnaeidae	*Radix luteola*	1
Total Number of Taxa			8

Table 19: Macroinvertebrate Taxa-List of Locality No.18; Bairia.

Number of scored Indicator taxa from NEPBIOS: 4; from GRS-BIOS: 7

For original NEPBIOS = ∑individual Score value/number of taxa scores

20/4 = 5.00 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

35/7 = 5.00 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

29/8 = 3.63 Water quality class- **III**

Plate 7: Sessile Macroinvertebrates of Large Water Bodies.

Fig. 1: Porifera: Demospongiae: Spongillidae; stagnant water of Kumhrar Pond, Patna, India, Bihar, Locality No. 13.

Fig. 2: Porifera: Demospongiae: Spongillidae; stagnant water Nagdaha Pond, Lalitpur, Kathmandu Valley, Nepal, Locality No. 40.

Figs 3, 4: Porifera: Demospongiae: Spongillidae; Subernarekha River at Chandil, India, Jharkhand.

Fig. 5: Bryozoa: Phylactolaemata: Plumatellidae: *Plumatella bombayana*; Rosi Khola, Panauti, Kavre, Nepal.

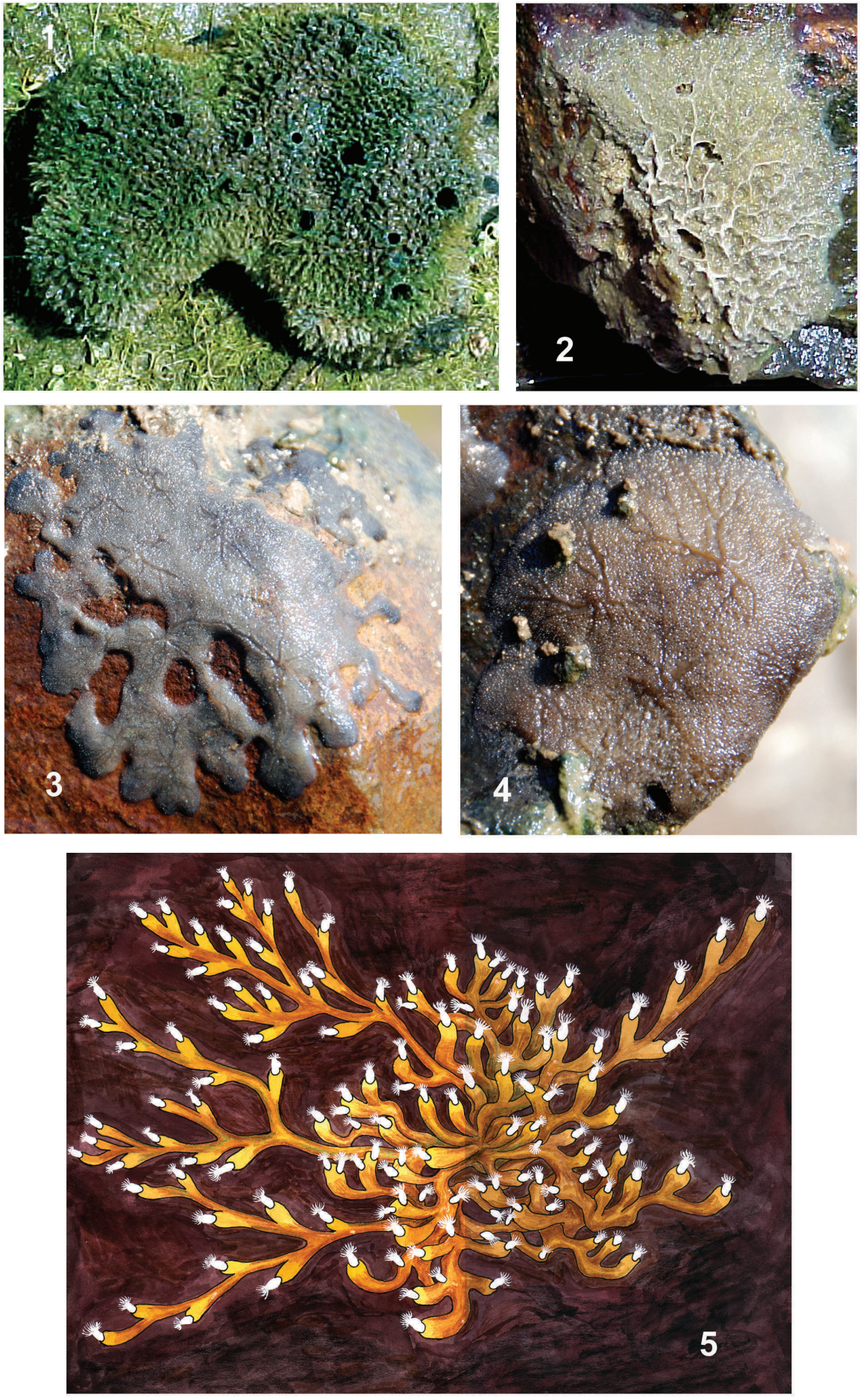


Plate 7: Sessile Macroinvertebrates of Large Water Bodies.

Plate 8: Aquatic Snails of Large Water Bodies.

Figs 1-3: Gastropoda: Viviparidae: *Mekongia crassa* attached on Macrolithal in the Ganga River at Krishnaghat and Old Palace, Patna, India, Bihar, Localities No. 3 and 9, March/April 2008.

Fig. 4: Gastropoda: Viviparidae: *Bellamya bengalensis*, stagnant water Nagdaha Pond, Lalitpur, Kathmandu Valley, Nepal, Locality No. 40, September 2008.

1

2

3

4

Plate 8: Aquatic Snails of Large Water Bodies.

3.3. Forest Streams and Wetlands of Nagpur, Maharashtra

Several natural and undisturbed water bodies of Nagpur surroundings could be shortly visited and investigated during the 18th International Symposium of Odonatology, under supervision of authorized Scientist from Hislop College, Nagpur. Two streams of the Pench Tiger Reserve, two lentic habitats of Ghorpad, one extended wetland-pond habitat of the Tahoba Tiger Reserve and one medium sized river could be sampled. The results are included into the present study, because they provide data from completely undisturbed water bodies in naturally forested landscapes; free from artificial pollution in the upstream catchments. This allows valuable conclusions about the impact of natural organic load on the biological water quality. All other similar study sites in lowlands and Plains of India and Nepal have at least some agricultural land use upstream from sampling area; impact of additional nutrients and water abstraction may bring more organic load.

Two streams, both tributaries of Pench River, are of particular interest as habitat of aquatic cockroaches, which were virtually unknown from India except of few observations published in the early 20th century.

Locality No. 19: Pench, forest spring stream (Tiger Reserve) 13.11. 2008

Order	Family	Genus/Species	Abundance
Odonata	Libellulidae		1
	Platycnemididae		adults
Heteroptera	Naucoridae		1
	Veliidae	*Microvelia* sp.	3
Coleoptera	Dytiscidae		2
	Scirtidae		1
Diptera	Athericidae		1
	Tipulidae		adults
Blattodea	Blattidae	*Rhicnoda natatrix*	2
Decapoda	Atyidae		3
	cf. Potamidae		1♀, 1♂
Lumbricina	Megascolecidae		2
Total Number of Taxa			12

Table 21: Macroinvertebrate Taxa-List of Locality No.19, Pench.

Number of scored Indicator taxa from NEPBIOS: 7; from GRS-BIOS: 10

For original NEPBIOS = ∑individual Score value/number of taxa scores

48/7 = 6.86 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

71/10 = 7.10 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

64/9 = 7.12 Water quality class- **I**

Locality No. 20: Pench, Ambakhori-Totladoah forest stream, waterfalls near small Mahadev Temple, (Tiger Reserve), 13.11. 2008

Order	Family	Genus/Species	Abundance
Odonata	Gomphidae	*Cf. Nihonogomphus sp.*	2
Heteroptera	Naucoridae		1
	Veliidae		3
Coleoptera	Dytiscidae		2
Diptera	Chironomidae: Chironominae		1
Blattodea	Blattidae	*Rhicnoda natatrix*	2
Decapoda	cf. Potamidae		1
Lumbricina	Megascolecidae		1
Prosobranchia	Thiaridae	*Thiara lineata*	2
		Thiara scabra	1
		Melanoides tuberculatus	2
Total Number of Taxa			11

Table 22: Macroinvertebrate Taxa-List of Locality No.20; Pench.

Number of scored Indicator taxa from NEPBIOS: 7; from GRS-BIOS: 8

For original NEPBIOS = ∑individual Score value/number of taxa scores

28/7 = 4.00 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

42/8 = 5.25 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

27/7 = 3.86 Water quality class- **IV**

Locality No. 21: Kamthi River north of Nagpur, Changaghat, 14. 11. 2008

Order	Family	Genus/Species	Abundance
Odonata	Gomphidae	*Nihonogomphus sp.*	3
Diptera	Chironomidae: Chironominae		1
Prosobranchia	Thiaridae	*Thiara lineata*	3
		Thiara scabra	1
		Melanoides pyramis	2
	Viviparidae	*Bellamya aff. bengalensis*	2
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	1
		Radix ovalis	1
	Planorbidae	*Indoplanorbis exustus*	2
Vneroida	Corbiculidae	*Corbicula striatella*	2
Unionoida	Unionidae	*Lamellidens sp.*	+
	Amblemidae	*Radiatula sp..*	+
		Parreysia corrugate nagporensis.	1
Total Number of Taxa			13

Table 23: Macroinvertebrate Taxa-List of Locality No.21; Kamthi River.

Number of scored Indicator taxa from NEPBIOS: 8; from GRS-BIOS: 12

For original NEPBIOS = ∑individual Score value/number of taxa scores

33/8 = 4.12 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

55/12 = 4.58 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

39/10 = 3.90 Water quality class- **IV**

Locality No. 22: Large and shallow pond in grassland; northwest of Nagpur, 7.11.2008

Order	Family	Genus/Species	Abundance
Odonata	Aeshnidae		1
	Libellulidae		2
	Coenagrionidae		2
Ephemeroptera	Baetidae		2
Heteroptera	Belostomatidae	*Diplonychus sp.*	1
Diptera	Chironomidae		1
Decapoda	Atyidae		1
	Parathelphusidae		+
Spinicaudata	Cyclestheriidae	*Cyclestheria hislopi*	3
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	3
	Planorbidae	*Gyraulus sp.*	1
Prosobranchia	Bithyniidae	*Digoniostoma pulchella*	3
	Viviparidae	*Bellamya bengalensis*	2
	Thiaridae	*Melanoides pyramis*	2
		Thiara lineata	2
Unionoida	Amblemidae	*Radiatula sp.*	2
Hirudinida	Glossiphoniidae		1
Total Number of Taxa			17

Table 24: Macroinvertebrate Taxa-List of Locality No.22; Ghorpad.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 16

For original NEPBIOS = ∑individual Score value/number of taxa scores

57/11 = 5.18 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

83/16 = 5.19 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

84/17 = 4.95 Water quality class- **III**

Locality No. 23: Small and shallow forest-pond northwest of Nagpur, 7.11.2008

Order	Family	Genus/Species	Abundance
Odonata	Libellulidae		3
Heteroptera	Corixidae		1
	Notonectidae		1
	Micronectidae	*Micronecta sp.*	2
Coleoptera	Dytiscidae		2
	Hydrophilidae		3
Diptera	Chironomidae: Chironominae		1
Hirudinida	Glossiphoniidae	*Placobdelloides sp.*	1
		Alboglossiphonia sp.	1
Total Number of Taxa			9

Table 25: Macroinvertebrate Taxa-List of Locality No.23; Ghorpad.

Number of scored Indicator taxa from NEPBIOS: 7; from GRS-BIOS: 6

For original NEPBIOS = ∑individual Score value/number of taxa scores

28/7 = 4.00 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

17/6 = 2.83 Water quality class- **IV**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

16/6 = 2.67 Water quality class- **IV**

Locality No. 24: Large shallow pond and wetlands at Tahoba, 11.Nov. 2008

Order	Family	Genus/Species	Abundance
Odonata	Gomphidae		2
	Libellulidae		3
	Coenagrionidae		3
	Protoneuridae		2
Ephemeroptera	Baetidae		2
Heteroptera	Corixidae		1
	Gerridae		1
	Notonectidae		2
	Pleidae		1
	Nepidae: Nepinae	*Laccotrephes sp.*	1
	Ranatrinae	*Ranatra sp.*	1
	Ranatrinae	*Cercothmetus sp.*	2
	Belostomatidae	*Diplonychus sp.1*	2
		Diplonychus sp.2	2
	Micronectidae	*Micronecta sp.*	3
Coleoptera	Dytiscidae		2
Diptera	Culicidae		1
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	3
		Radix luteola	2
	Planorbidae	*Indoplanorbis exustus*	2
		Gyraulus euphraticus	1
	Thiaridae	*Melanoides tuberculatus*	2
Prosobranchia	Bithyniidae	*Digoniostoma cerameopoma*	1
		Digoniostoma pulchella	3
	Viviparidae	*Bellamya bengalensis*	2
		Idiopoma dissimilis	2
	Ampullariidae	*Pila cf. globosa*	2
Unionoida	Unionidae	*Lamellidens sp.*	1
Decapoda	Atyidae		3
	Parathelphusidae		+
Spinicaudata	Cyclestheriidae	*Cyclestheria hislopi*	1
Total Number of Taxa			31

Table 26: Macroinvertebrate Taxa-List of Locality No.24; Tahoba.

Number of scored Indicator taxa from NEPBIOS: 17; from GRS-BIOS: 25

For original NEPBIOS = ∑individual Score value/number of taxa scores

77/17 = 4.53 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

119/25 = 4.76 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

89/16 = 5.57 Water quality class- **II**

Chapter 4. Lowlands of the Terai in Nepal

4.1. Karnali River of the Nepal Terai

Locality No. 25: Karnali River, Khote Ghat, Dothadi-9, Bardia

Sampling Date: 10.01.2008

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Procloeon sp.*	1
		Acentrella sp.	1
		Pseudocloeon sp.	1
	Caenidae	*Caenis sp.*	1
	Heptageniidae	*Ecdyonurus sp.*	1
	Neoephemeridae		2
	Ephemerellidae	*Torleya sp.*	1
Coleoptera	Hydrophilidae		2
	Dytiscidae		1
Heteroptera	Corixidae		4
Odonata	Gomphidae		1
Diptera	Chironomidae	Orthocladiinae	2
		Tanypodinae	1
		Tanytarsisni	1
	Ceratopogonidae		1
	Tabanidae		1
Decapoda	Aytidae		3
Plesiopora	Tubificidae		1
Total Number of Taxa			18

Table 27: Macroinvertebrate Taxa-List of Locality No.25; Karnali River.

Number of scored Indicator taxa from NEPBIOS: 9; from GRS-BIOS: 10

For original NEPBIOS = ∑individual Score value/number of taxa scores

48/9 = 5.33 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

50/10 = 5.00 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

105/15 = 7.00 Water quality class- **I**

Locality No. 26: Manau Ghat, Bardia

Sampling Date: 10.01.2008

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Procloeon sp.cf.*	1
		Acentrella sp.	2
		Baetis sp.	3
	Heptageniidae	*Cingmina sp.*	1
		Cinygmula sp.	2
	Neoephemeridae		2
	Ephemerellidae	*Torleya sp.*	1
		Serratella sp.	1
	Ephemeridae	*Ephemera sp.*	1
Trichoptera	Hydropsychidae	*Hydropsyche sp.*	1
	Glossosomatidae	*Glossosomatinae*	1
	Philopotamidae	*Chimarra sp.*	1
	Leptoceridae		1
	Hydroptilidae		1
Coleoptera	Hydrophilidae		2
Heteroptera	Apheloceiridae		1
	Corixidae		4
Odonata	Gomphidae		1
Diptera	Chironomidae	Orthocladiinae	1
		Tanypodinae	1
		Chironominae	2
	Simuliidae		1
	Tabanidae		1
Megaloptera	Corydalidae		1
Total Number of Taxa			24

Table 28: Macroinvertebrate Taxa-List of Locality No.26; Karnali River.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 15

For original **NEPBIOS** = ∑individual Score value/number of taxa scores

84/14 = 6.00 Water quality class- I

For **GRS-BIOS** = ∑individual Score value/the number of taxa scores

85/15 = 5.66 Water quality class- II

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

165/22 = 7.85 Water quality class- I

Locality No. 27: Chisapani, Karnali River

Sampling Date: 10.01.2008

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Procloeon sp.cf.*	1
		Acentrella sp.	2
		Baetis sp.	3
	Caenidae	*Caenis sp.*	2
	Leptophlebiidae		1
	Isonychiidae	*Isonychia sp.*	2
	Neoephemeridae		2
	Ephemerellidae	*Torleya sp.*	1
		Serratella sp.	2
Plecoptera	Perlidae	*Kamimura sp.*	1
Trichoptera	Hydropsychidae	*Hydropsyche sp.*	1
	Lepidostomatidae	*Paraphlegapteryx sp.*	1
	Philopotamidae	*Dolophilodes sp. cf.*	1
	Leptoceridae	*Ceraclea sp.Ref. col.*	1
	Stenopsychidae	*Stenopsyche sp.*	1
Coleoptera	Dytiscidae		1
	Elmidae	*Stenelmis sp.*	1
	Gyrinidae		1
	Psephenidae	Psephenoidinae	1
Heteroptera	Micronectidae	*Micronecta sp.*	1
Odonata	Gomphidae		1
Diptera	Chironomidae	Orthocladiinae	3
		Tanypodinae	2
		Chironominae	2
	Simuliidae		1
	Ceratopogonidae		1
	Limoniidae		2
	Empididae		1
	Tabanidae		1
Decapoda	Potamidae	*Himalayapotamon sp.*	1
Total Number of Taxa			30

Table 29: Macroinvertebrate Taxa-List of Locality No.27; Karnali River.

Number of scored Indicator taxa from NEPBIOS: 19; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

125/19 = 6.57 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

132/22 = 6.00 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

240/33 = 7.28 Water quality class- **I**

4.2. Wetlands of the Nepal Terai

Three large and more popular wetlands were investigated. They all are connected to small rivers, coming from the foothills. The larger water bodies are named ‘lakes’ but they are situated in Holocene riverbeds and receive their discharge either directly or as floodplain groundwater from the main rivers. All have permanent effluents throughout most time the year, some lake-effluent streams may become dry at the end of winter resulting from decreasing groundwater level. As per definition these wetland can be classified as Plesiopotanon type (Amoros and Roux 1988).

Localities No. 28-30: Terai Wetlands

Order	Family	Genus Species	BHT	GGT	JDR
Ephemeroptera	Baetidae		2	1	2
	Caenidae		2		1
Coleoptera	Dytiscidae		3	2	2
	Hydrophilidae		1	2	1
	Scirtidae		1		2
Odonata	Libellulidae		2		3
	Gomphidae		2	1	1
	Coenagrionidae		2	2	3
	Protoneuridae		2	1	1
	Platycnemididae				2
	Calopterygidae		1		
Heteroptera	Belostomatidae	*Lethocerus sp.*		1	
		Diplonychus sp.	2		
	Pleidae		1		2
	Helotrephidae				1
	Micronectidae	*Micronecta sp.*	2	1	2
	Nepidae: Ranatrinae	*Cercothmetus sp.*	1		
		Ranatra sp.	1		3
	Nepidae: Nepinae	*Laccotrephes sp.*	1	1	1
	Corixidae		1		1
	Gerridae		1		1
	Notonectidae		1		1
Trichoptera	Leptoceridae		1		1
Lepidoptera	Pyralidae		1		2
Diptera	Ceratopogonidae		2		1
	Chironomidae: Orthocladinae		1		1
	Tanypodinae		1		
	Chironominae	Chironomini	2	1	2
		Tanytarsini	2		

	Culicidae		2	1	1
	Stratiomyidae		1		1
	Limoniidae		2		1
	Athericidae		1		
Hydracarina			2	1	1
Spinicaudata	Cyclestheriidae	*Cyclestheria hislopi*	3		2
Decapoda	Palaemonidae	*Macrobrachium spec.*	2	2	2
	Parathelphusidae	*Sartoriana spinigera*	1		
Amphipoda	Talitridae	*Platorchestia platensis*	1		
Isopoda	Cirolanidae	*Cirolana parva*			2
Basommatophora	Planorbidae	*Indoplanorbis exustus*	2	2	1
		Gyraulus euphraticus	2	2	3
		Gyraulus convexiusculus	1	1	1
		Camptoceras lineatum	1	1	
		Segmentina calatha	2	1	2
		Segmentina trochoidea	1	1	
		Hippeutis umbilicalis		1	2
	Lymnaeidae	*Lymnaea acuminata*	2	2	2
		Radix ovalis	1		
		Radix luteola	1		1
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	2	3	2
		Idiopoma dissimilis	2		
	Ampullariidae	*Pila globosa*		2	3
	Bithyniidae	*Digoniostoma pulchella*	1	2	2
		Digoniostoma cerameopoma	1		1
		Gabbia stenothyroides			1
	Pleuroceridae	*Brotia costula*	2		
	Thiaridae	*Melanoides pyramis*	1		1
		Melanoides tuberculatus	2		2
		Thiara lineata			2

		Thiara scabra			2
Veneroida	Sphaeriidae	*Pisidium clarkeanum*			1
		Pisidium nevillianum	1		2
		Musculium indicum		2	
	Corbiculidae	*Corbicula striatella*			2
Unionoida	Unionidae	*Lamellidens narainporensis*			1
	Amblemidae	*Radiatula caerulea*			2
		Radiatula occata			2
Tubificina	Naididae	*Stylaria fossularis*	2		
		Pristina sp.	1		
		Dero nivea	1		
		Branchiodrilus semperi	2		1
		Aulophorus hymanae	1		
		Aulophorus flabelliger	2		
		Aulophorus tonkinensis	2		
		Aulophorus opistocystoides	1		
	Tubificidae	*Aulodrilus sp.*	1		
		Limnodrilus sp.			1
		Branchiura sowerbyi			2
Hirudinida	Haemadipsidae	*Haemadipsa sylvestris*	2		
	Hirudinidae	*Hirudinaria manillensis*	1		
	Glossiphoniidae	*Alboglossiphonia weberi*	1		1
		Alboglossiphonia pahariensis		2	
		Oosthuizobdella mahabiri		1	1
	Salifidae	*Salifa lateroculata*	1		
Ctenostomata	Plumatellidae	*Plumatella sp.*	1		
Turbellaria	“Microturbellaria”		2		
Total Number of Taxa			67	28	57

Table 30: Macroinvertebrate taxa identied from Locality No. 28: Bishazari Tal = BHT; Locality No. 29: Ghodaghori Tal = GGT; Locality No. 30: Jagadishpur Reservoir = JDR.

Locality No. 28: Bishazari Tal.

Number of scored Indicator taxa from NEPBIOS: 28; from GRS-BIOS: 53

For original NEPBIOS = ∑individual Score value/number of taxa scores

142/28 = 5.07 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

295/53 = 5.56 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

184/34 = 5.42 Water quality class- **II**

Locality No. 29: Ghodaghori Tal

Number of scored Indicator taxa from NEPBIOS: 16; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

68/16 = 4.25 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

108/22 = 4.91 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

83/17 = 4.89 Water quality class- **III**

Locality No. 30: Jagadishpur Reservoir

Number of scored Indicator taxa from NEPBIOS: 26; from GRS-BIOS: 46

For original NEPBIOS = ∑individual Score value/number of taxa scores

115/26 = 4.42 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

221/46 = 4.80 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

159/31 = 5.13 Water quality class- **II**

Bishazari Tal is a shallow dissected fern-shaped oxbow lake running northeast to southwest and surrounded by the Sal (*Shorea robusta*) forest and marshy land typical of the inner Terai. The lake is situated in the buffer zone of Chitwan National Park (CNP) adjacent to Khageri Irrigation Canal, within the Barandabhar forest patch; it is a habitat corridor between CNP and the Siwalik forests. It receives water from groundwater inflow; its level is kept up from Khageri Irrigation.

Ghodaghori Tal is a large and shallow oxbow lake with associated marshes and meadows. It is situated in Kailali District of Far Western Development Region of Nepal at an elevation of 205 m. It covers 2563 hectares with tropical deciduous forests and 14 lakes and ponds. The area is remarkable for its rich biodiversity and connectivity between the Terai Plains and the Siwalik Hills of Nepal. The forest and wetlands in the area serve as the wildlife corridor between the Terai plains and the Siwalik Hills.

Jagdishpur Reservoir (the largest Terai reservoir in Nepal) lies 10 km north of the city Taulihawa, in Kapilvastu District and Lumbini Zone, central Nepal at an elevation of 197 m. The reservoir having surface area of 157 ha was constructed in the early 1970s over the Jakhira Lake and agricultural lands for irrigation purposes. The water is fed from the Banganga from the Churia Hills catchments. The reservoir is surrounded by agricultural land and a few smaller lakes serving as buffer zone for birds' movements.

Altogether Forty-two taxa from Arthropoda, Twenty nine taxa from Mollusca, Seventeen taxa from Annelida and one taxon each from Bryozoa and Platelminthes phyla (Table 30) were recorded from the studied Lakes and Reservoir. Highest biodiversity was found in Ghodaghodi Tal and only twenty six taxa were recorded from Jagadishpur Reservoir.

Among the studied invertebrates, there were several genera and species, found in Nepal for the first time (*Cercotmetus* spec., *Oosthuizobdella mahabiri*) and others are very rare and endangered species (*Camptoceras lineatum*, *Hirudinaria manillensis*).

Coenagrionidae, Protoneuridae, Dytiscidae, Hydrophilidae, Libellulidae, Gomphidae and Chironomidae were highly abundant in all studied lakes and reservoirs. High population of *Ranatra* sp., *Lymnaea acuminata*, *Gyraulus euphraticus* and *Digoniostoma pulchella* were found in Jagadishpur reservoir. Similarly, *Indoplanorbis exustus*, *Gyraulus euphraticus*, *Gyraulus convexiusculus*, *Segmentina calatha*, *Segmentina trochoidea*, *Hippeutis umbilicalis* and *Alboglossiphonia weberi* were highly abundant in Ghodaghodi Tal while *Indoplanorbis exustus*, *Digoniostoma cerameopoma*, *Lymnaea acuminata*, *Camptocerus lineatum* and *Salifa lateroculata* were present in very few numbers.

The majority of the animals can be found amongst floating and attached algae and macrophytes, particularly around the littoral zones. Typically, Snails (Gastropoda), Water bug (Heteroptera), Water bettles (Coleoptera), Odonata larvae and water mites crawl amongst the plants eating the plants materials, organic matters and micro-organisms forming a film on the plants or eating other invertebrates. Free swimming forms of Ephemeroptera, predatory nature of water bugs live in open water, forming a food web that is based on phytoplankton that are consumed by zooplanktons (Yule and Hoi Sen 2004). Nepidae and Belosomatidae are common for the tropical lakes and reservoirs and stay in motionless position to catch prey and have known to catch even tadpoles and small fishes. Thus, larger aquatic bugs are at times of concern to fisheries as they are harmful to juvenile fishes. Water beetles (Dytiscidae and Hydrophilidae) were found in all studied lakes and reservoirs. Leptoceridae (Caddisfly) were recorded one to two numbers in Godaghori Tal and Jagadishpur reservoir having tube like cases that are made from plant parts. The presence of red chironomids in all studied lakes and reservoirs at bottom of mud can be concluded as occurrence of natural organic pollution.

The aquatic molluscs are represented with 29 species and their presence is dominated by snails, whereas bivalves occur only with a single species. Among the Gastropoda, the occurrence of rare species *Segmentina trochoidea* has to be mentioned. The finding of a living specimen of *Camptoceras lineatum* has to be highlighted since this rare species has only three recent records in the Ganga River system. It was hitherto known only from the Brahmaputra and Irrawaddy River Systems in Bangladesh and Manipur. It is recorded for the first time from the Ganga River System and Nepal.

Habitats are lakes, ponds and their effluents. Elsewhere it was found in Pokhara Valley, lake-effluent Khudi Khola downstream from Begnas. It is a slowly running stream with rich macrophytes vegetation and diverse fauna, representing the Epi- to Metapotamon biocoenotic region in elevation of 682 m asl. The Gastropoda fauna of Bishazari Tal has some typical running water species like *Brotia costula*. Viviparidae are very abundant with two species *Bellamya bengalensis* and the lentic species *Idiopoma dissimilis*.

The highlight among the Gastropoda is the first discovery of living *Gabbia stenothyroides* specimens in Jagadishpur reservoir during January 2008 sampling. Five living specimens and several shells were washed from Pelal- and Detrial substrate in 0.3 m depth; an open zone without macrophytes cover. The very rare species was previously known only from few drifted empty shells collected from debris in the splash zone area of Gandak in Bihar and Karnali in Nepal. Now the microhabitat of *G. stenothyroides* can be described as lentic water with Pelal substrate of Plesiopotamon type in lowlands. Leeches are present mostly with the terrestrial to amphibious *Haemadipsa sylvetris*. Smaller wetlands of the nearby old riverbeds are inhabited by the medicinal leech *Hirudinaria manillensis*. Booth Hirudiniformes are in general rare and endangered because of habitat destruction. They need undisturbed natural water bodies. The findings of *Oosthuizobdella mahabiri* are remarkable to the fauna of Nepal. It prefers large ponds and lakes of the Gangetic Plains, with rich submerged vegetation. It was known prior to the present study only from the type locality in India, Madhya Pradesh, Rewa (Baugh 1960a, 1960b). It was rediscovered after sixty years. Six species of Naididae were collected and occur in large density. The Naididae family is representing the most diversified non-insects macro-invertebrates within the study area and also in general in the tropical and subtropical zones. Here Naididae are more numerous in species, whereas Tubificidae are higher in species diversity in the temperate and cold zones of the Northern Hemisphere. Naididae have numerous morphological adaptations such as cases (similar to Trichoptera) and gills, which allow to survive in open water between floating macrophytes or on the sediment surface of very warm water bodies poor in dissolved oxygen. In contrast to several Tubificidae, which are often pollution-tolerant with mass occurrence, the presence of higher Naididae species and individual numbers usually indicates well to fair ecological integrity with beta-mesosaprobic water quality

condition of the classes' II and III. The clam-shrimp *Cyclestheria hislopi* was found abundantly; it has a circum-tropical distribution, occurring from approximately 30° N to 35° S latitude. It is hitherto known from India, Thailand, Sumatra, Java, Suwalesi, Malaysia, Cambodia (Martin et al. 2003) and newly recorded from Nepal by Nesemann et al. (2007). Here specimens were collected from a few localities in the terai region and one locality in the Himalayan middle mountains. Habitats are lowland rivers and adjacent oxbow lakes with high diversified benthic fauna and rich macrophytes grow. Among the higher Crustacea this family Talitridae of amphibious Amphipods has a worldwide distribution in the marine littoral. Only a few species of *Orchestia* and related genera inhabit continental waters or even terrestrial wetlands. The Talitridae are well represented along the seacoast of the Indian Ocean. Only two species are able to colonize inland waters. The new finding of Talitridae in Nepal is the first record from true freshwater habitat far away from ocean. It is represented with the single species *Platorchestia platensis*, previously known only from India: Andhra Pradesh, Vishakhapatnam. Habitats are the littoral of natural lowland waters, in dense vegetation and in decaying plant material. Hydracharina, freshwater mites have potential as bio-indicators of the water quality assessment.

The water quality class is II (ß -mesosaprobic) for Bishazari Tal. It shows moderate organic pollution, increased nutrient content and still good oxygen supply (despite possible oxygen super saturation or depletion). The sediment of Bishazari Tal is light or dark, but not black, and is often slippery due to biodegradation taking place in aerobic areas. Species diversity and abundances are very high for some lentic animal groups. The Khageri khola has ecological water quality class III or II (see Chapter 7). Ghodaghodi tal and Jagadishpur reservoir have transitional water quality class i.e., II or III (ß-mesosaprobic to α–mesosaprobic). It contains load of eutrophicating nutrients as well as organic, oxygen-consuming substances which are clearly visible. Black spots (reduction) were found beneath stones. Large quantities of chironiomids were found in Ghodaghodi Tal and Jagadispur Reservoir, especially tube-building forms in the fine sediments.

Locality No. 31:

Hetauda Fish Pond, Altitude: ≈ 445 m asl
Sampling date: September 2006

Family	**Genus species**	**Abundance**
Baetidae		1
Dytiscidae		2
Hydrophilidae		2
Libellulidae		2
Coenagrionidae		2
Gomphidae		2
Notonectidae	*Anisops sp.*	4
Belostomatidae	*Diplonychus sp.*	2
Nepidae	*Laccotrephes sp.*	1
Ranatrinae	*Ranatra sp.*	1
Veliidae		1
Chironomidae		2
Muscidae		1
Palaemonidae	*Macrobranchium sp.*	1
Planariidae		1
Glossiphonidae	*Placobdelloides fulvus*	1
Tubificidae		1
Lymnaeidae	*Lymnea acuminata*	1
	Radix ovalis	3
Planorbidae	*Indoplanorbis exustus*	4
	Gyraulus convexiusculus	3
	Segmentina calatha	1
Viviparidae	*Bellamya bengalensis*	3
Unionidae	*Lamelllidens jenkinsianus jemkinsianus*	3
Total Number of Taxa		24

Table 31: Macroinvertebrate Taxa-List of Locality No.31; Hetauda Fishpond.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 18

For original NEPBIOS = ∑individual Score value/number of taxa scores

61/14 = 4.357 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

91/18 = 5.055 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

70/14 = 5.00 Water quality class- **II**

The Fishponds are situated in the east of Hetauda and remain water from a small foothill stream Ghatte Khola. It was investigated first time in February 1994 (Sharma 1996) with finding population of the very large and thick-shelled freshwater mussel *Lamellidens jenkinsia*nus, first recorded from Nepal. Thorough sampling was done in September 2006 to give a more complete overview.

The dominating molluscs of pure Pelal -mud substrate are *Bellamya bengalensis* and *Lamellidens jenkinsianus*, together with Chironomidae. In some submerged terrestrial vegetation along the bank *Anisops* spec. was found in very high numbers. The presence of large *Diplonychus* spec. and *Ranatra* spec. indicates stable oxygen condition in the open water. The benthic diversity is with 24 identified taxa high, indicating good connectivity with the not shadowed banks and dense overhanging grasses. The bank vegetation is forming a submerged Phytal substrate for Odonata, Coleoptera and Heteroptera. The good ecological quality of the pond, despite the high fish population, might be a result of the natural organic load from Ghatte Khola. This stream has water quality class II and ecological river quality 2 with high diversity of macroinvertebrates of 38 identified taxa.

Plate 9: Wetlands of the Nepal Terai and Lower Gangetic Plains in Nepal and India.

Figs 1, 2: Bishazari Tal, Chitwan District, Nepal, November 2004, locality No. 28. The large part of water surface is covered by floating reeds growing beside mats of the water hyacinth *Eichhornia crassipes*.

Figs 3, 4: Bishazari Tal, Chitwan District, Nepal, after cleaning; September 2006. The large part of water surface is now covered by floating water nut *Trapa bispinosa*.

Fig. 4: Microhabitat of Heteroptera: Nepidae: *Cercotmetus* spec. in Bishazari Tal; here it was first time discovered as new record for Nepal.

Fig. 5: Khageri Khola near Sauraha 500 m upstream from the Confluence with (East-) Rapti River, Chitwan, Nepal, November 2004, below locality No. 47. It represents an Epi-/Metapotamon Biocoenotic Zone of a large Inner Terai lowland stream with River Quality Class II, feeding the Bishazari Tal via Groundwater exchange through the Khageri Irrigation Channel.

Fig. 6: Barahwa at Gaur, Rautahat, Nepal, Lower Gangetic Plain Eco-region, October 2006. This is a common Plesiopotamon Type of alluvial Riverbeds originating from a former branch of Lower Bagmati River. Reference Site of high biodiversity with Ecological Quality Class II; the banks are densely covered by the water hyacinth *Eichhornia crassipes*.

Fig. 7: Shallow temporary wetland near Barahwa Pond in Gaur, Rautahat, Nepal, Lower Gangetic Plain Eco-region, October 2006. This is a common Parapotamon Type flooded only during monsoon between Junes to October. Habitat of the endangered leech *Hirudinaria manillensis* and the snail *Idiopoma dissimilis*.

Fig. 8: Permanent Wetland Pond in Kumhrar, Patna, Bihar, India, Lower Gangetic Plain Eco-region, November 2008, locality No. 14. This is a rare Plesiopotamon Type without any agricultural land-use, water pollution or fish-farming, because it is situated in the natural Park area of the archaeological excavation site of the palace fundaments of the former king Ashoka. It is habitat of a rich Odonata fauna with Water Quality Class III.

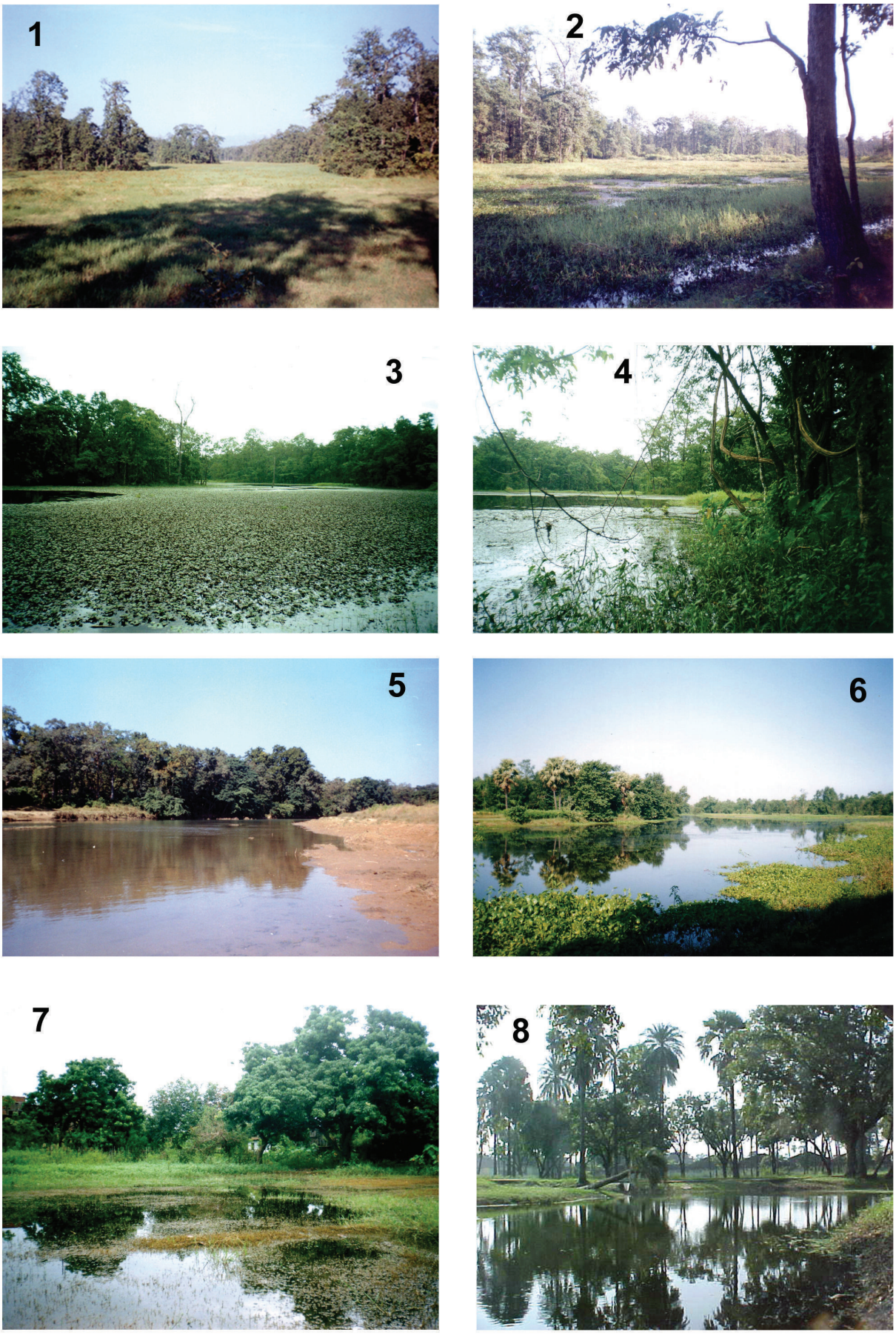


Plate 9: Wetlands of the Nepal Terai and Lower Gangetic Plains in Nepal and India.

Chapter 5. Inner Himalayan Valleys in Nepal

5.1. Wetlands of Pokhara Valley, Phewa Tal

Locality No. A-32: Macro-Invertebrate Inventory of Phewa Tal including adjacent wetlands

Class	Order	Family	Genus Species
Insecta	Ephemeroptera	Baetidae	
		Caenidae	
	Trichoptera	Leptoceridae	
		Molannidae	
	Coleoptera	Dytiscidae	
		Hydrophilidae	
		Elmidae	
	Odonata	Libellulidae	
		Corduliidae	
		Hageniidae	*Ictonogomphus sp.*
		Protoneuridae	
		Coenagrionidae	
	Heteroptera	Nepidae	*Laccotrephes sp.*
			Ranatra sp.
		Micronectidae	*Micronecta sp.*
		Notonectidae	*Anisops sp.*
		Belostomatidae	*Diplonychus sp.*
		Gerridae	
		Pleidae	*Paraplea sp. cf.*
		Corixidae	
		Veliidae	
		Helotrephidae	Limnotrephini
		Hydrometridae	*Hydrometra sp.*
	Diptera	Chironomidae	Tanypodinae
			Chironominae
	Lepidoptera	Pyralidae	
Arachnida	Acari	Hydracarina	
Malacostraca	Deacpoda	Palaemonidae	*Macrobrachium sp.*
Demospongiae	Spongillina	Spongillidae	
Turbellaria	Tricladida	Planariidae	*Dugesia sp.*
Oligochaeta	Haplotaxida	Naididae	*Chaetogaster limnaei*
			Chaetogaster crystallinus
			Chaetogaster langi
			Chaetogaster diastrophus
			Chaetogaster diaphanous
			Stylaria fossularis
			Nais communis
			Nais simplex
			Aulophorus flabelliger

			Aulophorus tonkinensis
			Aulophorus furcatus
			Aulophorus indicus
			Branchiodrilus hortensis
			Branchiodrilus semperi
			Dero phewatalensis
			Dero nivea
		Tubificidae	*Limnodrilus hoffmeisteri*
			Limnodrilus profundicola
			Aulodrilus pluriseta
			Aulodrilus pigueti
	Lumbricina	Octochaetidae	*Ramiella bishambari*
		Megascolecidae	*Amynthas cortices*
		Lumbricidae	*Eisenia fetida*
	Hirudinida	Salifidae	*Salifa lateroculata*
			Barbronia weberi
		Glossiphonidae	*Alboglosiphonia weberi*
			Alboglosiphonia pahariensis
		Hirudinidae	*Poecilobdellla granulose*
Bivalvia	Unionoida	Amblemidae	*Radiatula lima*
	Veneroida	Sphaeriidae	*Musculium indicum*
			Pisidium nevillianum
			Pisidium clarkeanum
			Pisidium prasongi
Gastropoda	Basommatophora	Planorbidae	*Gyraulus convexiusculus*
			Gyraulus euphraticus
			Gyraulus labiatus
			Indoplanorbis exustus
			Segmentina calatha
			Segmentina trochoidea
			Ferrissia verruca
		Lymnaeidae	*Lymnaea acuminata*
			Galba simulans
		Physidae	*Haitia mexicana*
	Mesogastropoda	Thiaridae	*Melanoides pyramis*
		Bithyniidae	*Digoniostoma pulchella*
			Digoniostoma cerameopoma
		Viviparidae	*Bellamya bengalensis*
			Idiopoma dissimilis
Total number of identified Taxa			78

Table 32: Macroinvertebrate Taxa-List of Locality No.A-32; Phewa Tal+Wetlands.

Number of scored Indicator taxa from NEPBIOS: 26; from GRS-BIOS: 66

For original NEPBIOS = ∑individual Score value/number of taxa scores

118/26 = 4.54 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

359/66 = 5.439 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

179/38 = 4.71 Water quality class- **III**

Locality No. 32:

Phewa Tal (2007/1) at Khapaudi, northernmost shore of the open lake, March 2007. Altitude: ≈ 798 m asl.

Family	**Genus species**	**Abundance**
Baetidae		1
Caenidae		1
Leptoceridae		2
Pleidae	*Paraplea sp.*	1
Chironomidae	*Tanypodinae*	1
Nepidae	*Ranatra sp.*	2
Belostomatidae	*Diplonychus sp.*	1
Dytiscidae		1
Hageniidae	*Ictinogomphus spec.*	1
Libellulidae		2
Coenagrionidae		2
Micronectidae		3
Gerridae		3
Palaemonidae	*Macrobranchium sp.*	3
Ostacoda		1
Copepoda		1
Cladocera		1
Nematoda		1
Spongillidae		1
Planorbidae	*Gyraulus euphraticus*	3
	Indoplanorbis exustus	2
	Gyraulus convexiusculus	1
	Gyraulus labiatus	2
	Ferrissia verruca	1
Viviparidae	*Bellamya bengalensis*	2
Thiaridae	*Melanopides pyramis*	2
Sphaeridae	*Pisidium nevillianum*	2
Naididae	*Aulophorus flabelliger*	3
	Aulophorus tonkinensis	3
	Branchiodrilus hortensis	3
Glossiphonidae	*Alboglogiphonia weberi*	2
	Alboglogiphonia pahariensis	1
Salifidae	*Salifa lateroculata*	3
Total Number of Taxa		33

Table 33: Macroinvertebrate Taxa-List of Locality No.32; Khapaudi.

Number of scored Indicator taxa from NEPBIOS: 15; from GRS-BIOS: 24

For original NEPBIOS = ∑individual Score value/number of taxa scores

67/15 = 4.4.6 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

123/24 = 5.12 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

97/20 = 4.85 Water quality class- **III**

Locality No. 33:

Phewa Tal (2007/2) Old Harpan Khola Branch 600 m southwest of Khapaudi, March 2007. Altitude: ≈ 795 m asl.

Family	**Genus species**	**Abundance**
Baetidae		1
Leptoceridae		3
Hydrophilidae		1
Dytiscidae		2
Notonectidae		1
Pleidae	*Paraplea sp.*	1
Coriixidae		4
Micronectidae	*Micronecta spp.*	2
Hydracarina		1
Libellulidae		2
Corduliidae		1
Protoneuridae		1
Hageniidae	*Ictinogomphus spec.*	3
Pyralidae		1
Chironomidae	Chironominae	3
	Tanypodinae	1
Palaemonidae	*Macrobranchium sp.*	3
Hydracarina		3
Planariidae	*Dugesia sp.*	1
Naididae	*Branchiodrilus hortensis*	1
	Chaetogaster sp.	1
	Nais sp,	1
Planorbidae	*Gyraulus euphraticus*	1
	Indoplanorbis exustus	1
	Segmintina calatha	1
Sphaeridae	*Pisidium navillianum*	2
Viviparidae	*Bellamya bengalensis*	2
	Idiopoma dissimilis	1
Lymnaeidae	*Lymnea accuminata*	4
	Ferrissia verruca	1 juvenil
Total Number of Taxa		30

Table 34: Macroinvertebrate Taxa-List of Locality No.33; Old Harpan Khola.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

62/14 = 4.43 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

115/22 = 5.23 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

88/20 = 4.40 Water quality class- **II**

Locality No. 34:

Phewa Tal (2007/3), southern shore, forest bank at Rani Ban, March 2007. Altitude: ≈ 795 m asl.

Family	**Genus species**	**Abundance**
Caenidae		1
Notonectidae		2
Micronectidae		1
Baetidae		2
Nepidae	*Laccoptrephes sp.*	1
Palaemonidae	*Macrobranchium sp.*	4
Libellulidae		1
Corduliidae		1
Hageniidae	*Ictinogomphus spec.*	1
Spongillidae		1
Viviparidae	*Bellamya bengalensis*	1
	Idiopoma dissimilisis	1
Planorbidae	*Indoplanorbis exustus*	2
	Gyraulus euphraticus	2
	Gyraulus covexiusculus	2
	Gyraulus labiatus	1
Sphaeriidae	*Pisidium nevillianum*	2
Amblemidae	*Radiatula lima*	1
Lymnaeidae	*Lymnea acuminata*	1
Total Number of Taxa		19

Table 35: Macroinvertebrate Taxa-List of Locality No.34; Rani Ban.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 17

For original NEPBIOS = ∑individual Score value/number of taxa scores

61/13 = 4.69 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

84/17 = 4.94 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

80/15 = 5.34 Water quality class- **II**

Locality No. 35:

Phewa Tal (2007/5) Location: Forest bank + Rocks, opposite lake side, southwest of Tal Barahi Temple, March 2007, Altitude: ≈ 795 m asl.

Identification date: August 2007

Family	**Genus species**	**Abundance**
Protoneuridae		2
Leptoceridae	*Mustacides sp.*	3
Molannidae		1
Chironomidae		1
Belostomatidae	*Diplonychus sp.*	1
Notonectidae		1
Heletrephidae	Limnotrephini Tribus	1
Veliidae	*Microvelia sp.*	4
Nepidae	*Ranatra sp.*	2
Micronectidae		3
Dytiscidae		1
Elmidae	larva	1
Hydracarina		4
Palaemonidae	*Macrobranchium sp.*	3
Planariidae	*Dugesia sp.*	2
Salifidae	*Salifa lateroculata*	1
	Barbonia weberi	1
Hirudinidae	*Poecilobdella granulosa*	1
Planorbidae	*Indoplanorbis exustus*	1
	Gyraulus euphraticus	2
	Gyraulus labiatus	2
Physidae	*Haitia mexicana*	1
Amblemidae	*Radiatula lima*	1
Total Number of Taxa		23

Table 36: Macroinvertebrate Taxa-List of Locality No.35; Tal Barahi Temple opp.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 17

For original NEPBIOS = ∑individual Score value/number of taxa scores

46/11 = 4.18 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

103/17 = 6.06 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

69/14 = 4.39 Water quality class- **III**

Phewa lake is situated at the southern edge of the Pokhara city. Phewa is the second largest lake of Nepal and become a souvenir of the Pokhara valley. Phewa lake is stream fed subtropical mountain lake having maximum depth 24 m and mean depth 7.5 m. It is located at an altitude of 798 m asl, in Pokhara valley at location of 28°07'-28°12'N to 84°07'-84°19'E. It occupies an area of 5.23 square kilometer, watershed area of 110 square kilometer (Rai et al., 1995).

Phewa Tal is a thermal ecosystem due to the presence of numerous warm springs. The water temperatures are ranging from 21 to 24 degree Celsius. These springs are situated along the eastern and northern shoreline of the lake. Thus faunal diversity is very high because of the presence of many warm-water species. Even macro-invertebrates of the lowlands and the terai region can be found. They have here isolated distribution and the Phewa Tal populations are forming their northernmost occurrence. The high taxa number also correlates with the rich macrophytes which are present in dense colonies in large parts of the water-body.

Phewa Tal has with 76 identified taxa a very rich subtropical macro-invertebrate fauna which is dominated by Mollusca (21 species), Annelida (27 taxa of Oligochaeta, Hirudinida), Insecta (24 taxa), aquatic Mites Hydracarina and Prawns, Macrobrachium species of the family Palaemonidae. The total number of species may exceed more than two hundred, because the identification of Arthropoda was hitherto possible only up to family or genus level. Sessile Invertebrates are certainly incomplete in the present study; Bryozoa are not yet found. Porifera are present with several species, but the material still awaits proper identification.

The highest diversity is represented by the family Naididae. They live on the sediment surface and in the submerged macrophyte vegetation. Among the Bivalvia there are mainly present Sphaeriidae in all sampling sites and Amblemidae along the forested western lake shore. *Pisidium nevillianum* and *Radiatula lima* are the more common species. Remarkable high diversity was recorded for the insects of Heteroptera with numerous families including the rare occurrence of Helotrephidae. Among the Odonata the rare family Hageniidae is present with *Ictinogomphus* spp. along the northwestern shoreline in backwaters of the wetland. Hydracarina were found in high abundance with concentration of individuals on the subsurface of Macrolithal substrate (Plate 3, Fig. 5).

The biological water quality shows generally different results using NEPBIOS, HKHBIOS and GRS-BIOS. The original NEPBIOS calculation confirms critical organic pollution of Class III, but for most sampling sites less than 50 % of the identified taxa are covered. Phewa Tal is moderately polluted using GRS-BIOS with Class II in all localities. The results may also reflect the increasing Eutrophication and discharge of organic load within the last two decades.

Nagdaha (Premonsoon) Locality No.36
Sampling date: 2 March 2007
Identification date: 15 August 2007

Family	Genus species	Abundance
Dytiscidae		2
Leptoceridae		2
Chironomidae: Tanypodinae		2
Chironominae		1
Stratiomyiidae		1
Libellulidae		1
Sphaeriidae	*Musculium indicum*	2
Planorbiidae	*Indoplanorbis exustus*	1
Lymnaeidae	*Lymnea accuminata*	3
	Radix luteola	2
Coenagrionidae		4
Physidae	*Haitia mexicana*	1
Spongillidae		1
Total Number of Taxa		13

5.2. Wetlands of Kathmandu Valley, Ponds.

Table 37: Macroinvertebrate Taxa-List of Locality No.36; Nagdaha Premonsoon.

Number of scored Indicator taxa from NEPBIOS: 8; from GRS-BIOS: 10

For original NEPBIOS = ∑individual Score value/number of taxa scores

32/8 = 4.00 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

38/10 = 3.80 Water quality class- **IV**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

42/11 = 3.82 Water quality class- **IV**

Locality No. 37:

Nagdaha (Monsoon) Locality No. 37
Sampling Date: 3 July 2007
Identification date: 9 August 2007
Weather condition: Shiny day
High water level
water temp= 260 C
Small fish , Inlet from Paddy field
Macrophytes: *Nymphaea pubescens*
Nelumbo nucifera
Trapa natans
Azolla pinnata

Family	Genus species	Abundance
Dytiscidae		1
Nepidae: Ranatrinae	*Ranatra sp.*	2
Hydrometridae		1
Corduliidae/Libellulidae		1
Chironomidae		1
Cyclestheriidae	*Cyclestheria hislopi*	3
Planariidae	*Dugesia spec.*	1
Spongillidae		2
Baetidae		1
Hydrophilidae		1
Notonectidae		1
Sciomyzidae		1
Pyralidae		2
Coenagrionidae		1
Nematoda		1
Hydrozoa	*Hydra spec.*	1
Plumatellidae	*Plumatella sp*	Floatoblast
Naididae	*Aulophorus flabelliger*	1
	Aulophorus tonkinensis	1
Enchytraeidae	*Enchytraeus albidus*	1
	Achaeta spec.	1
Salifidae	*Barbonia weberi*	1
Aeolosomatidae	*Aeolosoma viride*	1
Sphaeriidae	*Pisidium annandalei*	1
Total Number of Taxa		24

Table 38: Macroinvertebrate Taxa-List of Locality No.37; Nagdaha Monsoon July.

Number of scored Indicator taxa from NEPBIOS: 8; from GRS-BIOS: 16

For original NEPBIOS = ∑individual Score value/number of taxa scores

35/8 = 4.37 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

105/16 = 6.56 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

77/15 = 5.14 Water quality class- **II**

Locality No. 38:

Nagdaha Outlet,

Family	Genus species	Abundance
Sphaeiidae	*Musculium indicum*	1
Planorbidae	*Indoplanorbis exustus*	1
Tubificidae	*Branchiura sowerbyi*	1
	Limnodrilus hoffmeisteri	3
Salifidae	*Barbronia weberi*	2
Ceratopogonidae		2
Libellulidae		1
Chironomidae		3
Total Number of Taxa		8

Table 39: Macroinvertebrate Taxa-List of Locality No.38; Nagdaha Outlet.

Number of scored Indicator taxa from NEPBIOS: 6; from GRS-BIOS: 8

For original NEPBIOS = ∑individual Score value/number of taxa scores

20/6 = 3.33 Water quality class- **IV**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

25/8 = 3.12 Water quality class- **IV**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

25/9 = 5.14 Water quality class- **IV**

Locality No. 39:

Nagdaha (Monsoon)
Sampling Date: 19 August 2007
Identification date: 23 August 2007
Weather : Rainy
Time: 12pm

Family	Genus species	Abundance
Baetidae		1
Libellulidae		2
Hydracarina		1
Dytiscidae		2
Coenagrionidae		1
Stratiomyidae		1
Sciaridae		2
Chironomidae		2
Hydrophilidae		1
Scirtidae		1
Culicidae		1
Scathophagidae		1
Sphaeriidae	*Musculium indicum*	2
	Pisidium annandalei	3
	Pisidium clarkeanum dhulikhelensis	1
	Pisidium nevillianum	1
Lymnaeidae	*Lymnaea acuminata*	1
	Radix luteola	3
	Galba truncatula	2
Planorbidae	*Indoplanorbis exustus*	2
Bithyniidae	*Gabbia orcula*	1
Viviparidae	*Bellamya bengalensis*	3
Succineidae	*Oxyloma sp.*	2
Physidae	*Haitia mexicana*	3
Naididae	*Nais sp.*	3
Tubificidae	*Branchiura sowerbyi*	2
Glossiphoniidae	*Alboglossiphonia heteroclita*	1
Planariidae	*Dugesia sp.*	1
Total Number of Taxa		28

Table 40: Macroinvertebrate Taxa-List of Locality No.39; Nagdaha Monsoon August.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 24

For original NEPBIOS = ∑individual Score value/number of taxa scores

65/14 = 4.64 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

122/24 = 5.08 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

85/21 = 4.05 Water quality class- **III**

Locality No. 40: Nagdaha, stone substrate Macrolithal + Megalithal with sponges, 9.September 2008

Order	Family	Genus species	Abundance
Spongillina	Spongillidae		2
Odonata	Protoneuridae		1
	Coenagrionidae		1
	Libellilidae		2
	Gomphidae		1
Heteroptera	Notonectidae	*Anisops sp.*	2
	Mesoveliidae		2
	Micronectidae	*Micronecta sp.*	1
Lepidoptera	Pyralidae		3
	Baetidae	*Procloeon sp.*	2
Diptera	Tipulidae		1
Mesogastropoda	Viviparidae	*Bellamya bengalensis*	3
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	1
	Planorbidae	*Indoplanorbis exustus*	2
Hirudinida	Glossiphoniidae	*Placobdelloides fulvus*	1
	Salifidae	*Salifa lateroculata*	1
Haplotaxida	Tubificidae	*Limnodrilus hoffmeisteri*	1
Total Number of Taxa			17

Table 41: Macroinvertebrate Taxa-List of Locality No.40; Nagdaha Lithal.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

58/13 = 4.46 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

72/14 = 5.14 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

73/15 = 4.87 Water quality class- **II**

Locality No. 41: Nagdaha, Psammal near Restaurant, northeast 9. September 2008

Order	Family	Genus/Species	Abundance
Spongillina	Spongillidae		2
Turbellaria	Planariidae	*Dugesia sp.*	1
Basommatophora	Planorbidae	*Indoplanorbis exustus*	2
	Lymnaeidae	*Lymnaea acuminata*	3
		Radix luteola	1
	Physidae	*Haitia mexicana*	3
Styllomatophora	Succineidae	*Oxyloma sp.*	2
	Agriolimacidae	*Deroceras laeve*	2
Heteroptera	Nepidae: Nepinae	*Laccotrephes sp.*	1
	Corixidae		1
Odonata	Coenagrionidae		2
Lepidoptera	Pyralidae		3
Ephemeroptera	Baetidae	*Procloeon sp.*	2
Coleoptera	Hydrophilidae		1
Diptera	Chironomidae: Chironominae		2
	Tanypodinae		1
Spinicaudata	Cyclestheriidae	*Cyclestheria hislopi*	3
Haplotaxida	Tubificidae	*Branchiura sowerbyi*	1
Total Number of Taxa			18

Table 42: Macroinvertebrate Taxa-List of Locality No.41; Nagdaha Psammal.

Number of scored Indicator taxa from NEPBIOS: 9; from GRS-BIOS: 16

For original NEPBIOS = ∑individual Score value/number of taxa scores

32/9 = 3.55 Water quality class- **IV**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

76/16 = 4.75 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

65/16 = 4.07 Water quality class- **III**

Locality No. 42: Nagdaha Southwest, *Nelumbo nucifera* habitat, 9. September 2008

Order	Family	Genus/Species	Abundance
Turbellaria	Planariidae	*Dugesia sp.*	1
Odonata	Libellulidae		3
	Coenagrionidae		3
Lepidoptera	Pyralidae		1
Trichoptera	Leptoceridae		1
	Culicidae		1
Heteroptera	Corixidae		1
	Gerridae		1
	Notonectidae		2
	Pleidae		1
	Nepidae: Nepinae		1
Coleoptera	Dytiscidae		1
	Hydrophilidae		1
Diptera	Simuliidae		1
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	2
	Physidae	*Haitia mexicana*	3
Stylommatophora	Succineidae	*Oxyloma sp.*	1
Veneroidea	Sphaeriidae	*Pisidium dhulikhelensis*	1
		Pisidium annandalei	1
		Musculium indicum	1
Haplotaxida Tubificina	Tubificidae	*Limnodrilus hoffmeisteri*	1
		Branchiura sowerbyi	2
	Naididae	*Dero phewatalensis*	1
Hirudinida	Salifidae	*Salifa lateroculata*	2
Spinicaudata	Cyclestheriidae	*Cyclestheria hislopi*	2
Total Number of Taxa			25

Table 43: Macroinvertebrate Taxa-List of Locality No.42; Nagdaha Phythal.

Number of scored Indicator taxa from NEPBIOS: 15; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

61/15 = 4.066 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

101/22 = 4.59 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

85/19 = 4.48 Water quality class- **III**

Locality No. 43: Taudaha Lake, Sampling Date: 12 August, 2007

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		1
	Caenidae		2
Trichoptera	Ecnomidae		1
Lepidoptera	Pyralidae		1
Heteroptera	Corixidae		1
	Micronectidae		3
	Notonectidae		2
	Mesoveliidae		1
	Gerridae		1
Odonata	Libellulidae		2
	Coenagrionidae		2
	Protoneuridae		1
Diptera	Stratiomyiidae		1
	Simuliidae		1
	Tipulidae		1
	Psychodidae (black)		1
	Muscidae		1
	Chironomidae		1
Coleoptera	Sciritidae		1
	Dytiscidae		2
	Hydrophilidae		1
Decapoda	Potamidae	*Himalayapotamon sp.*	2
Mesogastropoda	Bithyniidae	*Gabbia orcula*	2
	Viviparidae	*Bellamya bengalensis*	1
Basommatophora	Physidae	*Haitia mexicana*	3
	Lymnaeidae	*Lymnaea acuminata*	1
	Planorbidae	*Segmentina calatha*	2
		Gyraulus convexiusculus	2
Veneroida	Sphaeriidae	*Pisidium annandalei*	3
Nemertini		*Prostoma sp. cf.*	1
Turbellaria		*Microturbellaria*	1
Tricladida	Planariidae	*Dugesia spec.*	3
Lumbricina	Megascolecidae	*Perionyx fluviatilis*	2
Haplotaxida	Tubificidae	*Branchiura sowerbyi*	3
	Naididae	*Pristina longiseta*	2
		Pristinella jenkinae	1
Hirudinida	Salifidae	*Barbonia weberi*	2
	Glossiphoniidae	*Placobdelloides fulvus*	1

Table 44: Macroinvertebrate Taxa-List of Locality No.43; Taudaha.

Number of scored Indicator taxa from NEPBIOS: 24; from GRS-BIOS: 28

For original NEPBIOS = ∑individual Score value/number of taxa scores

123/24 = 5.125 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

146/28 = 5.214 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

158/34 = 4.65 Water quality class- **III**

Chapter 6. Foothill- and Middle Mountain Streams

6.1. Small Inner Terai Foothill Streams

Locality No. 44:

Ghatte Khola, Hetauda
Inlet stream of Fish Pond
Altitude: ≈ 445 m asl

Sampling date: September 2006

Family	**Genus species**	**Abundance**
Baetidae		2
Caenidae		1
Heptageniidae		1
Ephemerellidae		1
Leptophlebiidae		1
Hydropsychidae		2
Perlidae		1
Psephenidae		1
Corduliidae		1
Macromiidae		1
Coenagrionidae		1
Protoneuridae		3
Hydrophilidae		2
Dytiscidae		2
Notonectidae	*Anisops sp.*	2
Gerridae		1
Corixidae		1
Micronectidae	*Micronecta sp.*	1
Naucoridae		1
Nepidae	*Laccotrephes sp.*	1
Chironomidae		2
Simuliidae		1
Ceratopogonidae		1
Haemadipsidae	*Haemadipsa sylvestris*	2
Planorbidae	*Gyraulus convexiusculus*	1
	Indoplanorbis exustus	1
	Ferrissia baconi	1
Tubificidae	*Limnodrilus hoffmeisteri*	1
	Branchiura sowerbyi	1
Naididae	*Pristina spec.*	1
Nematoda		1
Thiaridae	*Thiara scraba*	3
	Melanoides pyramis	3
Bithyniidae	*Digoniostoma pulchella*	1
Amblemidae	*Radiatula lima*	1
	Lamellidens narainporensis	1
Viviparidae	*Bellamya bengalensis*	2
Parathelphusidae	*Sartoriana spinigera*	2
Total Number of Taxa		38

Table 45: Macroinvertebrate Taxa-List of Locality No.44; Ghatte Khola, Hetauda.

Number of scored Indicator taxa from NEPBIOS: 25; from GRS-BIOS: 32

For original NEPBIOS = ∑individual Score value/number of taxa scores

132/25 = 5.28 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

166/32 = 5.187 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

159/28 = 5.68 Water quality class- **II**

Locality No. 46: Khageri Khola, 0.2-0.5 km upstream from road-bridge, 24.September 2006

Order	Family	Genus/Species	Abundance
Diptera	Tabanidae		
	Culicidae		
	Chironomidae		
Odonata	Gomphidae		
	Protoneuridae		
Heteroptera	Nepidae	*Laccotrephes spec.*	
	Notonectidae	*Anisops spec.*	
	Belostomatidae	*Diplonychus spec.*	
	Micronectidae	*Micronecta spec.*	
	Gerridae		
Ephemeroptera	Baetidae		
	Caenidae		
Coleoptera	Hydrophilidae		
	Dytiscidae		
Lepidoptera	Pyralidae		
Prosobranchia	Thiaridae	*Melanoides pyramis*	
		Melanoides tuberculatus	
		Thiara lineata	
		Digoniostoma cerameopoma	
	Bithyniidae		
Basommatophora	Lymnaeidae	*Lymnaea acuminata*	
		Radix ovalis	
		Gyraulus convexiusculus	
	Planorbidae	*Gyraulus euphraticus*	
Total Number of Taxa			23

Table 47: Macroinvertebrate Taxa-List of Locality No.46; Khageri Khola upstream.

Number of scored Indicator taxa from NEPBIOS: 14; from GRS-BIOS: 18

For original NEPBIOS = ∑individual Score value/number of taxa scores

60/14 = 4.28 Water quality class- **III**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

82/18 = 4.55 Water quality class- **III**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

71/13 = 5.47 Water quality class- **II**

Locality No. 47: Khageri Khola 0.3 km downstream from road-bridge, 24. Sept. 2006

Order	Family-	Genus- Species	Abundance
Odonata	Macromiidae		
	Protoneuridae		
Ephemeroptera	Baetidae		
Coleoptera	Hydrophilidae		
	Dytiscidae		
Heteroptera	Naucoridae		
Trichoptera	Hydropsychidae		
Diptera	Chironomidae		
Decapoda	Atyidae	*Caridina spec*.	
	Palaemonidae	*Macrobrachium spec*	
Prosobranchia	Viviparidae	*Bellamya bengalensis*	
		Idiopoma dissimilis	
	Pleuroceridae	*Brotia tuberculatus*	
	Thiaridae	*Thiara scraba*	
		Thiara lineata	
		Melanoides tuberculatus	
		Digoniostoma ceramepoma	
	Bithyniidae		
Basommatophora	Planorbidae	*Gyraulus euphraticus*	
Arhynchobdellida	Hirudinidae	*Hirudinaria manillensis*	
Total number of Taxa			19

Table 48: Macroinvertebrate Taxa-List of Locality No.47; Khageri Khola downstream.

Number of scored Indicator taxa from NEPBIOS: 12; from GRS-BIOS: 15

For original NEPBIOS = ∑individual Score value/number of taxa scores

60/12 = 5.00 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

84/15 = 5.60 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

74/12 = 6.17 Water quality class- **I**

Similarly, thirty two taxa were recorded from Khageri Khola representing order Ephemeroptera, Coleoptera, Lepidoptera, Heteroptera, Odonata, Diptera, Decapoda, Prosobranchia, Basommatophora and Arhynchobdellida.

Locality No. 45: Trichaudi Khola north of Hetauda.

Trichaudi Khola, left tributary of Rapti Nadi,
north of Hetauda.
Altitude: ≈ 490-500 m asl
Sampling date: September 2006

Family	**Genus species**	**Abundance**
Psephenidae		2
Perlidae		2
Baetidae		3
Heptageniidae		3
Hydropsychidae		2
Caenidae		1
Calamoceratidae		2
Philopotamidae		1
Limoniidae		1
Potamidae	*Himalayapotamon sp.*	1
Chlorocyphidae cf.		1
Lymnaeidae	*Lymnaea andersoniana simulans*	1
Total Number of Taxa		11

Table 46: Macroinvertebrate Taxa-List of Locality No.45; Trichaudi Khola.

Number of scored Indicator taxa from NEPBIOS: 10; from GRS-BIOS: 11

For original NEPBIOS = ∑individual Score value/number of taxa scores

66/10 = 6.60 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

77/11 = 7.00 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

83/11 = 7.55 Water quality class- **I**

6.2. Mahabharat Forest Streams

Locatity No 48: Sim Bhanjyang Khola between Daman and Sim Bhanjyang

Sampling date: 21. September 2006

Altitude: 2475 m asl.

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		3
	Heptageniidae	*Ecdyonurus* spec.	1
Plecoptera	Nemouridae		2
Trichoptera	Hydropsychidae		1
	Odontoceridae	*Odontocerum* sp.	1
Heteroptera	Corixidae		1
Odonata	Corduligastridae		1
Coleoptera	Dytiscidae		3
	Hydrophilidae		1
	Elmidae		1
Diptera	Simuliidae		1
	Chironomidae	Diamesinae Tanypodinae	3 1
Tricladida	Planariidae	*Dugesia sp.*	2
Haplotaxida	Tubificidae	*Limnodrilus hoffmeisteri*	3
Hirudinida	Haemadipsidae	*Haemadipsa zeylania agilis*	2
Veneroida	Sphaeriidae	*Pisidium casertanum*	3
Total Number of Taxa			17

Table 49: Macroinvertebrate Taxa-List of Locality No.48; Simbhanjyang Khola.

Number of scored Indicator taxa from NEPBIOS: 11; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

62/11 = 5.64 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

95/14 = 6.78 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

89/14 = 6.36 Water quality class- **I**

Locatity No. 49: Daman, Lower Stream of Sim Bhanjyang Khola

Sampling date: 21. September, 2006

Altitude: 2450 m asl

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		3
	Heptageniidae		3
Plecoptera	Nemouridae		3
Trichoptera	Hydropsychidae		3
	Psychomyiidae		3
	Philopotamidae		2
	Odontoceridae		1
Coleoptera	Elmidae	*Zaitzeviara sp.* *Stenelmis sp.* *Grouvelinus sp.*	1 1 1
	Dytiscidae	*Platynectes sp.*	1
Heteroptera	Gerridae		1
	Corixidae		1
Odonata	Aeshnidae		1
	Epiophlebiidae	*Epiophlebia laidlawi*	1
Diptera	Simuliidae		3
Tricladida	Planariidae	*Dugesia sp.*	2
Lumbricina	Megascolecidae	*Perionyx fluviatilis*	2
Total Number of Taxa			18

Table 51: Macroinvertebrate Taxa-List of Locality No.50; Simbhanjyang Khola.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 14

For original NEPBIOS = ∑individual Score value/number of taxa scores

83/13 = 6.38 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

93/14 = 6.64 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

143/19 = 7.53 Water quality class- **I**

Locality No. 50: Sim Bhanjyang Khola (3) Sampling date: 11.11.2007

Site description: Hygropetric-10%, Mesolithal-80%, and Akal-10%. 20% of the studied river stretch was covered with moss and 20% with leaf litters. Depth: max. 45 cm and min. 10 cm. with Width: max. 150 cm and min. 30 cm. Velocity 10 cm/sec. Water temperature 12°C.

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		2
	Heptageniidae	*Notacanthurus sp.*	2
	Leptophlebiidae	*Habrophleboides sp.*	4
Plecoptera	Perlidae	*Neoperla sp.*	2
	Nemouridae	*Mesonemoura sp.*	1
Trichoptera	Glossosomatidae		1
	Lepidostomatidae		4
	Limnephilidae		1
	Polycentropodidae		1
	Rhyacophilidae		1
	Odontoceridae		1
Coleoptera	Dytiscidae		1
	Elmidae	*Grouvelinus sp.*	3
	Hebridae		1
	Hydrophilidae		1
	Hydraenidae		1
	Helophoridae cf.		1
Heteroptera	Gerridae		2
	Veliidae cf.		1
Odonata	Aeshnidae		1
	Corduliidae/Libellulidae		1
	Epiophlebiidae	*Epiophlebia laidlawi*	1
	Gomphidae		1
Diptera	Athericidae		1
	Chironomidae		2
	Limoniidae		2
	Sciaridae		2
	Simuliidae		3
Copepoda	Fam. Gen.		1
Opisthopora	Megascolecidae	*Perionyx fluviatilis*	1
Veneroida	Sphaeriidae	*Pisidium casertanum*	1
Total Number of Taxa			31

Table 51: Macroinvertebrate Taxa-List of Locality No.50; Simbhanjyang Khola.

Number of scored Indicator taxa from NEPBIOS: 22; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

157/22 = 7.14 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

155/22 = 7.045 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

258/34 = 7.59 Water quality class- **I**

Locality No. 51: Left Tributary of Sim Bhanjyan Khola, Sampling date: 11.11.2007, Altitude: ≈ 2500 m asl. Site description: Hygropetric-80%, Akal-20%. The sampling area is 100% covered by moss. Width: max-25cm, min-10cm. Depth: max-15cm, min-5cm. Velocity: max: 15cm/s, min-10cm/s. Temperature 12^0C

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		1
	Leptophlebiidae		3
Plecoptera	Perlodidae		1
Trichoptera	Philopotamidae		1
	Polycentropodidae		1
	Hydroptilidae		1
	Odontoceridae		3
	Rhyacophilidae		2
Coleoptera	Elmidae	*Grouvelinus sp.*	2
	Scirtidae		1
Heteroptera	Gerridae		1
Odonata	Gomphidae		1
	Coenagrionidae		1
Diptera	Chironomidae		2
	Dixidae		1
	Psychodidae (Black)		2
	Sciaridae		1
	Simuliidae		3
Veneroida	Sphaeriidae	*Pisidium casertanum*	2
Total Number of Taxa			19

Table 52: Macroinvertebrate Taxa-List of Locality No.51; Left Tributary.

Number of scored Indicator taxa from NEPBIOS: 13; from GRS-BIOS: 16

For original NEPBIOS = ∑individual Score value/number of taxa scores

86/13 = 6.615 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

109/16 = 6.81 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

112/16 = 7.00 Water quality class- **I**

Locality No. 52: Right Tributary of Sim Bhanjyan Khola, Sampling date: 11.11.2007, Altitude: ≈ 2475 m asl

Site description: width: max-60cm, min-15cm. depth: max-45cm, min-10cm. velocity-10cm/s. Algae-25%, emergent macrophytes-75%.

Order	Family	Genus species	Abundance
Plecoptera	Nemouridae	*Indonemoura sp.?*	2
Trichoptera	Phryganeidae	*Eubasilissa sp.*	1
	Polycentropodidae		2
Coleoptera	Dytiscidae		2
	Hydrophilidae		1
Heteroptera	Gerridae		3
Odonata	Coenagrionidae		2
	Libellulidae		1
Diptera	Chironomidae		2
		Tanypodinae	1
		Chironominae	2
	Culicidae		1
	Ceratopogonidae		1
	Dixidae		1
	Limoniidae		1
Veneroida	Sphaeriidae	*Pisidium casertanum*	1
Total Number of Taxa			16

Table 53: Macroinvertebrate Taxa-List of Locality No.52; Right Tributary.

Number of scored Indicator taxa from NEPBIOS: 10; from GRS-BIOS: 12

For original NEPBIOS = ∑individual Score value/number of taxa scores

56/10 = 5.60 Water quality class- **II**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

64/12 = 5.33 Water quality class- **II**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

77/15 = 5.14 Water quality class- **I**

Locality No. 53: Sim Khola (upstream), Sampling date: 11.11.2007, Altitude: ≈ 2415 m asl.

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		3
	Heptageniidae	*Notacanthurus sp.*	3
	Leptophlbiidae		2
Plecoptera	Leuctridae		1
	Nemouridae	*Protonemura sp.cf.*	2
Trichoptera	Hydropsychidae		2
	Odontoceridae		2
	Polycentropodidae		1
	Phrygaeidae		1
	Rhyacophilidae		1
Coleoptera	Dytiscidae		1
	Elmidae	*Grouvelinus sp.*	2
	Hydrophilidae		1
	Scritidae		1
Heteroptera	Gerridae		2
	Mesoveliidae		1
Odonata	Aeshnidae		1
	Coenagrionidae		1
Diptera	Athericidae		1
	Chironomidae		2
	Dixidae		1
	Limoniidae		2
	Tipulidae		1
	Simuliidae		3
Tricladida	Planariidae		2
Haplotaxida	Tubificidae		1
Total Number of Taxa			26

Table 54: Macroinvertebrate Taxa-List of Locality No.53; Upper Sim Khola.

Number of scored Indicator taxa from NEPBIOS: 20; from GRS-BIOS: 22

For original NEPBIOS = ∑individual Score value/number of taxa scores

136/20 = 6.80 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

149/22 = 6.77 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

166/24 = 6.92 Water quality class- **I**

Locality No. 54: Sim Khola (midstream), Sampling date: 10.11.2007**,** Altitude: ≈ 2310 m asl

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Baetis sp.*	2
		Baetiella sp.	1
		Pseudocloeon sp.	2
	Heptageniidae	*Iron sp*	1
		Ecdyonurus sp.	2
		Notacanthurus sp.	2
	Ephemeridae	*Ephemera sp.*	1
	Leptophlebiidae	*Indialis sp.* *Habrophebiodes sp.*	1
		Serratella sp.	1
Plecoptera	Perlidae	*Kamimura sp.*	2
		Tyloperla sp. Cf	1
	Nemouridae	*Amphinemoura sp.*	1
	Peltoperlidae		2
Trichoptera	Hydropsychidae	*Hydropsyche sp.*	2
	Odontoceridae		1
	Lepidostomatidae	*Paraplegopteryx sp.*	1
	Rhyacophilidae		2
Coleoptera	Elmidae	*Stenelmis sp.*	1
		Grouvelious sp.	2
	Scirtidae		2
	Hydraenidae		1
Heteroptera	Hebridae		1
Odonata	Epiophlebiidae	*Epiophlebia laidlawi*	2
Diptera	Limoniidae		1
	Simuliidae		1
	Tipulidae		1
Blattodea	Blaberidae	*Rhicnoda natatrix*	1
Decapoda	Potamidae	*Himalayapotamon spec.*	1
Lumbricina	Megascolecidae	*Perionyx fluviatilis*	1
Total Number of Taxa			29

Table 55: Macroinvertebrate Taxa-List of Locality No.54; Middle Sim Khola.

Number of scored Indicator taxa from NEPBIOS: 18; from GRS-BIOS: 20

For original NEPBIOS = ∑individual Score value/number of taxa scores

139/18 = 7.72 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

153/20 = 7.65 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

333/40 = 8.33 Water quality class- **I**

Locality No. 55: First Tributary of Sim Khola, Sampling date: 10.11.2007Altitude: ≈ 2385 m asl.

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Baetinae*	1
		Notacanthurus sp.	1
	Ephemeridae	*Ephemera sp.*	1
Plecoptera	Perlidae	*Kamimura sp.cf.*	2
	Perlodidae		1
	Nemouridae	*Mesonemoura sp.*	2
Trichoptera	Hydropsychidae		*3*
	Philopotamidae	*Chimarra sp.*	3
	Lepidostomatidae	*Paraplegopteryx sp.*	2
	Polycentropodidae		2
	Limnephilidae	*Potamophylax sp.*	2
	Odontoceridae		1
Coleoptera	Dryopidae		1
	Dytiscidae		1
	Elmidae	*Stenelmis sp.*	1
		Grouvelinus sp.	2
	Scirtidae		2
	Hydraenidae		1
Heteroptera	Mesoveliidae		1
Odonata	Epiophlebiidae	*Epiophlebia laidlawi*	2
	Gomphidae		1
	Aeshnidae		1
	Coenagrionidae		1
	Calopterygidae		1
Diptera	Athericidae		1
	Ceratopogonidae		1
	Chironomidae	Orthocladiinae	2
		Tanypodinae	1
		Tanyitarsini	2
	Dolichopodidae		1
	Limoniidae		2
	Sciaridae		2
	Simuliidae		2
	Tabanidae		1
	Tipulidae		2
Blattodea	Blaberidae	*Rhicnoda natatrix*	2

Chilopoda			1
Oniscoidea			1
Tricladida	Planariidae		3
Lumbricina	Megascolecidae	*Perionyx fluviatilis*	1
Bassomatophora	Planorbiidae	*Segmentina calatha*	1
Veneroida	Sphaeriidae	*Pisidium casertanum*	2
Total Number of Taxa			42

Table 56: Macroinvertebrate Taxa-List of Locality No.55; First Tributary.

Number of scored Indicator taxa from NEPBIOS: 27; from GRS-BIOS: 29

For original NEPBIOS = ∑individual Score value/number of taxa scores

188/27 = 6.96 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

206/29 = 7.103 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

300/42 = 7.15 Water quality class- **I**

Locality No. 56: Third Tributary of Sim Khola, Sampling date: 11.11.2007, Altitude: ≈ 2440 m asl

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae	*Baetis sp.*	2
	Heptageniidae	*Notacanthurus sp.*	2
		Epeorus sp.	1
	Ephemeridae	*Ephemera sp.*	1
	Ephemerellidae	*Torleya sp.*	1
Plecoptera	Perlidae	*Neoperla sp.*	2
		Kamimura sp.	2
	Nemouridae	*Amphinemoura sp.*	2
Trichoptera	Hydropsychidae	*Chumatopsyche sp.*	2
	Calamoceratidae	*Anisocentopus sp.*	2
	Philopotamidae	*Chimarra sp.*	1
		Dolophilodes sp.	1
	Polycentropodidae		1
	Lepodostomatidae	*Paraplegopteryx sp.*	1
	Odontoceridae	*Psilotreta sp.*	1
	Rhyacophilidae		1
Coleoptera	Elmidae	*Stenelmis sp.*	1
		Grouvllinus sp.	1
	Scritidae		1
Odonata	Ashenidae		1
Diptera	Athericidae		1
	Ceratopogonidae		1
	Limoniidae		1
	Sciaridae		2
	Simuliidae		2
	Tipulidae		1
	Tabanidae		1
Veneroida	Sphaeriidae	*Pisidium casertanum*	1
Total Number of Taxa			28

Table 57: Macroinvertebrate Taxa-List of Locality No.56; Third Tributary.

Number of scored Indicator taxa from NEPBIOS: 20; from GRS-BIOS: 23

For original NEPBIOS = ∑individual Score value/number of taxa scores

150/20 = 7.50 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

160/23 = 6.956 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

208/28 = 7.43 Water quality class- **I**

Locality No. 57: Sim Khola below Sim Bhanjyang, Sampling date: 10.11.2007**,** Altitude: ≈ 2370 m asl.

Order	Family	Genus species	Abundance
Ephemeroptera	Baetidae		3
	Heptageniidae	*Epeorus sp.*	2
		Iron sp.	1
		Notacanthurus sp.	3
	Ephemeridae		1
	Leptophlebiidae	*Habrophlebiodes sp.*	1
Plecoptera	Perlidae	*Neoperla sp. cf.*	3
		Kamimura sp.	2
		Tyloperla sp.?	1
	Nemouridae	*Mesonemoura sp.*	1
Trichoptera	Hydropsychidae		1
	Glossosomatidae		1
	Philopotamidae	*Chimarra sp.*	2
	Polycentropodidae		1
	Hydroptilidae		1
	Rhyacophilidae		2
	Limnephilidae		1
	Philopotamidae cf.		1
	Lepidostomatidae		1
	Odontoceridae		2
Coleoptera	Elmidae	*Stenelmis sp.*	1
		Grouvelinus sp.	1
	Hydrophilidae		1
	Dryopidae cf.		1
	Hydraenidae		1
	Gyrinidae		1
	Scirtidae		1
Heteroptera	Mesoveliidae		1
Odonata	Aeshenidae		1
	Coenagrionidae		1
Diptera	Chironomidae		2
	Athericidae		1
	Sciaridae		2
	Simuliidae		2
	Ceratopogonidae		1
	Tipulidae		1

	Limoniidae		1
Decapoda	Potamidae	*Himalayapotamon sp.*	1
Tricladida	Planariidae		1
Veneroida	Sphaeriidae	*Pisidium casertanum*	1
Total Number of Taxa			40

Table 58: Macroinvertebrate Taxa-List of Locality No.57; Lower Sim Khola.

Number of scored Indicator taxa from NEPBIOS: 27; from GRS-BIOS: 30

For original NEPBIOS = ∑individual Score value/number of taxa scores

194/27 = 7.185 Water quality class- **I**

For GRS-BIOS = ∑individual Score value/the number of taxa scores

215/30 = 7.166 Water quality class- **I**

For HKHBIOS = ∑individual Score value · weight/the number of taxa weight

312/43 = 7.26 Water quality class- **I**

Plate 10: Mahabharat Mountainous Streams of Nepal.

Fig. 1: Forested Mahabharat Range, view from Daman to Southeast with 2560 m asl. Hill tops in the watershed of Sim-Khola and Simbhanyjang Khola. The northern slope is dominated by *Pinus wallichiana*, whereas the southern part has mainly *Quercus semecarpifolia* forests.

Fig. 2: Lotic Habitat of Simbhanyjang Khola, locality No. 49, with natural Gigalithal substrate, structurally rich streambed with riffles, and small water falls. Here youngest instar larvae of the Himalyan Relict Dragonfly *Epiophlebia laidlawi* were discovered for the first time in November 2007.

Fig. 3: Lentic Pool-Habitat of Simbhanyjang Khola, locality No. 48, with natural Psammal, Pelal and Detrial substrate, structurally rich streambed with shallow runs and riffles, Lithal substrate is densely covered by aquatic mosses. Here large forms of the holarctic peaclam *Pisidium casertanum* were discovered for the first time in September 2006.

1

2

3

Plate 10: Mahabharat Mountainous Streams of Nepal.

Chapter 7. Quality Assessment

7.1. The Average Score Per Taxon Value (ASPT)

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
1.	Ganga, Chunar, lenthic,	Large Meta-Potamon	28	4.00	5.25	4.54
2.	Ganga, Chunar, lotic	Large Meta-Potamon	22	4.36	5.38	4.23
3.	Ganga, Patna, Krishnaghat	Large Meta-Potamon	18	4.33	5.53	4.34
4.	Ganga Springs, Mahendrughat, Patna	Meta-Potamon/ Helocrenal	19	3.63	4.64	3.30
5.	Ganga, downstream Mahendrughat	Large Meta-Potamon	16	4.20	4.78	4.39
6.	Ganga, Adalat-Ghat, Patna, Periphyton	Large Meta-Potamon	8	3.40	4.50	2.75
7.	Ganga, Adalat Ghat, Patna	Large Meta-Potamon	20	4.46	4.60	4.54
8.	Ganga, Gandhi Ghat, Patna	Large Meta-Potamon	21	4.38	5.11	4.07
9.	Ganga, Old Palace, Patna, Lithal	Large Meta-Potamon	26	4.36	5.79	4.73
10.	Ganga, Old Palace, Patna, Phytal	Large Meta-Potamon	23	4.42	4.82	5.16
11.	Punpun, Gaurichak, Phytal	Meta-Potamon	27	4.94	5.42	4.91
12.	Punpun, Gaurichak, Pelal, Psammal	Meta-Potamon	25	4.80	5.20	4.54
13.	Patna, Kumhrar, Bivalvia pond	Wetland. Plesio-Potamon	27	4.50	4.66	4.40

14.	Patna, Kumhrar, central *Phoenix sylvestris* pond	Wetland. Plesio-Potamon	27	4.83	4.85	4.53
15.	Patna, Fishpond north of Pahari	Wetland. Plesio-Potamon	19	4.36	4.77	3.94
16.	Patna, Wetland-Channel at Pahari	Wetland. Paleo-Potamon	18	3.81	4.60	3.54
17.	Patna, Bairia, *Eichhornia crassipes* Pond	Wetland. Paleo-Potamon	18	4.55	4.57	3.75
18.	Patna, Bairia, *Trapa natans* Pond	Wetland. Paleo-Potamon	8	5.00	5.00	3.63

Table 59: Average Score Per Taxon Value (ASPT) for the Gangetic Plains in India (Uttar Pradesh: 1,2; Bihar: 3-18) using three Scoring calculations. Altitudinal range 54-120 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
19.	Pench, forest spring stream (Tiger Reserve)	Limnocrenal/ Hypocrenal	12	6.85	7.10	7.12
20.	Pench, Ambakhori-Totladoah forest stream	Metarhithron /Hyporhithron	11	4.00	5.25	3.86
21.	Kamthi River north of Nagpur, Changaghat	Epipotamon	13	4.12	4.58	3.90
22.	Shallow pond in grassland, Ghorpad	Pluvial Pond	17	5.18	5.18	4.95
23.	Shallow forest-pond, Ghorpad	Pluvial temporary Pond	9	4.00	2.83	2.67
24.	Large pond and wetlands at Tahoba	'Old' Pond + swamps	31	4.52	4.76	5.57

Table 60: Average Score Per Taxon Value (ASPT) for the Forest water bodies in India (Maharashtra) using three Scoring calculations. Altitudinal range 250-400 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
25.	Karnali River, Khote Ghat,	Large Epipotamon	18	5.33	5.00	7.00
26.	Karnali River, Manau Ghat	Large Epipotamon	24	6.00	5.66	7.58
27.	Karnali River, Chisapani	Large Hyporhithron	30	6.57	6.00	7.28
28.	Bishazari Tal, Chitwan District	Plesiopotamon	67	5.07	5.56	5.42
29.	Ghodaghori Tal, Kailali District	Plesiopotamon	27	4.25	4.90	4.89
30.	Jagadishpur Reservoir, Kapilvastu District	Plesiopotamon	56	4.42	4.80	5.13
31.	Hetauda Fish-Pond, Makwampur District	Artificial stagnant water	24	4.35	5.05	5.00

Table 61: Average Score Per Taxon Value (ASPT) for the Terai-/Inner Terai region of Nepal using three Scoring calculations. Altitudinal range 195-450 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
[A-32]	Phewa Tal, all Collections, 2005-2007	Large Limnion including Littoral	78	4.53	5.43	4.71
32.	Phewa Tal at Khapaudi, northernmost shore	Eulittoral of Lake	33	4.46	5.12	4.85
33.	Phewa Tal, Old Harpan Khola Branch	Eulittoral/ Epipotamon	30	4.42	5.22	4.40
34.	Phewa Tal southern shore, at Rani Ban	Eulittoral of Lake	19	4.69	4.94	5.34
35.	Phewa Tal, southwest of Tal Barahi Temple	Eulittoral of Lake	23	4.18	6.05	4.93

Table 62: Average Score Per Taxon Value (ASPT) for the Phewa Tal and adjacent wetlands in Nepal using three Scoring calculations. Altitudinal range 798-850 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
36.	Nagdaha, Lalitpur district, Premonsoon	Eulittoral of large 'old' pond	13	4.00	3.80	3.82
37.	Nagdaha, Lalitpur district, Monsoon, July	Eulittoral of large 'old' pond	24	4.37	6.56	5.14
38.	Nagdaha Outlet Stream, Monsoon, July	Eulittoral of large 'old' pond	8	3.33	3.12	2.78
39.	Nagdaha, Lalitpur district, Monsoon, August	Eulittoral of large 'old' pond	28	4.64	5.08	4.05
40.	Nagdaha, East, Lithal Substrate, September	Eulittoral of large 'old' pond	17	4.46	5.14	4.87
41.	Nagdaha, Northwest, Psammal Substrate, September	Eulittoral of large 'old' pond	18	3.55	4.75	4.07
42.	Nagdaha Southwest, *Nelumbo nucifera* habitat, September	Eulittoral of large 'old' pond	25	4.06	4.59	4.48
43.	Taudaha Lake, Kirtipur, Monsoon, August	Eulittoral of large 'old' pond	38	5.12	5.21	4.65

Table 63: Average Score Per Taxon Value (ASPT) for some stagnant water locations of Kathmandu Valley in Nepal using three Scoring calculations. Altitudinal range 1150-1350 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
44.	Ghatte Khola, Hetauda, Makwanpur	Hyporhithron→ Epipotamon	38	5.28	5.18	5.68
45.	Trichaudi Khola north of Hetauda	Epirhithron	11	6.60	7.00	7.55
46.	Khageri Khola Ratnanahar, u/s.	Epipotamon	23	4.28	4.55	5.47
47.	Khageri Khola Ratnanahar, d/s.	Epipotamon	19	5.00	5.60	6.17

Table 64: Average Score Per Taxon Value (ASPT) for some Terai-/Inner Terai Foothill streams in Nepal using three Scoring calculations. Altitudinal range 200-500 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa Number	ASPT NEPBIOS	ASPT GRS-BIOS	ASPT HKHBIOS
48.	Sim Bhanjyan Khola, Daman - Sim Bhanjyan	Metarhithron	17	5.64	6.78	6.36
49.	Lower Sim Bhanjyang Khola,	Metarhithron	18	6.38	6.64	7.53
50.	Middle Sim Bhanjyan Khola	Metarhithron	31	7.13	7.04	7.59
51.	Left Tributary of Sim Bhanjyan Khola	Epirhithron	19	6.61	6.81	7.00
52.	Right Tributary of Sim Bhanjyan Khola	Epirhithron	16	5.60	5.33	5.14
53.	Sim Khola (upstream)	Epi/-Metarhithron	26	6.80	6.77	6.92
54.	Sim Khola (midstream)	Metarhithron	29	7.72	7.65	8.33
55.	First Tributary of Sim Khola	Epirhithron	42	6.96	7.10	7.15
56.	Third Tributary of Sim Khola	Epirhithron	28	7.50	6.95	7.43
57.	Sim Khola below Sim Bhanjyan	Metarhithron	40	7.18	7.16	7.26

Table 65: Average Score Per Taxon Value (ASPT) for some Mahabharat mountain streams in Nepal using three Scoring calculations. Altitudinal range 2200-2470 m asl.

7.2. Comparison of ∑identified taxa; of ∑scored indicator taxa and of calculated ASPT value difference.

No.	Sampling Site	Identified Taxa	NEP BIOS Taxa	NEPBIOS % of identified Taxa	GRS-BIOS Taxa	GRS-BIOS % of identified Taxa	ASPT-Difference NEPBIOS GRS-BIOS	ASPT-Difference NEPBIOS HKHBIOS
1.	Ganga, Chunar, lenthic,	28	10	35.70	24	85.70	1.25	0.54
2.	Ganga, Chunar, lotic	22	11	50.00	18	81.82	1.02	0.13
3.	Ganga, Patna, Krishnaghat	18	9	50.00	15	83.33	1.20	0.01
4.	Ganga Springs, Mahendrughat, Patna	19	11	57.89	14	73.68	1.01	0.33
5.	Ganga, downstream Mahendrughat	16	10	62.50	14	87.50	0.58	0.19
6.	Ganga, Adalat-Ghat, Patna, Periphyton	8	5	62.50	6	75.00	1.10	0.65
7.	Ganga, Adalat Ghat, Patna	20	13	65.00	15	75.00	0.13	0.08
8.	Ganga, Gandhi Ghat, Patna	21	13	61.90	18	85.71	0.73	0.31
9.	Ganga, Old Palace, Patna, Lithal	26	11	42.31	24	92.31	1.43	0.37
10.	Ganga, Old Palace, Patna, Phytal	23	14	60.87	17	73.91	0.39	0.74
11.	Punpun, Gaurichak, Phytal	27	17	62.96	21	77.77	0.49	0.03
12.	Punpun, Gaurichak, Pelal, Psammal	25	15	60.00	20	80.00	0.40	0.26
13.	Patna, Kumhrar, large Bivalvia pond	27	16	59.23	21	77.77	0.16	0.10
14.	Patna, Kumhrar, central *Phoenix sylvestris* pond	27	12	44.44	21	77.77	0.02	0.30
15.	Patna, Fishpond north of Pahari	19	11	57.89	13	68.42	0.40	0.42
16.	Patna, Wetland-Channel at Pahari	18	11	61.11	15	83.33	0.78	0.27
17.	Patna, Bairia, *Eichhornia crassipes* Pond	18	9	50.00	14	77.77	0.02	0.80
18.	Patna, Bairia, *Trapa natans* Pond	8	4	50.00	7	87.50	0.00	1.37
19.	Pench, forest spring stream (Tiger Reserve)	12	7	58.33	10	83.33	0.24	0.27

20.	Pench, Ambakhori-Totladoah forest stream	11	7	63.63	8	72.72	1.25	0.14
21.	Kamthi River north of Nagpur, Changaghat	13	8	61.54	12	92.31	0.458	0.22
22.	Shallow pond in grassland, Ghorpad	17	11	64.70	16	94.12	0.0057	0.23
23.	Shallow forest-pond, Ghorpad	9	7	77.77	6	66.66	1.16	1.33
24.	Large pond and wetlands at Tahoba	31	17	54.84	25	80.64	0.23	1.05
25.	Karnali River, Khote Ghat,	18	9	50.00	10	55.55	0.33	1.66
26.	Karnali River, Manau Ghat	24	14	58.33	15	62.50	0.33	1.58
27.	Karnali River, Chisapani	30	19	63.33	22	73.33	0.5789	0.71
28.	Bishazari Tal, Chitwan District	67	28	41.18	53	77.94	0.49	0.35
29.	Ghodaghori Tal, Kailali District	27	16	59.26	22	81.48	0.659	0.64
30.	Jagadishpur Reservoir, Kapilvastu District	56	26	46.43	46	82.14	0.38	0.71
31.	Hetauda Fish-Pond, Makwampur District	24	14	58.33	18	75.00	0.689	0.65
[A-32]	Phewa Tal, all Collections, 2005-2007	78	26	33.34	66	84.62	0.90	0.18
32.	Phewa Tal at Khapaudi, northernmost shore	33	15	45.45	24	72.72	0.659	0.39
33.	Phewa Tal, Old Harpan Khola Branch	30	14	46.66	22	73.33	0.799	0.02
34.	Phewa Tal southern shore, at Rani Ban	19	13	68.42	17	89.47	0.248	0.65
35.	Phewa Tal, southwest of Tal Barahi Temple	23	11	47.83	17	73.91	1.877	0.75
36.	Nagdaha, Lalitpur district, Premonsoon	13	8	61.58	10	76.92	0.20	0.18
37.	Nagdaha, Lalitpur district, Monsoon, July	24	8	33.33	16	66.66	2.1875	0.77
38.	Nagdaha Outlet Stream, Monsoon, July	8	6	75.00	6	100.00	0.208	0.55
39.	Nagdaha, Lalitpur district, Monsoon, Aug.	28	14	50.00	24	85.71	0.44	0.59

40.	Nagdaha, East, Lithal Substrate, September	17	13	76.47	14	82.35	0.68	0.41
41.	Nagdaha, Northwest, Psammal Substrate, September	18	9	50.00	16	88.88	1.20	0.52
42.	Nagdaha Southwest, *Nelumbo nucifera* habitat, September	25	15	60.00	22	88.00	0.53	0.42
43.	Taudaha Lake, Kirtipur, Monsoon, August	38	24	63.16	28	73.68	0.089	0.47
44.	Ghatte Khola, Hetauda, Makwanpur	38	25	65.79	32	84.21	0.093	0.40
45.	Trichaudi Khola north of Hetauda	11	10	90.90	11	100.00	0.40	0.95
46.	Khageri Khola Ratnanahar, u/s.	23	14	60.89	18	78.26	0.27	1.19
47.	Khageri Khola Ratnanahar, d/s.	19	12	63.16	15	78.95	0.60	1.17
48.	Sim Bhanjyan Khola, Daman - Sim Bhanjyan	17	11	64.70	14	82.35	1.146	0.72
49.	Lower Sim Bhanjyang Khola,	18	13	72.22	14	77.77	0.26	1.15
50.	Middle Sim Bhanjyan Khola	31	22	70.97	22	70.97	0.091	0.46
51.	Left Tributary of Sim Bhanjyan Khola	19	13	68.42	16	84.21	0.197	0.38
52.	Right Tributary of Sim Bhanjyan Khola	16	10	62.50	12	75.00	0.267	0.46
53.	Sim Khola (upstream)	26	20	76.92	22	84.61	0.03	0.12
54.	Sim Khola (midstream)	29	18	62.07	20	68.96	0.072	0.61
55.	First Tributary of Sim Khola	42	27	64.28	29	69.05	0.143	0.19
56.	Third Tributary of Sim Khola	28	20	71.43	23	82.14	0.544	0.07
57.	Sim Khola below Sim Bhanjyan	40	27	67.50	30	75.00	0.019	0.08

Table 66: Comparison of ∑identified taxa; of ∑scored indicator taxa and of calculated ASPT value difference for all sampling sites using three indices.

7.3. Diversity: Taxa Richness and Water Quality Classes of the study sites

Identified Taxa	Sampling Site	Typology	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
42	First Tributary of Sim Khola	Epirhithron	I	I	I
40	Sim Khola below Sim Bhanjyan	Metarhithron	I	I	I
38	Ghatte Khola, Hetauda, Makwanpur	Hyporhithron Epipotamon	II	II	II
31	Middle Sim Bhanjyan Khola	Metarhithron	I	I	I
30	Karnali River, Chisapani	Large Hyporhithron	I	I	I
29	Sim Khola (midstream)	Metarhithron	I	I	I
28	Ganga, Chunar, lentic,	Large Meta-Potamon	III	II	III
28	Third Tributary of Sim Khola	Epirhithron	I	I	I
27	Punpun, Gaurichak, Phytal	Meta-Potamon	III	II	III
26	Ganga, Old Palace, Patna, Lithal	Large Meta-Potamon	III	II	III
26	Sim Khola (upstream)	Epi/-Metarhithron	I	I	I
25	Punpun, Gaurichak, Pelal, Psammal	Meta-Potamon	III	II	III
24	Karnali River, Manau Ghat	Large Epipotamon	I	II	I
23	Ganga, Old Palace, Patna, Phytal	Large Meta-Potamon	III	III	II
23	Khageri Khola Ratnanahar, u/s.	Epipotamon	III	III	II
22	Ganga, Chunar, lotic	Large Meta-Potamon	III	II	III
21	Ganga, Gandhi Ghat, Patna	Large Meta-Potamon	III	II	III
20	Ganga, Adalat Ghat, Patna	Large Meta-Potamon	III	III	III
19	Ganga Springs, Mahendrughat, Patna	Meta-Potamon/ Helocrenal	IV	III	IV
19	Khageri Khola Ratnanahar, d/s.	Epipotamon	II	II	I
19	Left Tributary of Sim Bhanjyan Khola	Epirhithron	I	I	I
18	Ganga, Patna, Krishnaghat	Large Meta-Potamon	III	II	III
18	Karnali River, Khote Ghat,	Large Epipotamon	II	II	I
18	Lower Sim Bhanjyang Khola,	Metarhithron	I	I	I
17	Sim Bhanjyan Khola,	Metarhithron	II	I	I

	Daman - Sim Bhanjyan				
16	Ganga, downstream Mahendrughat	Large Meta-Potamon	III	III	III
16	Right Tributary of Sim Bhanjyan Khola	Epirhithron	II	II	II
13	Kamthi River north of Nagpur, Changaghat	Epipotamon	III	III	IV
12	Pench, forest spring stream (Tiger Reserve)	Limnocrenal/ Hypocrenal	I	I	I
11	Pench, Ambakhori-Totladoah forest stream	Metarhithron /Hyporhithron	III	II	IV
11	Trichaudi Khola north of Hetauda	Epirhithron	I	I	I
8	Ganga, Adalat-Ghat, Patna, Periphyton	Large Meta-Potamon	IV	III	IV

Table 67: Correlation of Macro-benthic faunal diversity, Typology according biocoenotic region, and Ecological Quality of the studied Running water bodies, ranking according to Taxa Richness.

Identified Taxa Richness (TR)	Sampling Site	Typology/ Biocoenotic Zone	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
76	Phewa Tal, all Collections, 2005-2007	Large Limnion including Littoral	III	II	III
67	Bishazari Tal, Chitwan District	Plesiopotamon	II	II	II
56	Jagadishpur Reservoir, Kapilvastu District	Plesiopotamon	III	III	II
38	Taudaha Lake, Kirtipur, Monsoon, August	Eulittoral of large 'old' pond	II	II	III
33	Phewa Tal at Khapaudi, northernmost shore	Eulittoral of Lake	III	II	III
31	Large pond and wetlands at Tahoba	'Old' Pond + swamps	III	III	II
30	Phewa Tal, Old Harpan Khola Branch	Eulittoral/ Epipotamon	III	II	III
28	Nagdaha, Lalitpur district, Monsoon, August	Eulittoral of large 'old' pond	III	II	III
27	Patna, Kumhrar, large Bivalvia pond	Wetland. Plesio-Potamon	III	III	III
27	Patna, Kumhrar, central *Phoenix sylvestris* pond	Wetland. Plesio-Potamon	III	III	III
27	Ghodaghori Tal, Kailali District	Plesiopotamon	III	III	III
25	Nagdaha Southwest, *Nelumbo nucifera* habitat, September	Eulittoral of large 'old' pond	III	III	III
24	Nagdaha, Lalitpur district, Monsoon, July	Eulittoral of large 'old' pond	III	I	II
24	Hetauda Fish-Pond, Makwampur District	Artificial stagnant water	III	II	II
23	Phewa Tal, southwest of Tal Barahi Temple	Eulittoral of Lake	III	I	III
19	Patna, Fishpond north of Pahari	Wetland. Plesio-Potamon	III	III	IV
19	Phewa Tal southern shore, at Rani Ban	Eulittoral of Lake	III	III	II
18	Patna, Wetland-Channel at Pahari	Wetland. Paleo-Potamon	IV	III	IV
18	Patna, Bairia, *Eichhornia*	Wetland.	III	III	IV

	crassipes Pond	Paleo-Potamon			
18	Nagdaha, Northwest, Psammal Substrate, September	Eulittoral of large 'old' pond	IV	III	III
17	Shallow pond in grassland, Ghorpad	Pluvial Pond	II	II	III
17	Nagdaha, East, Lithal Substrate, September	Eulittoral of large 'old' pond	III	II	III
13	Nagdaha, Lalitpur district, Premonsoon	Eulittoral of large 'old' pond	III	IV	IV
9	Shallow forest-pond, Ghorpad	Pluvial temporary Pond	III	IV	IV
8	Patna, Bairia, *Trapa natans* Pond	Wetland. Paleo-Potamon	II	II	IV
8	Nagdaha Outlet Stream, Monsoon, July	Eulittoral of large 'old' pond	IV	IV	IV

Table 68: Correlation of Macro-Benthic Faunal Diversity, Typology according Biocoenotic Zone, and Ecological Quality of the studied Stagnant water bodies, ranking according to Taxa Richness.

7.4. Ecological- and Water Quality Classes of the Study Sites

Ecological Quality Classes

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
1.	Ganga, Chunar, lenthic,	Large Meta-Potamon	28	III Moderate	II Good	III Moderate
2.	Ganga, Chunar, lotic	Large Meta-Potamon	22	III Moderate	II Good	III Moderate
3.	Ganga, Patna, Krishnaghat	Large Meta-Potamon	18	III Moderate	II Good	III Moderate
4.	Ganga Springs, Mahendrughat, Patna	Meta-Potamon/ Helocrenal	19	IV Poor	III Moderate	IV Poor
5.	Ganga, downstream Mahendrughat	Large Meta-Potamon	16	III Moderate	III Moderate	III Moderate
6.	Ganga, Adalat-Ghat, Patna, Periphyton	Large Meta-Potamon	8	IV Poor	III Moderate	IV Poor
7.	Ganga, Adalat Ghat, Patna	Large Meta-Potamon	20	III Moderate	III Moderate	III Moderate
8.	Ganga, Gandhi Ghat, Patna	Large Meta-Potamon	21	III Moderate	II Good	III Moderate
9.	Ganga, Old Palace, Patna, Lithal	Large Meta-Potamon	26	III Moderate	II Good	III Moderate
10.	Ganga, Old Palace, Patna, Phytal	Large Meta-Potamon	23	III Moderate	III Moderate	II Good
11.	Punpun, Gaurichak, Phytal	Meta-Potamon	27	III Moderate	II Good	III Moderate
12.	Punpun, Gaurichak, Pelal, Psammal	Meta-Potamon	25	III Moderate	II Good	III Moderate
13.	Patna, Kumhrar, Bivalvia pond	Wetland. Plesio-Potamon	27	III Moderate	III Moderate	III Moderate

14.	Patna, Kumhrar, central *Phoenix sylvestris* pond	Wetland. Plesio-Potamon	27	III Moderate	III Moderate	III Moderate
15.	Patna, Fishpond north of Pahari	Wetland. Plesio-Potamon	19	III Moderate	III Moderate	IV Poor
16.	Patna, Wetland-Channel at Pahari	Wetland. Paleo-Potamon	18	IV Poor	III Moderate	IV Poor
17.	Patna, Bairia, *Eichhornia crassipes* Pond	Wetland. Paleo-Potamon	18	III Moderate	III Moderate	IV Poor
18.	Patna, Bairia, *Trapa natans* Pond	Wetland. Paleo-Potamon	8	II Good	II Good	IV Poor

Table 69: Ecological- and Water Quality Classes of the study sites in the Gangetic Plains in India (Uttar Pradesh: 1, 2; Bihar: 3-18) using three Scoring calculations. Altitudinal range 54-120 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
19.	Pench, forest spring stream (Tiger Reserve)	Limnocrenal/ Hypocrenal	12	I Excellent	I Excellent	I Excellent
20.	Pench, Ambakhori-Totladoah forest stream	Metarhithron /Hyporhithron	11	III Moderate	II Good	IV Poor
21.	Kamthi River north of Nagpur, Changaghat	Epipotamon	13	III Moderate	III Moderate	IV Poor
22.	Shallow pond in grassland, Ghorpad	Pluvial Pond	17	II Good	II Good	III Moderate
23.	Shallow forest-pond, Ghorpad	Pluvial temporary Pond	9	III Moderate	IV Poor	IV Poor
24.	Large pond and wetlands at Tahoba	'Old' Pond + swamps	31	III Moderate	III Moderate	II Good

Table 70: Ecological- and Water Quality Classes of the study sites for the Forest water bodies in India (Maharashtra) using three Scoring calculations. Altitudinal range 250-400 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
25.	Karnali River, Khote Ghat,	Large Epipotamon	18	II Good	II Good	I Excellent
26.	Karnali River, Manau Ghat	Large Epipotamon	24	I Excellent	II Good	I Excellent
27.	Karnali River, Chisapani	Large Hyporhithron	30	I Excellent	I Excellent	I Excellent
28.	Bishazari Tal, Chitwan District	Plesiopotamon	67	II Good	II Good	II Good
29.	Ghodaghori Tal, Kailali District	Plesiopotamon	27	III Moderate	III Moderate	III Moderate
30.	Jagadishpur Reservoir, Kapilvastu District	Plesiopotamon	56	III Moderate	III Moderate	II Good
31.	Hetauda Fish-Pond, Makwampur District	Artificial stagnant water	24	III Moderate	II Good	II Good

Table 71: Ecological- and Water Quality Classes of the study sites for the Terai-/Inner Terai region of Nepal using three Scoring calculations. Altitudinal range 195-450 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
[A-32]	Phewa Tal, all Collections, 2005-2007	Large Limnion including Littoral	78	III Moderate	II Good	III Moderate
32.	Phewa Tal at Khapaudi, northernmost shore	Eulittoral of Lake	33	III Moderate	II Good	III Moderate
33.	Phewa Tal, Old Harpan Khola Branch	Eulittoral/ Epipotamon	30	III Moderate	II Good	III Moderate
34.	Phewa Tal southern shore, at Rani Ban	Eulittoral of Lake	19	III Moderate	III Moderate	II Good
35.	Phewa Tal, southwest of Tal Barahi Temple	Eulittoral of Lake	23	III Moderate	I Excellent	III Moderate

Table 72: Ecological- and Water Quality Classes of the study sites for the Phewa Tal and adjacent wetlands in Nepal using three Scoring calculations. Altitudinal range 798-850 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
36.	Nagdaha, Lalitpur district, Premonsoon	Eulittoral of large 'old' pond	13	III Moderate	IV Poor	IV Poor
37.	Nagdaha, Lalitpur district, Monsoon, July	Eulittoral of large 'old' pond	24	III Moderate	I Excellent	II Good
38.	Nagdaha Outlet Stream, Monsoon, July	Eulittoral of large 'old' pond	8	IV Poor	IV Poor	IV Poor
39.	Nagdaha, Lalitpur district, Monsoon, August	Eulittoral of large 'old' pond	28	III Moderate	II Good	III Moderate
40.	Nagdaha, East, Lithal Substrate, September	Eulittoral of large 'old' pond	17	III Moderate	II Good	III Moderate
41.	Nagdaha, Northwest, Psammal Substrate, September	Eulittoral of large 'old' pond	18	IV Poor	III Moderate	III Moderate
42.	Nagdaha Southwest, *Nelumbo nucifera* habitat, September	Eulittoral of large 'old' pond	25	III Moderate	III Moderate	III Moderate
43.	Taudaha Lake, Kirtipur, Monsoon, August	Eulittoral of large 'old' pond	38	II Good	II Good	III Moderate

Table 73: Ecological- and Water Quality Classes of the study sites for some stagnant water locations of Kathmandu Valley in Nepal using three Scoring calculations. Altitudinal range 1150-1350 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
44.	Ghatte Khola, Hetauda, Makwanpur	Hyporhithron→ Epipotamon	38	II Good	II Good	II Good
45.	Trichaudi Khola north of Hetauda	Epirhithron	11	I Excellent	I Excellent	I Excellent
46.	Khageri Khola Ratnanahar, u/s.	Epipotamon	23	III Moderate	III Moderate	II Good
47.	Khageri Khola Ratnanahar, d/s.	Epipotamon	19	II Good	II Good	I Excellent

Table 74: Ecological- and Water Quality Classes of the study sites for some Terai-/Inner Terai-Foothill streams in Nepal using three Scoring calculations. Altitudinal range 200-500 m asl.

No.	Sampling Site	Biocoenotic Zone, Typology	Taxa No.	Ecological Quality Class NEPBIOS	Ecological Quality Class GRS-BIOS	Ecological Quality Class HKHBIOS
48.	Sim Bhanjyan Khola, Daman - Sim Bhanjyan	Metarhithron	17	II Good	I Excellent	I Excellent
49.	Lower Sim Bhanjyang Khola,	Metarhithron	18	I Excellent	I Excellent	I Excellent
50.	Middle Sim Bhanjyan Khola	Metarhithron	31	I Excellent	I Excellent	I Excellent
51.	Left Tributary of Sim Bhanjyan Khola	Epirhithron	19	I Excellent	I Excellent	I Excellent
52.	Right Tributary of Sim Bhanjyan Khola	Epirhithron	16	II Good	II Good	II Good
53.	Sim Khola (upstream)	Epi/-Metarhithron	26	I Excellent	I Excellent	I Excellent
54.	Sim Khola (midstream)	Metarhithron	29	I Excellent	I Excellent	I Excellent
55.	First Tributary of Sim Khola	Epirhithron	42	I Excellent	I Excellent	I Excellent
56.	Third Tributary of Sim Khola	Epirhithron	28	I Excellent	I Excellent	I Excellent
57.	Sim Khola below Sim Bhanjyan	Metarhithron	40	I Excellent	I Excellent	I Excellent

Table 75: Ecological- and Water Quality Classes of the study sites for some Mahabharat mountain streams in Nepal using three Scoring calculations. Altitudinal range 2200-2470 m asl.

Chapter 8. Aquatic Insects as Bioindicators (in part)

Aquatic Insecta as Bioindicators in Lowlands and Lentic Habitats:

	Number of Species and Subspecies worldwide	Number of Species and Subspecies in India	Number of Species and Subspecies in Nepal
Order Odonata	6611	499	202
Order Blattodea	≈ 4560	186	unknown
Suborder Heteroptera	4810 [+>1100 undescribed]	275	13
Infraorder Nepomorpha	> 2006	153	6

Table 76: Diversity of the studied groups of aquatic insects, source for Nepal are the Publications of Sharma (1998), Thapa (2000) and Zettel (pers. com.).

The commonly applied biotic score indices to evaluate the biological water quality and ecological status are mainly based on benthic macroinvertebrates from the stream fauna of temperate zones in the Holarctic. Insect orders of fast running Rhithron-habitats usually named as EPT-taxa (E = Ephemeroptera, P = Plecoptera, T = Trichoptera) are well represented. In the study area the EPT-taxa are common only in higher altitudes above 1000 m asl; or in large glacio-nivale rivers coming from the Himalayan mountain range. The benthic macroinvertebrates of lowlands and Potamon-habitats are more dominated by Mollusca, Annelida, Crustacea and sessile animals e.g. Porifera, Bryozoa, whereas the EPT-taxa are less represented or even partially absent. The distinction of lowland (< 1000 m) and midland (≥ 1000 m) was initially based on Sharma and Moog (2005) with new transformation table describing separately the water quality. During the fieldwork of the present study [beside the very difficult aquatic Diptera] mainly Heteroptera and Odonata were recognized as very important benthic insects of lentic water bodies and the Gangetic Plains. Main emphasis is given to provide new information that is not yet available and published. The Blattodea are included since there is very little known about aquatic forms and they were almost overlooked. In the present study Blattodea were found in several unpolluted and undisturbed sites always in association with naturally forested banks. In some localities they occur together with *Epiophlebia* larvae. These are only two

reasons to make aquatic cockroaches interesting for Biomonitoring. The number of presently known species and subspecies is given in Table 76 demonstrating the deficits of exact data from Nepal and the Himalayan region.

Most insects have a soft and delicate exoskeleton that makes their preservation in sediments over a long time difficult, although Holocene fossils are known from lacustrine deposits. Altogether there is a relatively 'better' fossil record of Odonata, Hemiptera and Blattodea than for any other freshwater insects; allowing conclusions about phylogeny, origin, age and morphological adaptations.

8. Dragonflies and Damselflies

8.1. Odonata Larvae

The Origin of the Order Odonata

The Odonata Order dates back to the Triassic Period. They all are originated and derived from the Paleozoic Order Odonatoptera (Zessin, 2008a), traditionally known for a long time as Protodonata. The Odonatoptera were already existent before 320 Million years and their alleged origin is believed before 350 Million years. They are also named as "Oldest Dragonflies", because their existence is documented from the Carboniferous period onwards with German locality Hagen-Vorhalle from the uppermost 'Namurian B' sediments. The first known genus of Odonatoptera was described as *Namurotypus sippeli* by Braukmann & Zessin in the year 1989. Same locality revealed also *Erasipteroides valentini* (Braukmann 1985) with three pairs of wings (one pair prothoracal wings) and the smallest *Zessinella siope* Braukmann (1988) with wingspan only 5 cm. Altogether 37 genera of the oldest Dragonflies are distinguished from the Paleozoic (Zessin, 2008c). Among them *Meganeuropsis permiana* before 280 Million years had a wingspan of 720 mm. The development of such large insects was correlated with higher pressure of atmosphere and higher oxygen 35 % O2 (21 % O2 today) in the Carboniferous. All the Giant dragonflies were not able to adapt their mode of live to the rapidly decreasing oxygen concentration in the air at the end of the Permian period and became completely extinct. Other, smaller Odonatoptera with petiolate wing-base survived the

Permian/Triassic crisis and gave the origin to the rich diversity of the Mesozoic and to the recent species. The two living Odonata-Suborders Anisoptera [Dragonflies] and Zygoptera [Damselflies] were already present in Jurassic.

Anisozygoptera [Relict Dragonflies] were rich in Mesozoic forms with around > 30 fossil genera. They show combined features of Anisoptera and Zygoptera. They are regarded as ancestors or stem group of the Anisoptera, a theory which is much supported by their earlier fossil presence. According to Bechly (1999) the Triassic dragonflies *Italophlebia paganoniae* and *Italophlebia gervasuttii* of superfamily Isophlebioptera/Isophlebioidea are the oldest known stem group representatives of Anisoptera. The formerly well represented Anisozygoptera became nearly extinct from Cretaceous/Tertiary onwards and the single extant genus *Epiophlebia* with two species is regarded as "living fossil".

In Upper Jurassic of Solnhofen in Germany there was already a very rich Odonata fauna present and common recent families like Gomphidae were accompanied by extinct Mesozoic Aeschnidiidae, Stenophlebiidae and Tarsophlebiidae (Malz & Schröder, 1979). From Lower Cretaceous in Brazil there are altogether 384 specimens of Odonata found, representing 12 families with 34 species (Bechly 1999). Nel and Jarzembowski (1996) described remarkable dragonflies from the non-marine Lower Cretaceous of southern England belonging to four Anisozygoptera families. *Stenophlebia corami* are the first Cretaceous records of the predominantly Jurassic family Stenoplebiidae. *Proeuthemis pritykinae* represents the family Euthemistidae. In addition, a Campterophlebiidae is described but not named, providing fossil evidence of the superfamily Isophlebioidea in northwestern Europe. *Mesoepiophlebia bexleyi* is extending the range of the relict extant family Epiophlebiidae.

Fossil larvae of Paleozoic Odonatoptera are still yet unknown and fossil larvae of Odonata were known for a long time only from Tertiary (Neozoic) deposits. This gave raise to the question if the aquatic life of Dragonflies is a secondary adaptation and the whole life cycle was originally terrestrial (Xylander and Günther, 2003). Most other authors argued that suitable freshwater deposits for preservation of Paleozoic and Mesozoic larvae are not explored and accessible. Meanwhile a larger number of Cretaceous larvae was discovered and partially described from Brazil and China

(Zhang 2000). The Santana/Crato-Formation in northeastern Brazil has revealed > 120 larvae together with 264 adults. More then 50 % belong to the super-family/group of Gomphides. In China larvae were found in the Yixian Formation of Liaoning which is dated from latest Jurassic to Mid-Early Cretaceous (Zhang and Zhang 2001). Two species of the extinct family Aeschnidiidae were described: *Dracontaeschnidium orientale*, *Stylaeschnidium rarum*, the latter one based on different instars larvae.

The extant Odonata

The modern order Odonata is highly diversified with 5747 [accepted] extant species, 864 [accepted] extant subspecies and approximately 600 fossil species (Xylander and Günther 2003, Van Tol 2008). The highest species number is known from the Oriental region which has more than 1000 species. From India exactly 499 species were recorded until recent years (Mitra, 2005). The taxonomy and knowledge of Odonata from the Indian Subcontinent is largely based on the terrestrial adults. Among all the species and subspecies within this geographical limit, the figure or description is known only for 78 taxa (Mitra, 2005). For Nepal the number of species and subspecies was previously 172 published by Vick (1989). Later Sharma (1998) listed 202 taxa for the same country. In Bhutan Mitra (2006) has published an actualized Odonata List with 31 taxa, to which the occurrence of *Epiophlebia laidlawi* around Thimpu can be added (New findings by the Department of Hydrobiology, BOKU, Vienna, Austria, 2006).

The genus and species identification in many countries is mostly based on the terrestrial adults and there is already an old tradition in publication of very high quality color figures for each species. It dates back to the important works of Drury (1770, 1773, 1782), who has for the first time published several hundred Dragonfly adults arranged on one hundred fifty color plates. In recent years all known Odonata species from Japanese Archipelago were published by Okudaira et al. (2005) giving booth color figures of larvae and adults.

For the Odonata fauna of the Ganga River System and adjacent watersheds Mitra (2003) gives an updated list of the regional species composition for the different eco-regions. It allows recognizing the local faunas and the possible presence of their

aquatic larvae for the Himalayan regions. In contrast the distinction of aquatic Odonata from the same territory is poorly known. Even the identification of the Family level remains difficult for many Zypoptera (Superfamilies Coenagrionoidea, Lestoidea) and some Anisoptera (Libellulidae vs. Corduliidae).

The objective of the present study is to fill the gap for Odonata Larvae and to provide a pictorial catalogue helping in their identification. Therefore 58 examples from recent collections are presented to give their morphological characters as well as live color. The problems of sampled aquatic macroinvertebrates are their decreasing color change due to preservation, which is mostly done with alcohol or formaldehyde. Thus only fresh samples collected by the author were included. Color was studied in living material in the field.

The classification of the Order Odonata on family level is a matter of controversy discussions. The number of Families recognized by different authors varies largely. The 15 families in St. Quentin and Beier (1967), 27 families in Trueman and Rowe (2001), 56 families in Xylander and Günther (2003) demonstrate the different views. The present study follows the proposed system of Trueman and Rowe (2001) with one addition. More recently the genera Macromia, Macromidia and *Epophthalmia* were separated from Corduliidae and given family rank Macromiidae, previously already distinguished as subfamily Epophthalmiinae.

Identification Characters of Odonata Larvae

Srivastava (1990) highlighted that the aquatic phase of life cycle comprises eggs, pro-larval and larval stages, and 70-95 % of the whole life span is passed in water. Larvae undergo approximately 10-20 molts (mostly 11-14), over a time between 3 month (e.g. some Libellulidae) and about 6-10 years (e.g. Epiophlebiidae) depending on the species. One characteristic shared by all Odonata larvae is the conspicuous grasping labium (mask), used for capturing the prey. At rest the labium is held folded underneath head. In prey capture the labium is shot rapidly forward and prey is grasped with paired hand-like lateral lobes (palps). Form, size and number of mental setae can be used for family or even Genus identification but requires binocular. Even from above and with mask retracted, identification of larvae to Suborder and Family

is very easy, based on several other features. These are namely the apices of abdomen, number and form of caudal gills, presence of abdominal gills, form, size and number of segments of antennae, presence of teeth along the anterior margin of the lateral lobes (palps) of labium (mask) and anal pyramid with length relationship of epiproct, paraprocts and cerci. Furthermore the shape, consistency (firm or soft) and color of body make identification of Suborders possible.

About the identification problems of better known North-American Odonata larvae Pennak (1978, p. 557) gave a suitable statement: “The identification of a nymph, even to genus, is often no easy matter because of the fact that morphological differences are so slight. Keys must therefore be used with great care.”

The identification of the collected and figured specimens was mainly based on descriptions given for the Odonata fauna of Japan (Okudaira et al. 2005, Kawai 2003) of Malaysia (Yule and Hoi Sen 2004), and a few available publications from the Western Himalayan Region (Kumar 1973, Mitra 2005). Recently a combined key to the families was also applied (Hartmann 2006). The identification result reached in the present study remains mostly on family level. Only in a few cases the genus or species level could be reached.

8.2. Illustrated Catalogue

Family Coenagrionidae (Synonym: Agrionidae)

Brief Characters:

The larvae have leaf-like caudal gills of similar shape and length. The gills not usually clearly divided into proximal and distal portions. The caudal gills shorter than the abdomen with rounded apices and conspicuous tracheal branching. The anterolateral margins of the labial mentum are not toothed and 3-5 premental setae are usually situated on either side of the midline of the mentum. The third segment of antenna is shorter than the second.

This family has the highest species number among all Zygotera with 1080 taxa and worldwide distribution. Aquatic Coenagrionidae inhabit a wide range of running and stagnant waters; the most diversified fauna is found in wetlands and lentic zones of rivers and streams. In the study area they occur numerously together with Libellulidae in submerged macrophytes of ponds, reservoirs and lakes. The general color appearance includes light yellow brown forms, dark striped forms, and bright green to dark brown forms. The distinction between Coenagrionidae and Protoneuridae is very easy based on the form of head and color but the identification of Genus- or Species level is almost impossible due to the high number of taxa with completely unknown larvae.

Plate 11: Coenagrionidae

Fig. 1: Coenagrionidae, length 14.5 mm, Nepal, Godagori Tal.
Fig. 2: Coenagrionidae, length 18.2 mm, Nepal, Kavre, Dobi Khola near Kathmandu University, Dhulikhel.
Fig. 3: Coenagrionidae, length 12.5 mm, Nepal, Kavre, Dobi Khola near Kathmandu University, Dhulikhel.
Fig. 4: Coenagrionidae, length 13 mm, Nepal, Hetauda, Ghatte Khola, Inlet of fishpond.

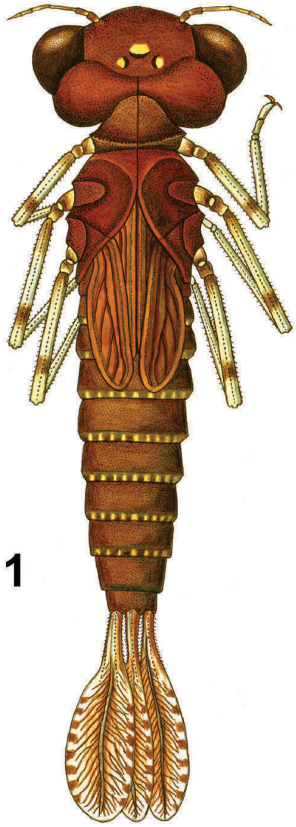
Family Caliphaeidae with caudal gills similar to Calopterygidae

Plate 12: Caliphaeidae.

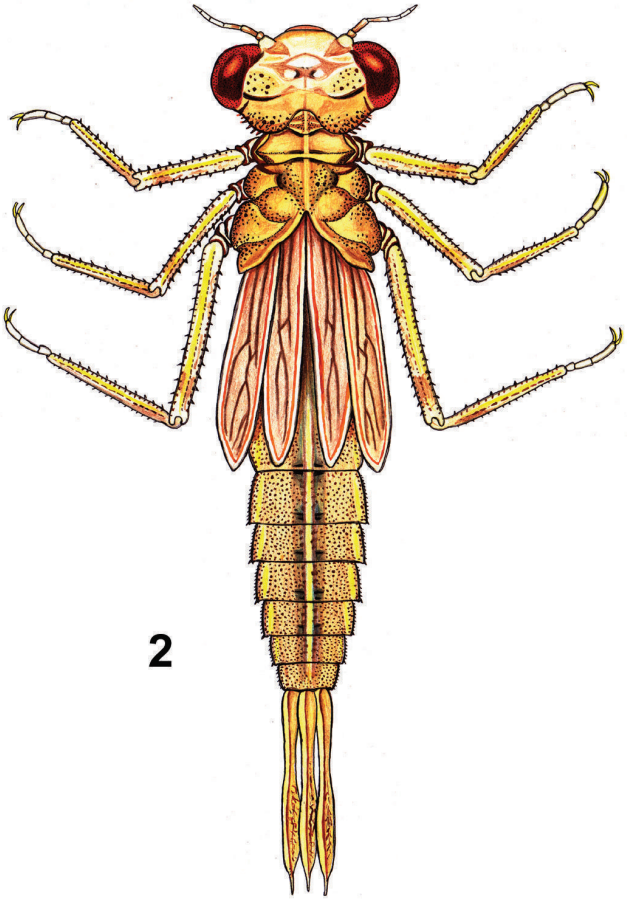
Fig 1: Caliphaeidae, length 19 mm, India, Jharkhand, Subernarekha River downstream from Chandil Reservoir dam, altitude 148 m asl.

Brief Characters:

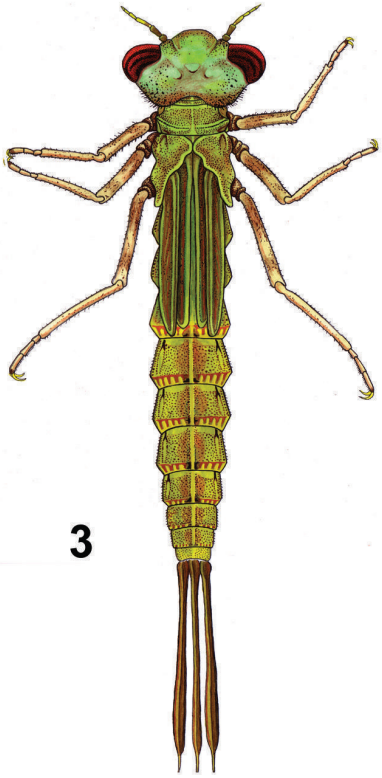
In general appearance these larvae have combined characters from Superfamily Coenagrionoidea and Superfamily Calopterygoidea. The body is firm and hard similar to the Family Amphyipterygidae. There is dark pigmentation of the body and the legs are very long, approximately ¼ longer than in other Coenagrionidae. The labium is of



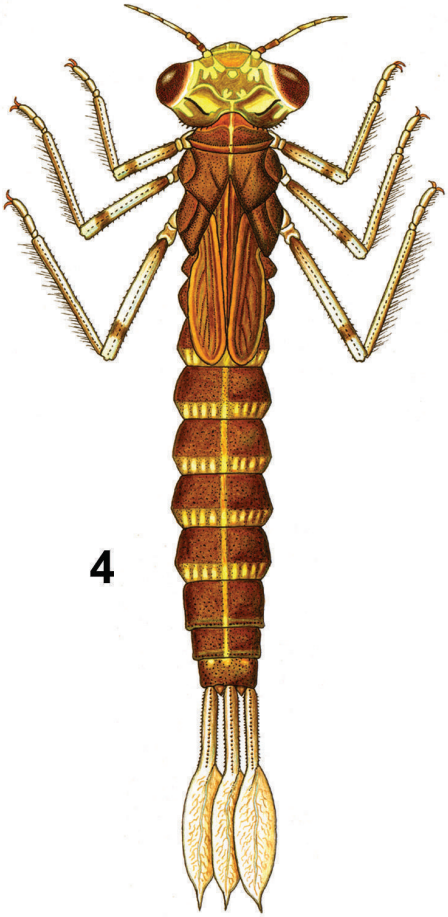
1



2



3



4

Plate 11: Coenagrionidae.

typical Coenagrionid-type with three premental setae each. The last four abdominal segments are armed with prominent lateral spines (3 each). All caudal gills are thick and hard with rows of spines. The lateral gills are of triquetral type like in the Family Calopterygidae. The median gill is 1/5 shorter than the lateral gills; it is square-shaped in cross-section.

According to the combined characters, the larvae can not be identified and certainly assigned to any genus. The caudal gills are not lamelliform and leaf-like as in Coenagrionidae and Platycnemididae; they are not divided into a thickened dark proximal portion and a thin, paler distal part as in Protoneuridae.

These larvae were found on Megalithal substrate in the main channel of Metapotamon-type, having water quality class II using booth NEPBIOS (9 indicator taxa, value 5.22) and GRS-BIOS (10 indicator taxa, value 5.50). The macroinvertebrate fauna comprises 13 identified taxa and is dominated by filter-feeders.

Family Platycnemididae

Brief Characters:

The caudal gills are very long, they have approximately the same length as the abdomen with apices somewhat pointed or attenuated and inconspicuous tracheal branching. The gills are not usually clearly divided into proximal and distal portions. The third segment of antenna is slightly longer than the second. The anterolateral margins of the labial mentum are not toothed. Certain records of larvae in the study area were rare. Only in one locality from lowland Platycnemididae were more abundant.

Plate 13: Protoneuridae, Platycnemididae.

Fig. 2: Platycnemididae, length 15 mm, Nepal, Kailali, Jagadishpur Reservoir.

1

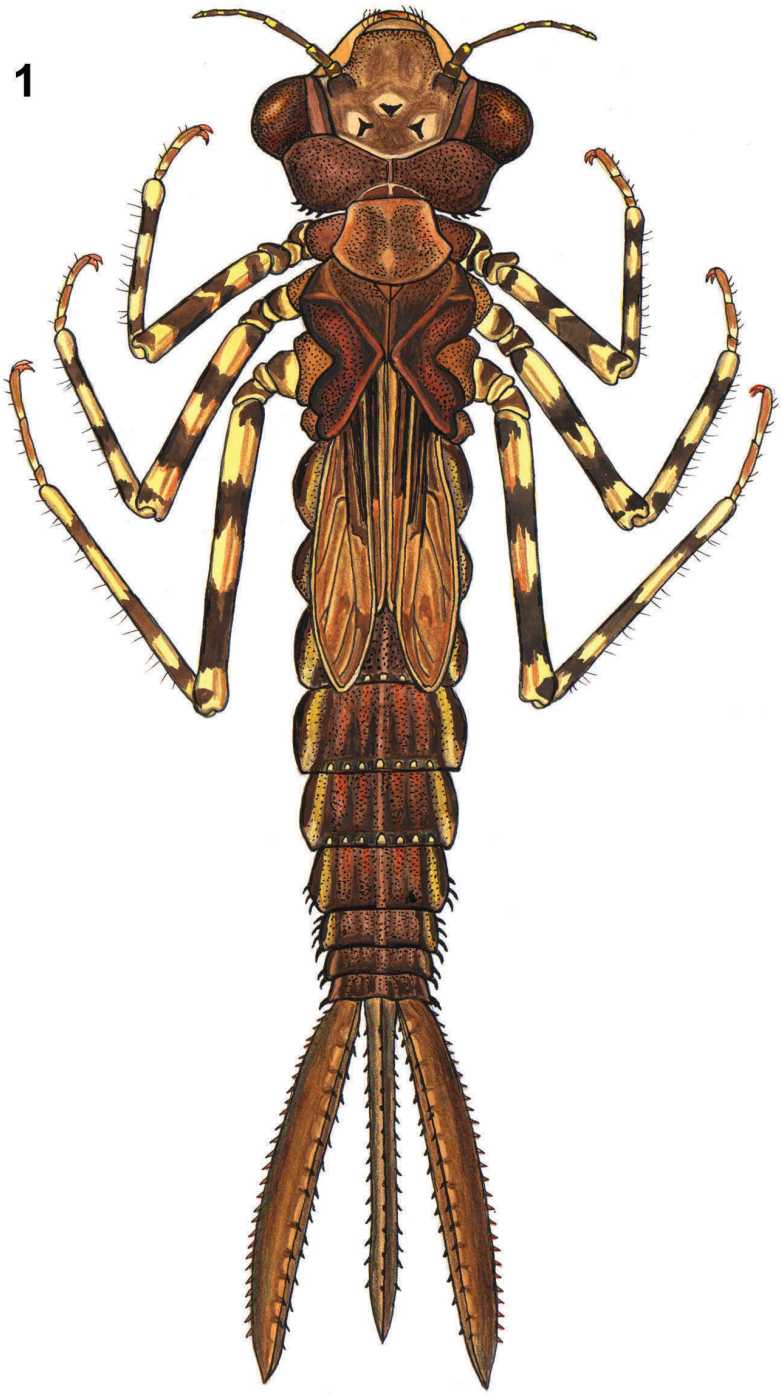


Plate 12: Platycnemididae

Disparoneura quadrimaculata

Family Protoneuridae

Brief Characters:

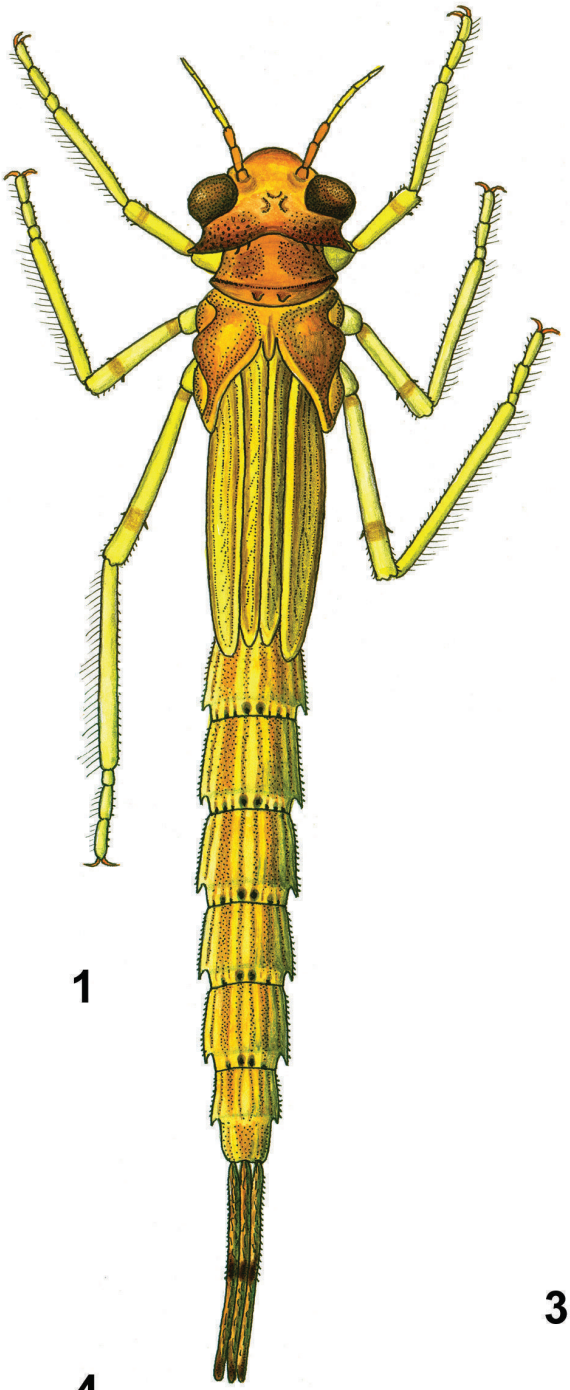
This family has delicate aquatic larvae with flattened bodies and relatively long antennae; the long, slender legs are fringed with setae. The larvae of this family have two-segmented leaf-like caudal gills of similar shape and length. The gills are clearly divided into a thickened dark proximal portion and a thin, paler distal part. The anterolateral margins of the labial mentum are fringed with tiny teeth. One premental seta is situated on either side of the midline of the mentum. There are three setae on the palpal lobes. The posterior margin of the head forms two lateral horn-like extensions, whereas it is smoothly rounded in Coenagrionidae.

Protoneuridae have a wide distribution in tropical and subtropical zones but they are insufficiently known and not generally recognized as family by traditional Odonatology. Aquatic Protoneuridae inhabit a narrow range of slowly running and stagnant waters; the most abundant fauna is found in wetlands and lentic zones of rivers and streams in lowlands and plains. In the study area they may occur numerously together with Coenagrionidae in submerged macrophytes of ponds, reservoirs and lakes. The general color appearance of the observed larval forms is uniform light yellow brown. The distinction between Coenagrionidae and Protoneuridae is comparatively easy based on the form of head and color but the identification of Genus- or Species level is almost impossible due to the high number of taxa with completely unknown larvae.

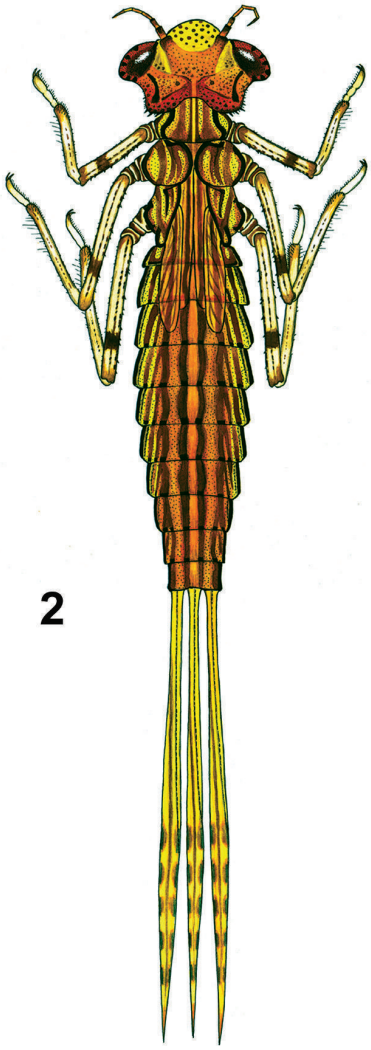
Plate 13: Protoneuridae, Platycnemididae.

Fig. 1: Protoneuridae, length 13 mm, Nepal, Hetauta, Ghate Khola, Inlet of fishpond. Figs 3, 4: Habitat of Protoneuridae, Nepal, Lalitpur, Nagdaha pond; Microhabitat with *Nelumbo nucifera*, *Nymphaea* spp. and [submerged] *Utricularia* spp.

Plate 13: Protoneuridae, Platycnemididae.



1



2

3

4

Family Euphaeidae

Brief Characters:

The larvae are medium-sized to large and robust with stonefly-like, flattened body form. They have three very large caudal gills that are saccoid. In addition there are filamentous gills on the underside of abdominal segments II-VIII that are light grey-blue and un-pigmented. The characters mentioned above allow easy identification of the family in field.

Euphaeidae (and some related families) are restricted on the oriental region from the Mediterranean in the West to Japan in East. The pollution-sensitive larvae are highly specialized on lotic microhabitats. They are locally common in fast running streams and smaller rivers of the Himalayan middle mountains. They prefer unpolluted waters with low organic load. Usually they are found on the underside of large stones in high water current of riffles and rapids together with large stoneflies of the family Perlidae. Earlier Euphaeidae were often united with other similar forms as families Polythoridae and Epallagidae (Xylander and Günther 2003).

Plate 14: Euphaeidae.

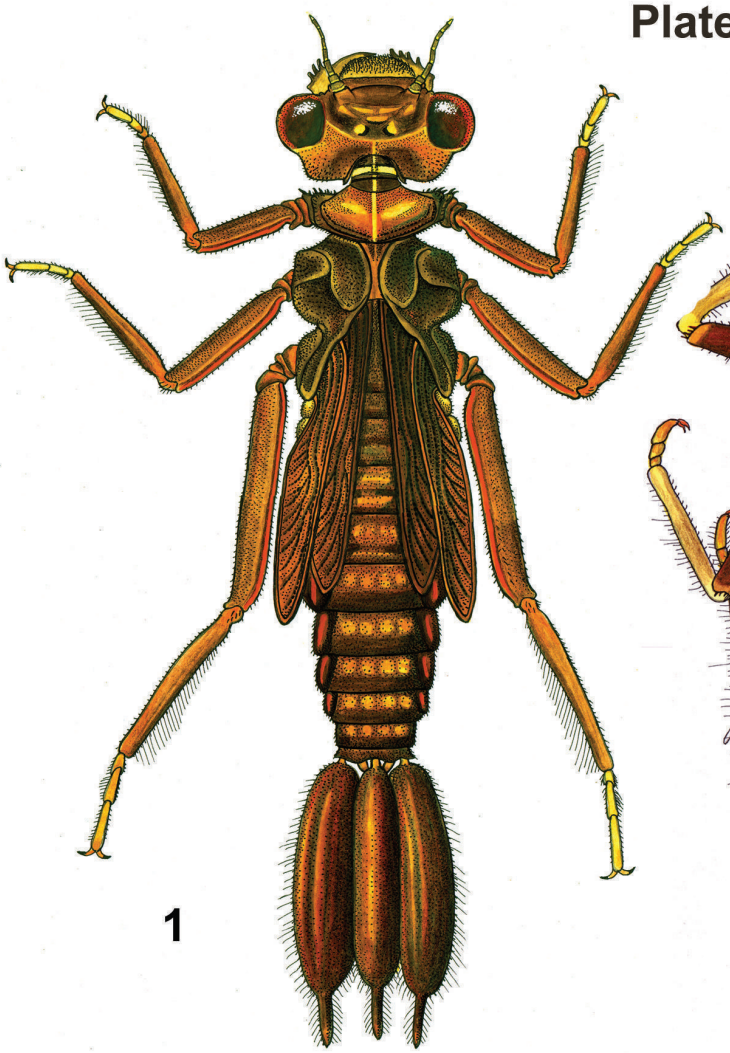
Fig. 1: Euphaeidae, length 29.3 mm, Nepal, Khimti Khola.
Fig. 2: Euphaeidae, length 21 mm, Nepal, Pokhara, Yangdi Khola.
Fig. 3: Habitat of Euphaeidae, Nepal, Kaski, Dhoti Khola, left tributary of Modi Khola, Western Himalayan Pine forest, Reference site of class I water quality.

Family Libellulidae

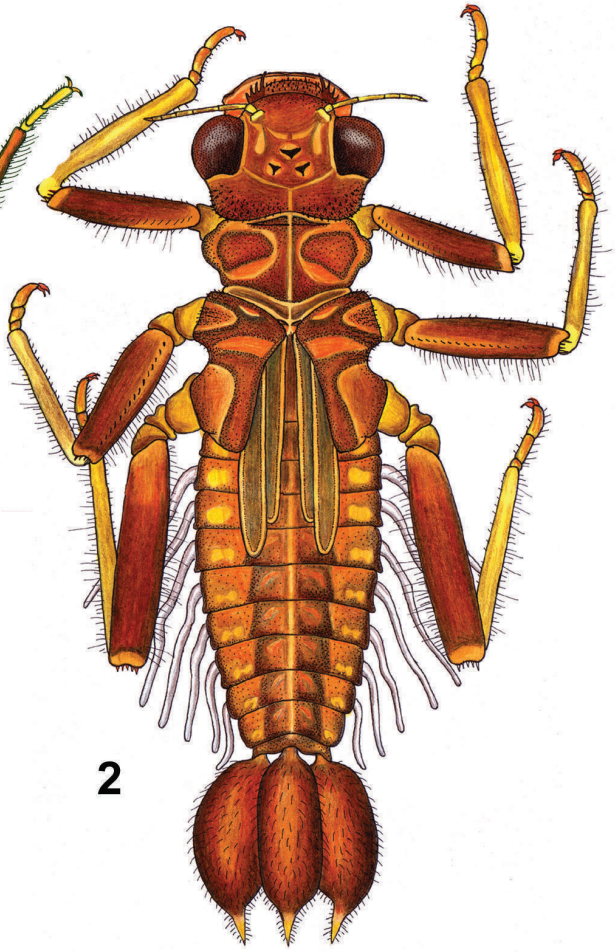
Brief Characters:

The aquatic larvae are minute to medium-sized and have a delicate comparatively soft body. Their legs are rather short and the apex of the femur does not extend beyond abdominal segment VIII. The abdomen is not markedly depressed or circular in outline. The cerci generally are not more than one-half as long as paraprocts.

Plate 14: Euphaeidae.



1



2

3

The largest family of Anisoptera has a cosmopolitan distribution and more than 970 described species are enclosed. They larvae are very similar in appearance and shape to Corduliidae but differ by their anal pyramid. In Libellulidae the length of the cerci is less than half as long as epiproct. The color of larval body of the different species may cover a wide range from bright yellow, light greenish to dark brown. Larvae are usually very abundant in all types of stagnant waters and are able to colonize successfully smallest water bodies with low oxygen wherein other Odonata can not survive.

Plate 15: Libellulidae of Lentic habitats in Lowlands.

Fig. 1: Libellulidae, affinis: *Macrodiplax* spec., length 13.8 mm, India, Patna, Kumhrar park, "Phoenix" pond.
Fig. 2: Libellulidae, length 12.2 mm, India, Bihar, Patna, Kumhrar park, "Bivalvia" pond.
Fig. 3: *Neurothemis fulva*, length 11.5 mm, India, Bihar, Patna, Kumhrar park, "Bivalvia" pond.
Fig. 4: Living *Neurothemis fulva* from lower Subernarekha, West Bengal.
Fig. 5: Habitat of *Neurothemis fulva*, *Neurothemis* spec., *Macrodiplax* spec., Kumhrar, Patna,

Plate 16: Libellulidae of Running waters in Himalayan Valleys.

Fig. 1a: Libellulidae, length 18 mm, Nepal, Kavre, small spring pools in Kathmandu University, Dhulikhel.
Fig. 1b: Anal pyramid enlarged.
Fig. 2a: *Pantala flavescens*, length 24 mm, Nepal, Kavre, Kuntabesi, Cha Khola irrigation channel near Kunta.
Fig. 2b: Anal pyramid enlarged.
Fig. 3: Habitat of mud-burrowing Libellilidae, Nepal, Begnas Tal effluent Khudi Khola at Begnas.

Plate 17: Libellulidae of Lentic Habitats in Kathmandu Valley.

Fig. 1: *Brachythemis* spec., length 12.5 mm, Nepal, Kathmandu Valley, Taudaha "Lake", Kirtipur.
Fig. 2: *Neurothemis* spec., length 11.5 mm, Nepal, Kathmandu Valley, Nagdaha pond, Lalitpur.
Fig. 3: Nagdaha Pond, Lalitpur, Nepal, Locality No. 42, September 2008.

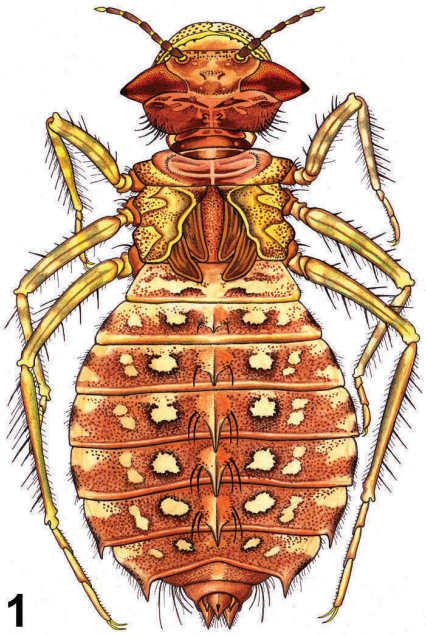
Family Corduliidae

Brief Characters:

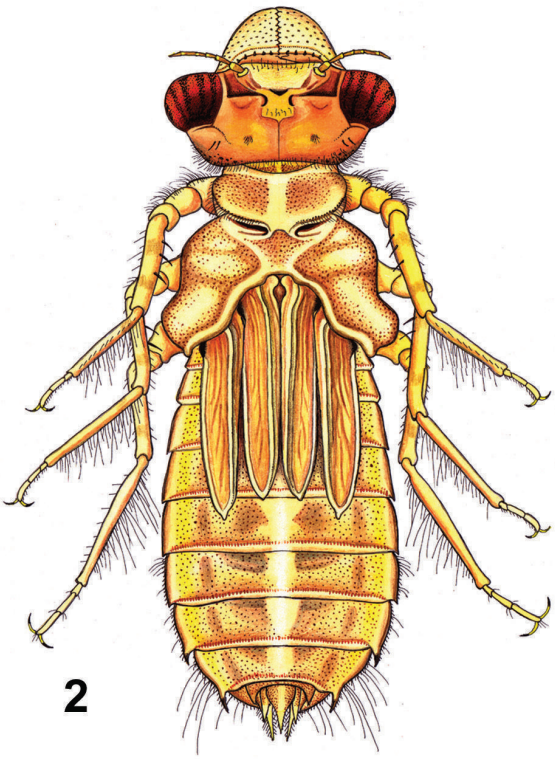
The larvae of Corduliidae resemble Libellulidae, but their size is usually larger and the body is more firm than the latter ones. Their legs are rather short and the apex of the femur does not extend beyond abdominal segment VIII. The abdomen is not markedly depressed or circular in outline. The cerci are generally more than one-half as long as paraprocts.

The total number of species is 255 worldwide; in Asia the family is less represented. Historically there was no clear distinction between the three families Libellulidae, Corduliidae and Macromiidae. They all were placed into a single family Libellulidae. More recently fundamental characters of the anal pyramid allow distinguishing larvae. In Corduliidae the length of cerci exceeds always more than half as long as epiproct, whereas in Libelluludae the length of cerci is less than half as long as epiproct (Okudaira et al. 2005, p. 360). Aquatic Corduliidae were rarely collected in the study area from slowly running stretches of stream and river with β-mesosaprobic to α-mesosaprobic conditions. It is not possible to recognize and separate them in field from Libellulidae; proper identification can be only done in Laboratory with binocular.

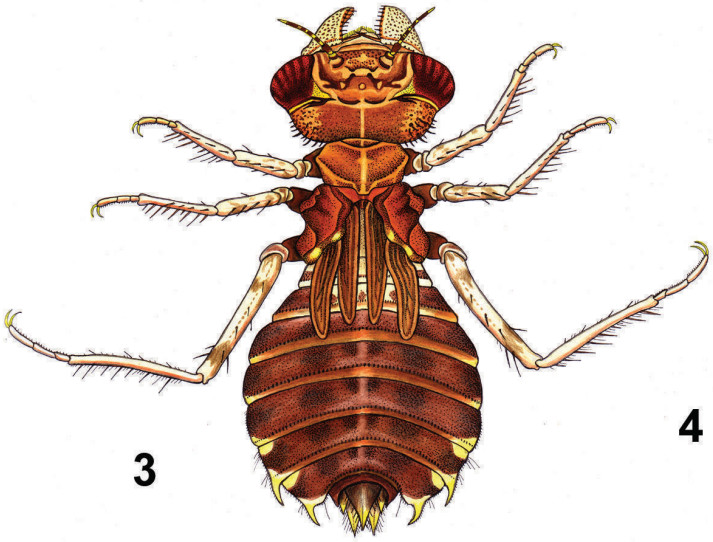
Plate 15: Libellulidae of Lentic habitats in Lowlands



1



2

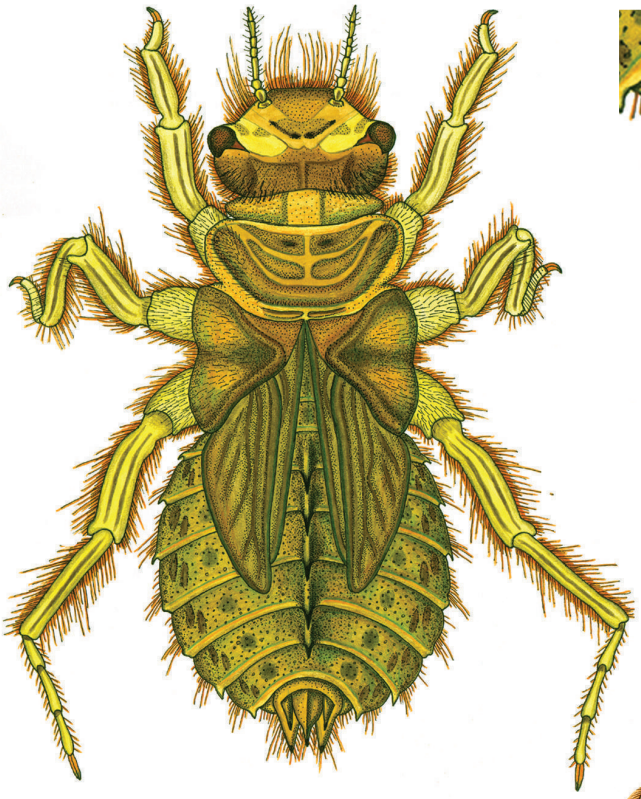


3

4

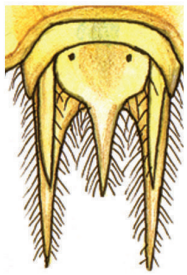
5

Plate 16: Libellulidae of Running waters in Himalayan Valleys

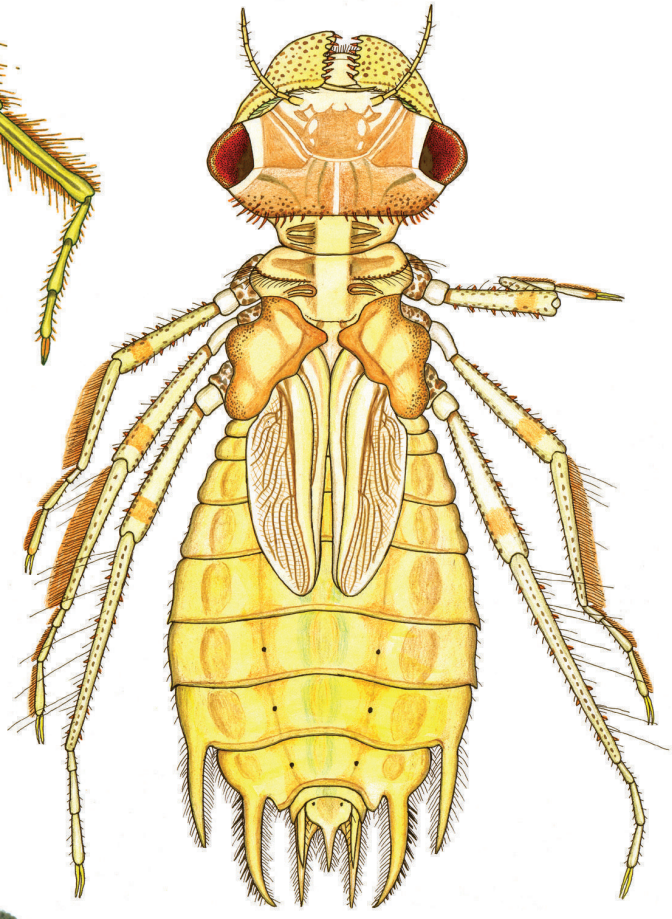


1a

1b



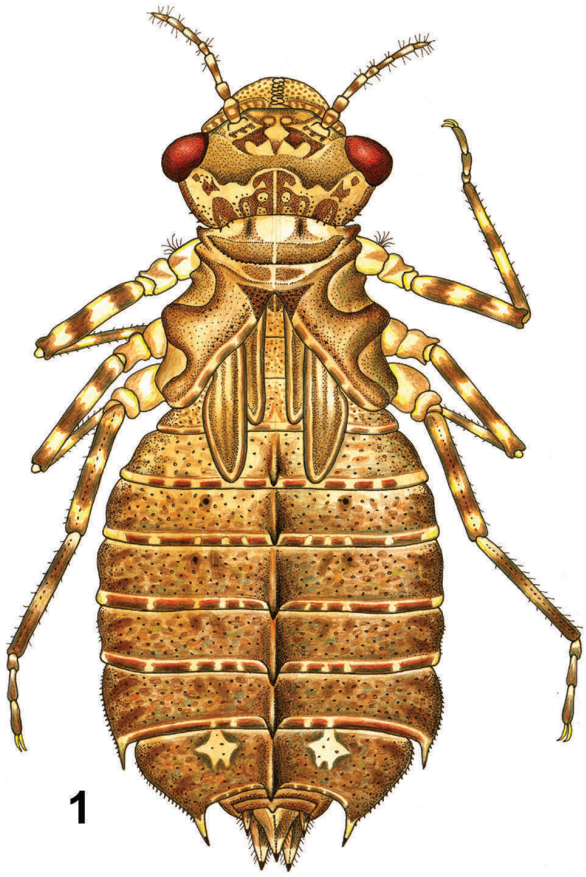
2b



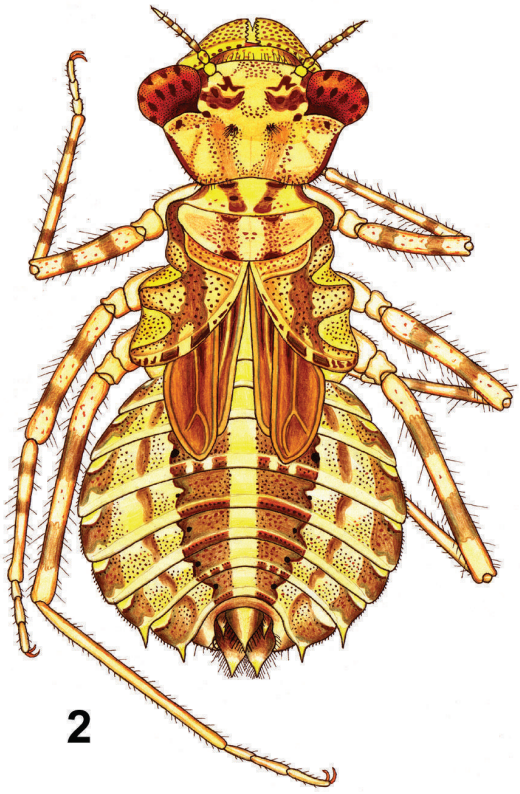
2a

3

Plate 17: Libellulidae of Lentic Habitats in Kathmandu Valley.



1



2

3

Plate 18: Corduliidae.

Fig. 1: Corduliidae, length 26.3 mm, Nepal, Kavre, Dobi Khola near Kathmandu University, Dhulikhel.
Fig. 2: Corduliidae, length 22 mm, Nepal, Hetauda, Ghate Khola, Inlet of fishpond.
Fig. 3: Habitat of Corduliidae, Subernarekha River downstream Jamshedpur, Jharkhand, India, January 2009.

Family Macromiidae

Brief Characters:

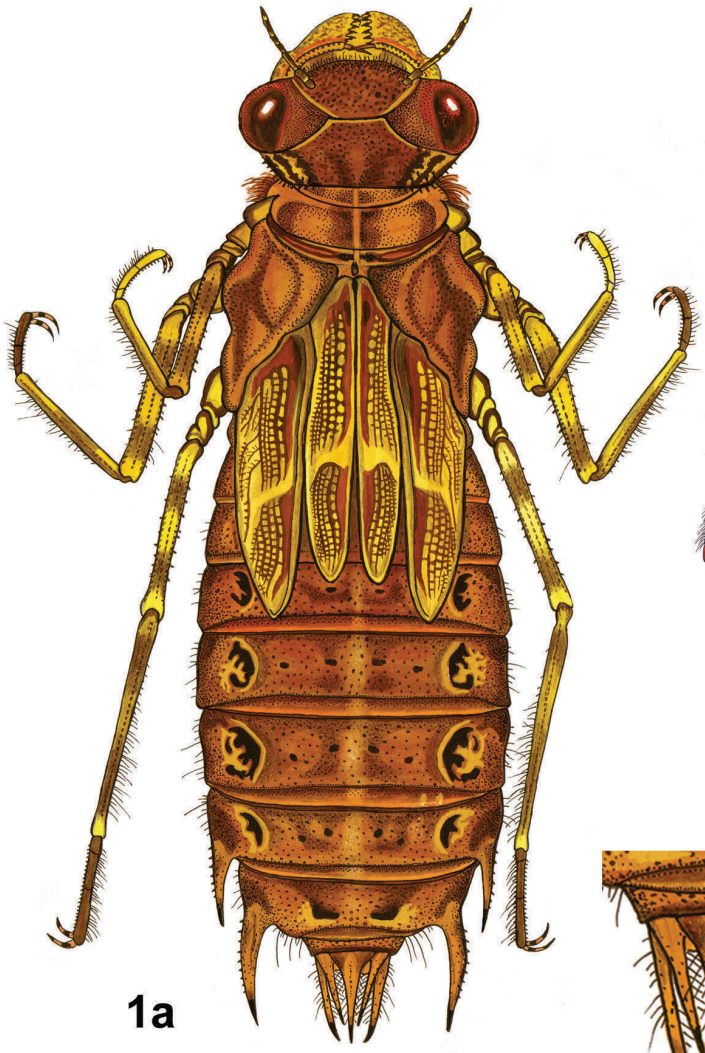
The legs are very long giving the larvae a "spidery" appearance. The abdomen is depressed and more or less circular in outline. On the head a small "horn" is present between the antennal bases. The labium bears rather long, regular teeth along the distal margins of the palpal lobes.

The family has a worldwide distribution but their occurrence is restricted on the tropical, subtropical and warm temperate zones except South America. There are approximately 120 species known. They prefer running waters with low organic pollution and are found in oligo-saprobic and β-mesosaprobic stretches. The larvae have extremely long legs. A few *Macromia* and *Epophthalmia* species are recorded from northern India and Nepal (Sharma 1998, Mitra 2003). The Macromiidae were recently raised to Family level, previously they were placed as Subfamily Epophthalmiinae into Family Corduliidae.

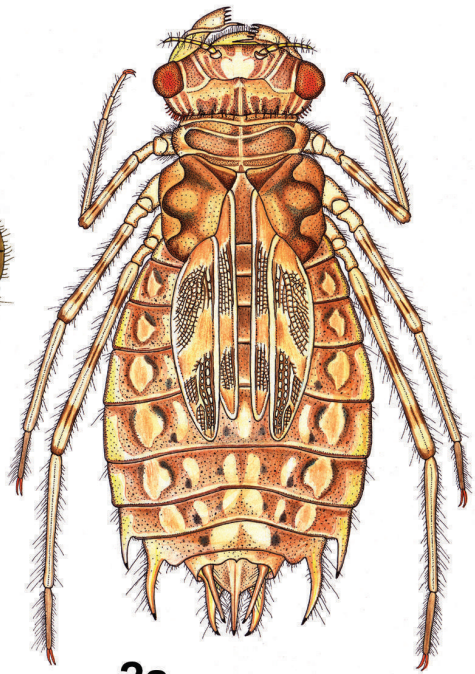
Plate 19: Macromiidae of Hill-Streams.

Fig. 1: *Macromia moorei*, length 23.5 mm, Nepal, Bhaktapur, upper Mahadev Khola.
Fig. 2: Upper Mahadev Khola.
Fig. 3: Microhabitat of *Macromia moorei* in upper Mahadev Khola.

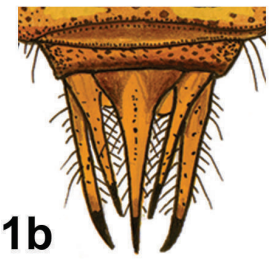
It is frequently recorded from upper regions of undisturbed forest streams in the Himalayan Middle Mountains from 800 to 1970 m asl. The figured specimen might



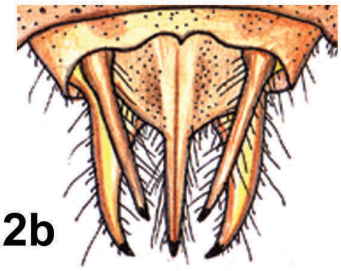
1a



2a



1b



2b

3

Plate 18: Corduliidae.

belong to *Macromia moorei moorei*, which is spread widely over the northern Indian subcontinent. The larvae living on coarse-grained sand or gravel substrate (Psammal, Akal) deposited behind or under large stones. The habitat is a reference site with biological water quality class I and ecological river quality 1.

Plate 20: Macromiidae of Lowland-Rivers.

Fig. 1: *Macromia* spec., length 21 mm, India, West Bengal, Subernarekha River at Gopiballabpur; Altitude 41 m asl.
Figs 2, 3: Living specimens of *Macromia* spec.
Fig. 4: Lentic bay, sedimentation bank of Subernarekha River.
Fig. 5: Microhabitat of *Macromia* spec. in Subernarekha River.

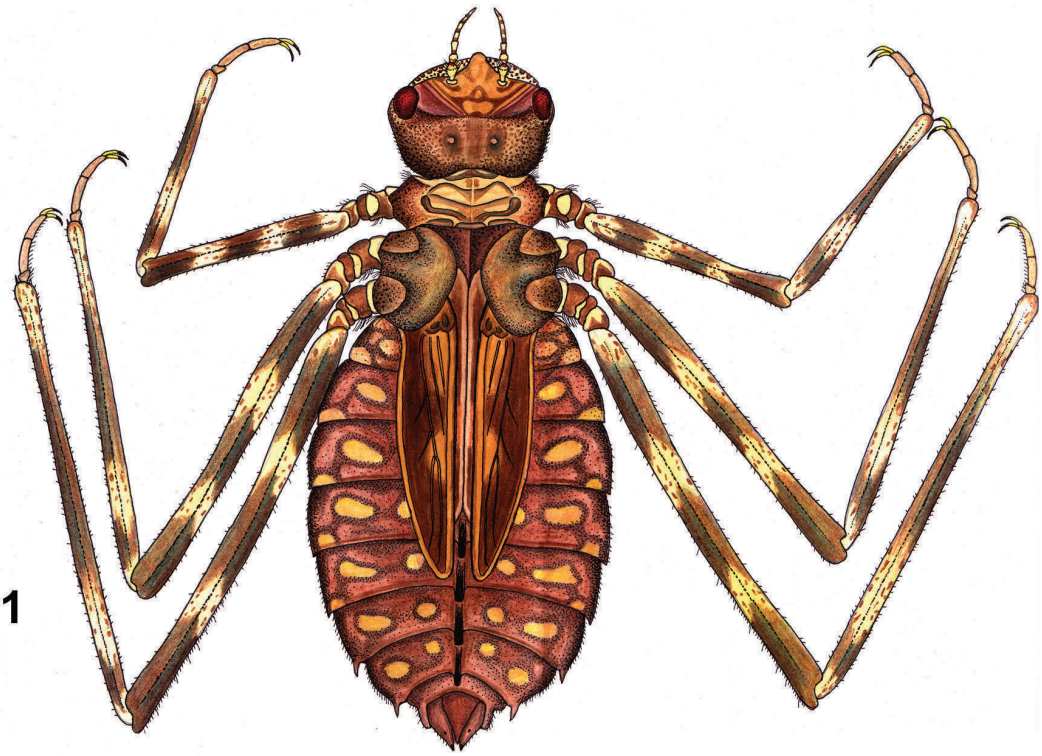
In the middle reach of second-largest River basin coming from Chhotanagpur plateau a yellow-brownish light *Macromia* spec. lives on fine substrate of Psammal or Psammo-Pelal mixed with detritus. It was only found on open sediment without plant cover, but it was not collected from silt, mud or dense submerged macrophytes. The habitat represents Metapotamon-type (Large River) with 27 identified Taxa of Macroinvertebrates and water quality class II using booth NEPBIOS (14 indicator taxa, value 5.00) and GRS-BIOS (17 indicator taxa, value 5.235).

Family Gomphidae

Brief Characters:

The general shape of the body is compact, elongated with an ovate dorso-ventrally flattened abdomen. The antennae are four-segmented, with the third segment enlarged. The tarsi of the first two pairs of legs are two-segmented. The labial mentum is more or less quadrate and the anterior margin of labial mentum is never cleft.

The larvae mostly inhabit running waters and are highly diversified in lowlands and floodplains of large rivers. Worldwide there are more than 875 species known. The legs and often the whole larval body is covered with various types of hairs, setae and spines. All Gomphidae are burrowers in sediment. The larvae process various



1

2

3

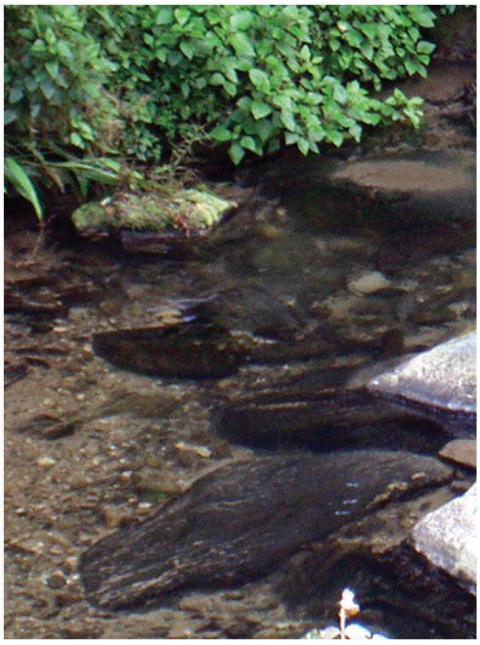
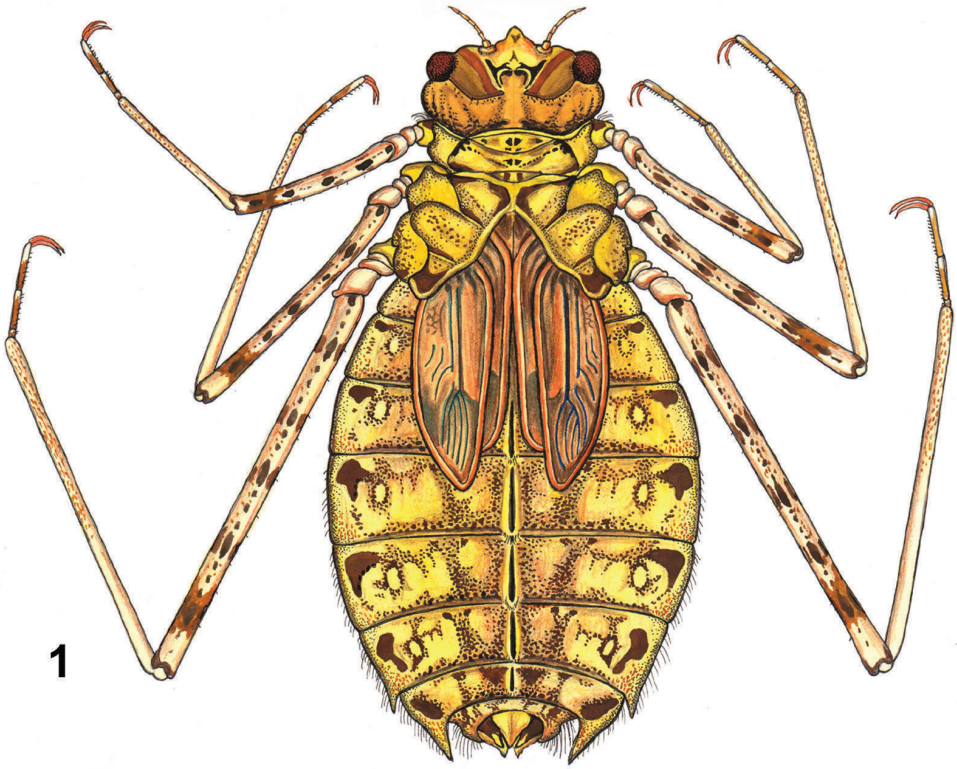


Plate 19: Macromiidae of Hill-Streams.



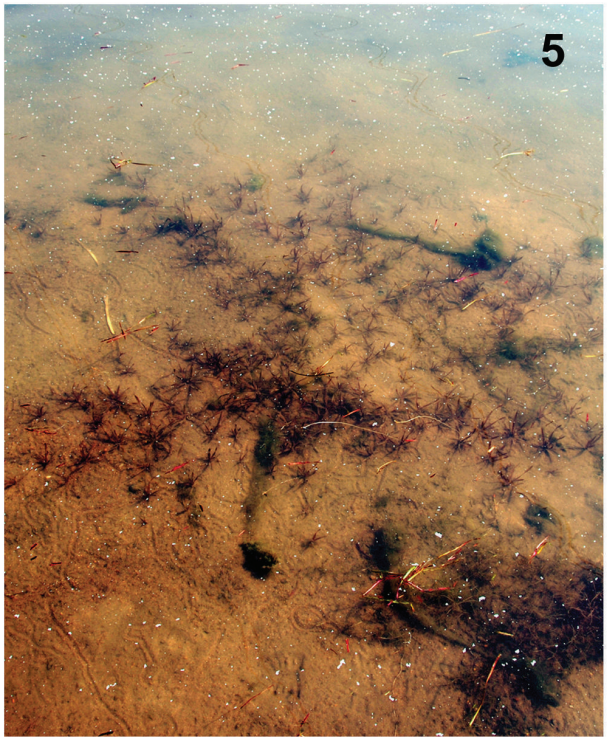


Plate 20: Macromiidae of Lowland-Rivers.

morphological adaptations to different sediment types. Despite their burrowing life-style some Gomphidae are very good swimmers too.

Plate 21: Gomphidae of Rivers.

Fig. 1: Gomphidae, affinis: *Asiagomphus* spec., length 21 mm, India, Patna, Ganga River, right bank at Ghandi Ghat.
Fig. 3: Habitat at Ganga River at Krishna Ghat, Locality No. 3, April 2008.

The burrowing larvae inhabit fine sand and silt (Psammopelal, Pelal) and their body is covered with fine hairs. Living specimens have attracting light greenish color. They were found in β-mesosaprobic zones.

Plate 21: Gomphidae of Rivers.

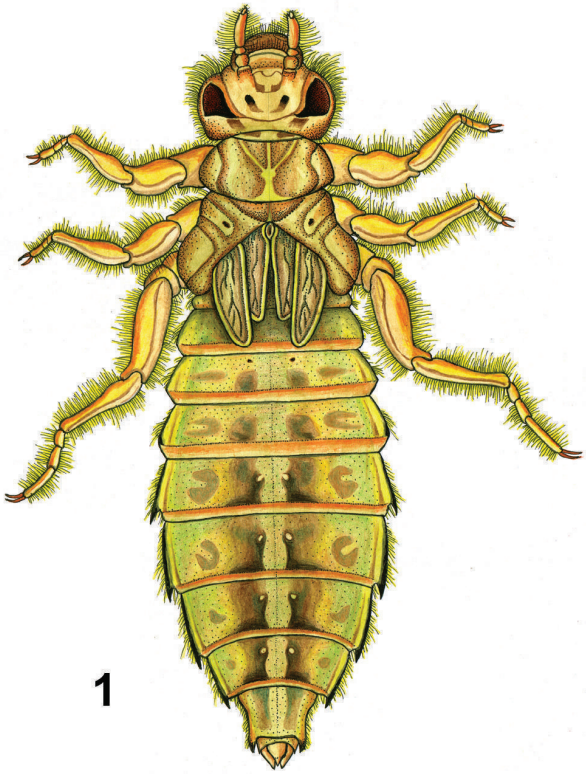
Fig. 2: Gomphidae, affinis: *Sinogomphus* spec., length 18 mm, Nepal, Kaski, lower Bijayipur Khola, Seti basin.

The burrowing larvae inhabit fine gravel (Akal) and only the legs covered with fine hairs. The third antenna segment is broadened spooned-shaped. Living specimens have yellow-orange brownish color. They were found in oligo- to β-mesosaprobic zones. The figured specimen was found in the same habitat of *Aphelocheirus* spec. (Plate 37, Fig. 3, 4).

Plate 22: Gomphidae of Lentic Habitats in Rivers.

Fig. 1: Gomphidae, affinis: *Stylurus* spec., length 23 mm + Analsiphon 8.5 mm, India, West Bengal, Subernarekha River at Jaleshwar.
Figs. 2, 3: *Stylurus* spec., living specimens.
Fig. 4: Habitat of *Stylurus* spec. at Gopiballabpur.
Fig. 5: Habitat of *Stylurus* spec. at Jaleshwar.

Larvae with enlarged 10th abdominal segment, forming a respiratory organ, are known as genera *Aphylla* (nearctic), *Trigomphus* and *Stylurus* (oriental). They are



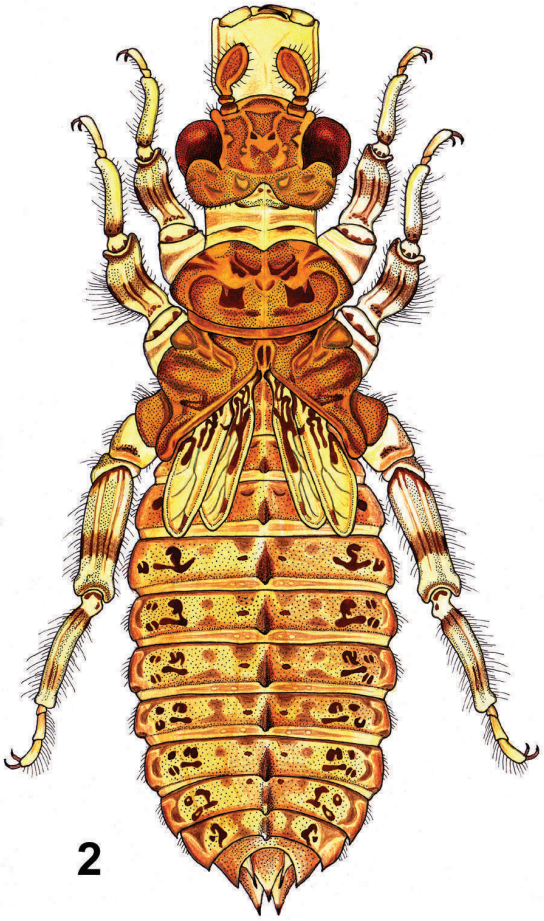
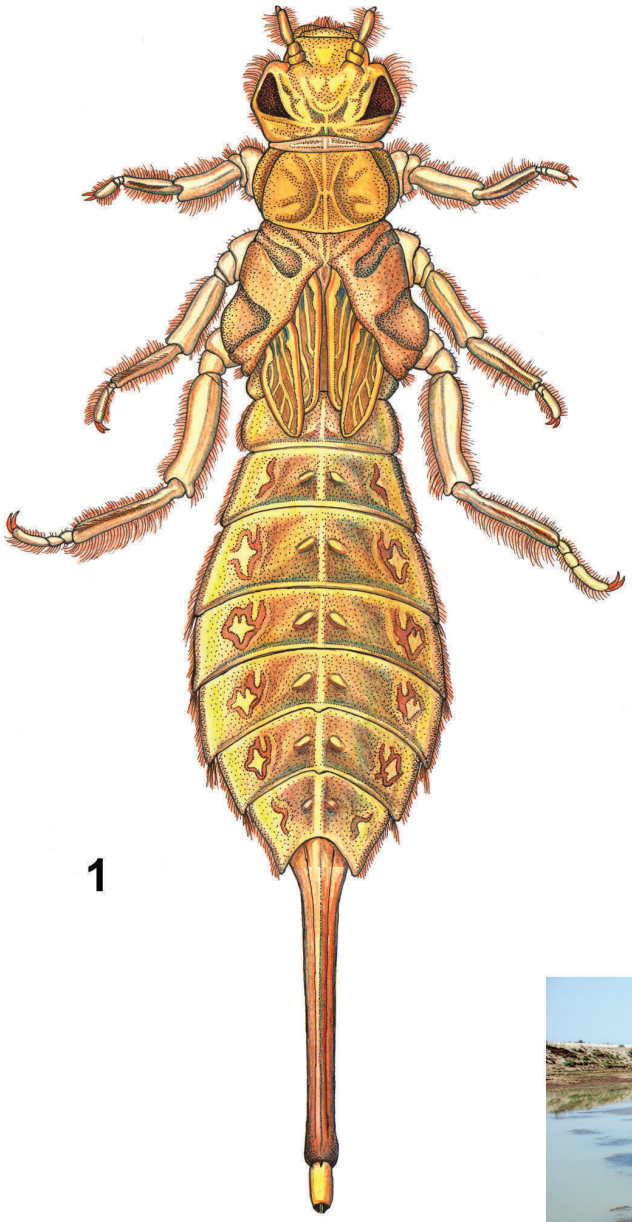


Plate 21: Gomphidae of Rivers.

Plate 22: Gomphidae of Lentic Habitats in Rivers.



1

2

3

3

4

burrowing in mud of lentic zones with high natural organic load. In the study area, species resembling most to Stylurus spp. from Japan were rarely found (compare: Okudaira et al. 2005: 307, Fig. 2, 376: Figs. 2A, 2B, 2D; Kawai 2005: 72, Figs 2a-e, 3a-d). A few specimens were studied from Subernarekha River at Gopiballabpur and Jaleshwar, having much longer extended 10th abdominal segment. Booth habitats are representing Metapotamon-type (Large river) with 27 and 26 identified Taxa of Macroinvertebrates and water quality class II, β-mesosaprobic condition.

The respiratory organ or "anal-siphon" resembles that of aquatic bugs (families Nepidae, Belostomatidae) in size and shape but the function is different. It is most comparable to the physiological gill of the Tubificidae *Aulodrilus* spp. Adults of Heteroptera using their anal-siphon to receive atmospheric oxygen from water surface. Larvae of *Stylurus* spec. lying completely burrowed in sediment, waiting for prey. They are using their anal-siphon to receive dissolved oxygen from the open water; it is stretched to sediment surface and hold outside.

Plate 23: Gomphidae of lotic Psammal-Habitats.

Fig. 1: Gomphidae, affinis: *Nihonogomphus* spec., length 24 mm, India, West Bengal, Subernarekha River at Gopiballabpur.
Fig. 3: Typical Habitat of *Nihonogomphus* spec., sand dominated part of Subernarekha River upstream Jamshedpur.

The larvae are living in large fractioned sand as burrowers; surprisingly they were also observed as excellent, fast swimmers crossing through the open water like small fishes. The dorsal color is light yellowish-ochre with dark brownish ornamental markings which are more pronounced on the 6th and 9th abdominal segments, giving the body a striped appearance. The 3rd antenna segment is cylindrical and the 4th segment is modified into a claw-like structure of different red-brown color. The lateral margin of abdominal segments IV-IX forms a spiny extension. Larvae of this type are dominating large macroinvertebrates of the sand-fauna in lowland rivers, especially in the main-channel of Khamti (Maharashtra) and Subernarekha (Jharkhand/West Bengal). They inhabit β-mesosaprobic or β- to α-mesosaprobic rivers of water quality class II and III.

Plate 23: Gomphidae of lotic Psammal-Habitats.

Fig. 2: Gomphidae, affinis: *Mesogomphus* spec., length 17 mm, India, Maharashtra, Pench, Ambakori-Totladoah.

The general body shape is mole-like and elongated of uniform dark brown color without any further dorsal pattern. The 3rd antenna segment is cylindrical and the 4th segment is modified into a strong spiny claw of dark brown color. The lateral margin of abdominal segments V-IX forms a spiny extension. The anal pyramid is prominent with long appendices; epiproct, paraprocts and cerci are all of the same length.

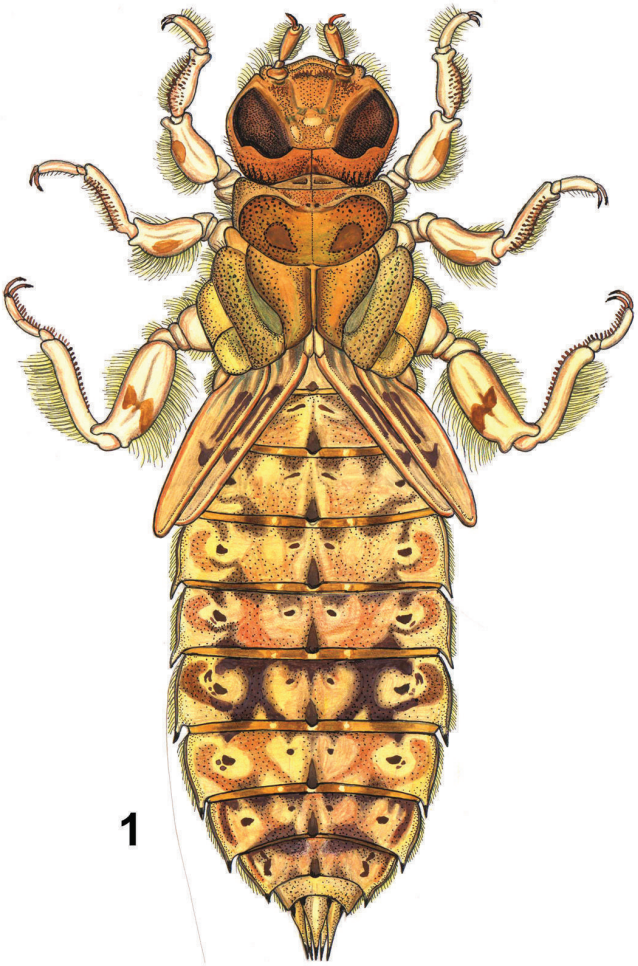
The larvae were found in pools downstream from water falls in a natural forest stream with water quality class III (NEPBIOS), or II (GRS-BIOS). They are burrowing in loose coarse-grained sand (Psammal).

Family Hageniidae

Brief Characters:

This family comprises the genera *Hagenius* in North-America, *Ictinogomphus* and *Sieboldius* in Asia. The larvae are very large and robust with circular flattened abdomen. Previously they were traditionally placed into the family Gomphidae, but differ in several characters and life style. The larvae have different body form. The labium is enlarged and much broader than in Gomphidae. They aquatic Hageniidae larvae are not sediment-inhabiting; they were found exclusively as climbers on submerged macrophytes. They colonize large stagnant water bodies and slowly running rivers from lowlands up to 800 meter above sea level.

Adults are very large and have a longer life span than Gomphidae. The adults differ from Gomphidae by their wing venation. The triangle of fore wings and hind wings has same shape and size.



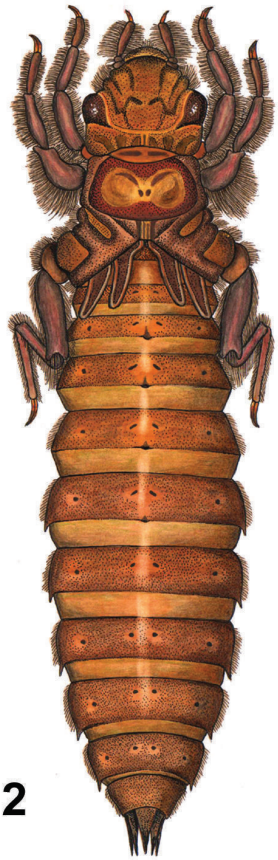


Plate 23: Gomphidae of Lotic Psammal-Habitats.

Hageniidae were already separated from the majority of Gomphidae on subfamily level as Hageniinae by several authors (St. Quentin and Beier 1968, p. 8). More recent publications raise them to family level (Xylander and Günther 2003, p. 141).

Plate 24: Hageniidae.

Fig. 1: *Ictinogomphus rapax*, length 24.5 mm, India, West Bengal, Subernarekha River at Jamshola.
Fig. 3: Habitat of *Ictinogomphus rapax* at Jamshola.

The color of the body is dark ochre-brown. The larva was found climbing on submerged macrophytes in a lentic zone of Metapotamon-type (Large River). There were 30 identified Taxa of Macroinvertebrates and the water quality class is III using NEPBIOS (16 indicator taxa, value 4.5625) or II using GRS-BIOS (21 indicator taxa, value 5.1904).

Plate 24: Hageniidae.

Fig. 2: *Ictinogomphus* spec., length 20.5 mm, Nepal, Kaski, lower Orlan Khola, Phewa basin.
Fig. 4: Habitat of *Ictinogomphus* spec. at Tahoba, Maharashtra.

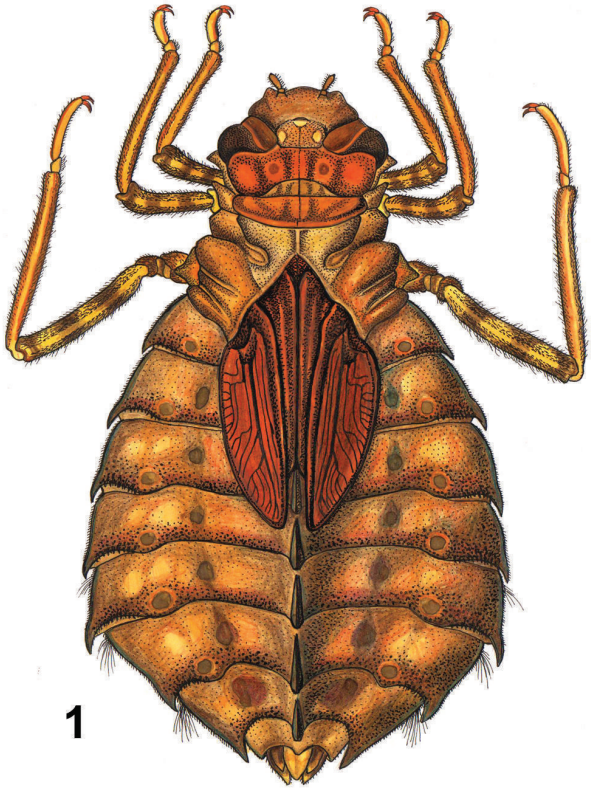
It is locally abundant in floating macrophytes, found in Nepal (Phewa Tal wetlands, Begnas Tal effluent), Jharkhand (upper Subernarekha River) and Maharashtra (Tahoba wetland), preferring *Eichhornia crassipes* as substrate.

Family Cordulegastridae

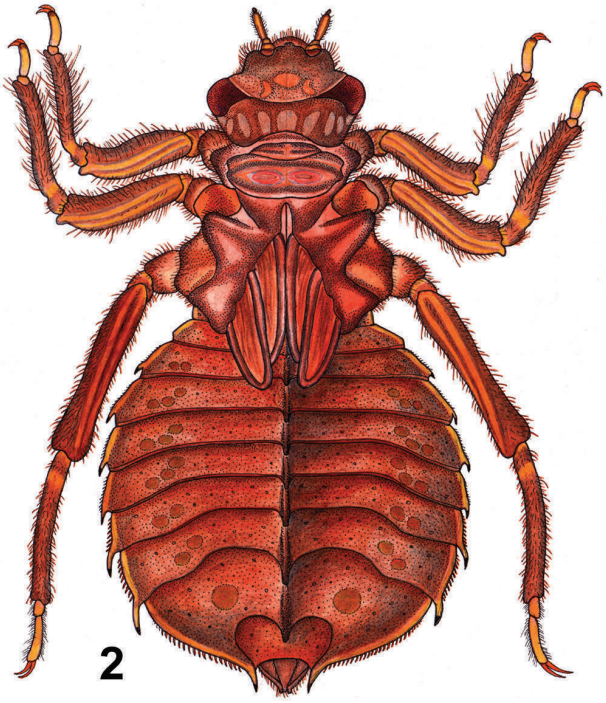
Brief Characters:

The body elongate and covered with bristles or tufts of setae. The distal margin of the palpal lobes of the labium are with large irregular teeth which interlock with those on the corresponding lobe. The anterior margin of the mentum is cleft. The color appearance is dominated by dark brown background with some blackish markings,

Plate 24: Hageniidae.



1



2

3

4

regularly arranged on the dorsal side of the abdominal segments.

The family has a limited distribution range in the Palearctic and Oriental regions. The larvae are crawlers on sand and muddy sediments of fast running cool streams and rivers, especially in the Himalayas. They are usually lying half buried in the surface sediment layer in wait for prey. Cordulegasteridae larvae are pollution-sensitive and demand high oxygenated water. They are not common and were recorded during the present study only from upper stretches of small rivers and stream inside natural forests above 1500 meters.

Plate 25: Cordulegastridae.

Fig. 1: *Cordulegaster* spec., length 33.5 mm, Nepal, Sindupalanchwock, Pengul Khola.

Family Aeshnidae

Brief Characters:

Aeshnidae larvae of the study area are among the largest Odonata and aquatic insects, reaching more than 5 cm length. The larvae are rather elongated with robust, cylindrical abdomen and very large eyes. The antennae are six or seven-segmented and filamentous. The tarsi of all legs have three segments. The labial mentum is widest in the distal portion and narrowing towards the posterior part with a cleft in the anterior margin. The body surface of larvae is smooth, any hairs, setae or bristles are lacking. The larval color display a wide range from light yellow, bright green, ochre brown to dark brownish often with segmental arranged dark pattern on the dorsal side of abdomen.

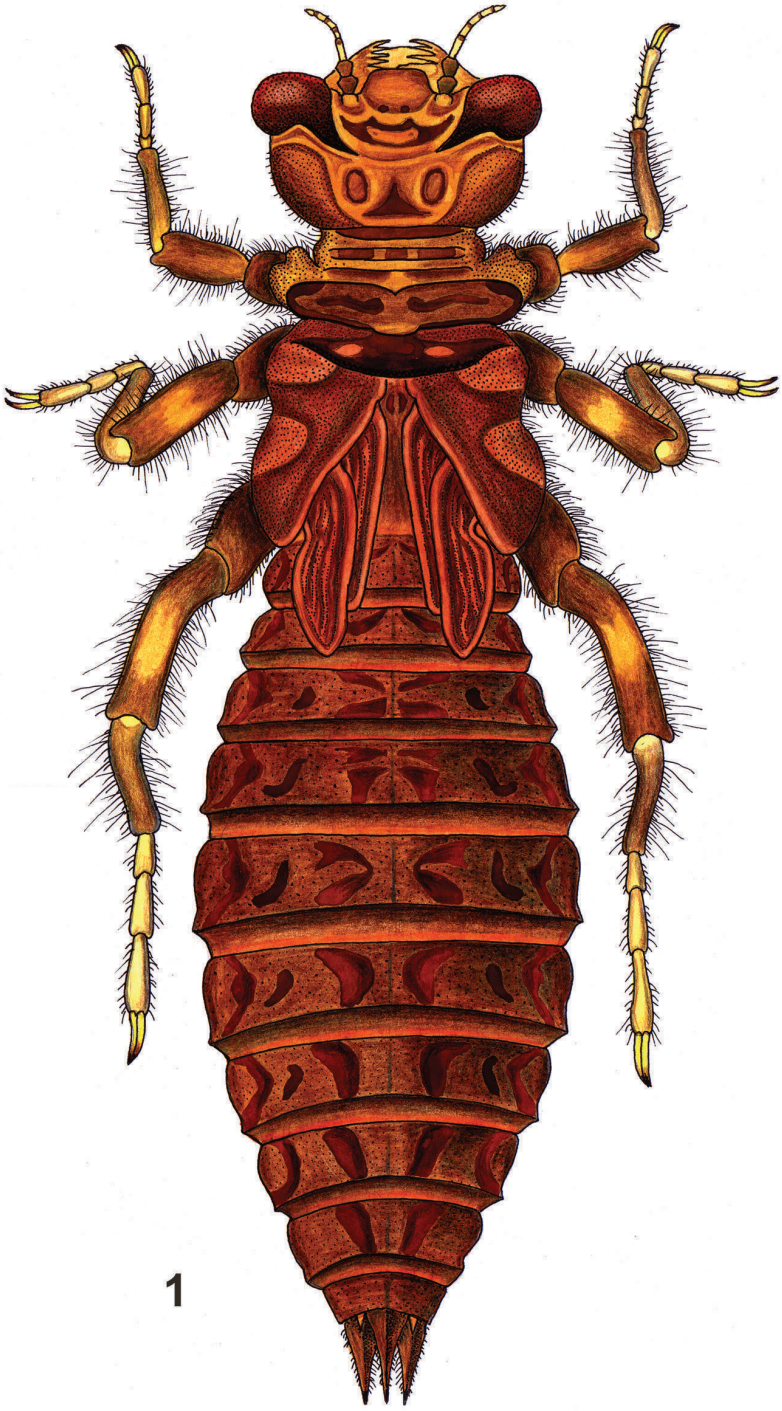


Plate 25: Cordulegastridae.

Within the family Aeshnidae, the subfamily Anactinae is mainly confined to the Ethiopian and Oriental regions with range extension of some species into the temperate Palearctic. In the Ganga River System they were found sporadically in various undisturbed, natural, oligo-saprobic to β-mesosaprobic waters free from anthropogenic pollution. Nowhere are they abundant or common and only small numbers of individuals were observed.

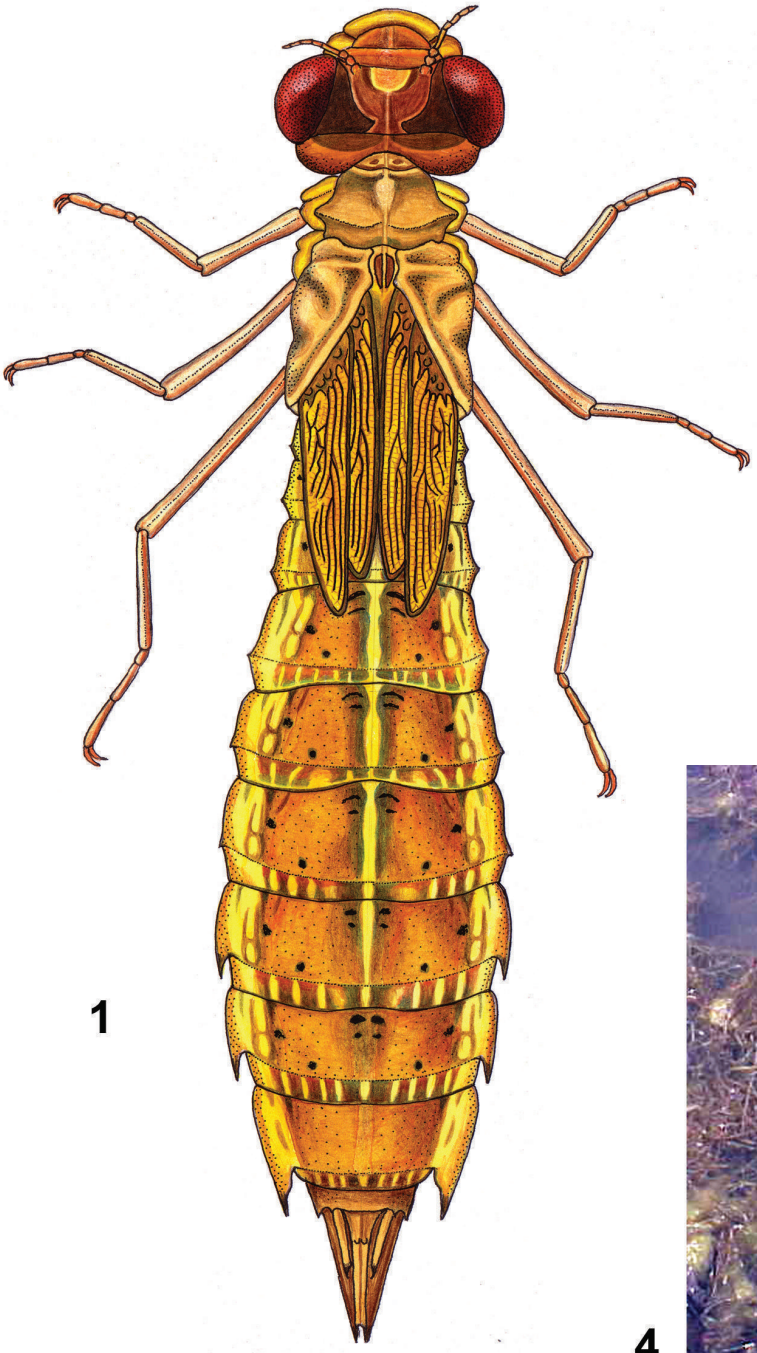
Plate 26: Aeshnidae of Lowlands.

Fig. 1: *Anax* sp., length 53 mm, Nepal, Rautahat, Gaur, Municipality pond.
Fig. 2: *Anax* sp., length 10.3 mm, India, Bihar, Patna, Punpun River, Gaurichak.
Fig. 3: Punpun River, Gaurichak.
Fig. 4: Microhabitat of *Anax* sp., Punpun River, dense vegetation with *Potamogeton pectinatus*, *Potamogeton crispus* and *Najas* spec.

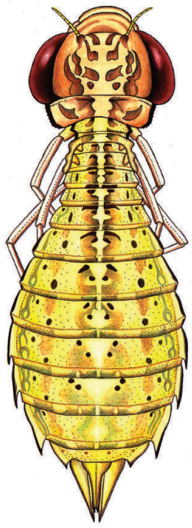
Plate 27: Aeshnidae of Himalayan Lotic Habitats.

Fig. 1: *Polycathagina* spec., length 30.5 mm, Nepal, Khimti Khola.
Fig. 2: Aeshnidae, affinis *Aeschnophlebia* spp., length 26.5 mm, Nepal, Kavre, Nagarkot hills, Jaljale Khola, upper Punyamata watershed.
Fig. 3: Habitat of Aeshnidae in Phusre Khola, Pokhara Valley, Nepal.

Plate 26: Aeshnidae of Lowlands.



1

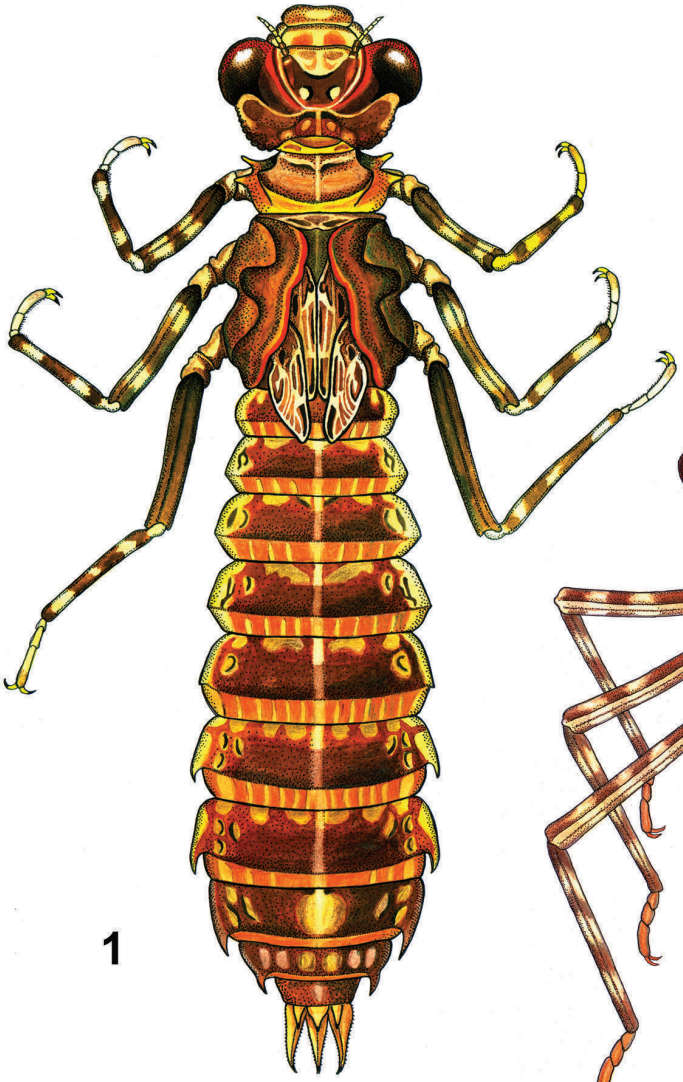


2

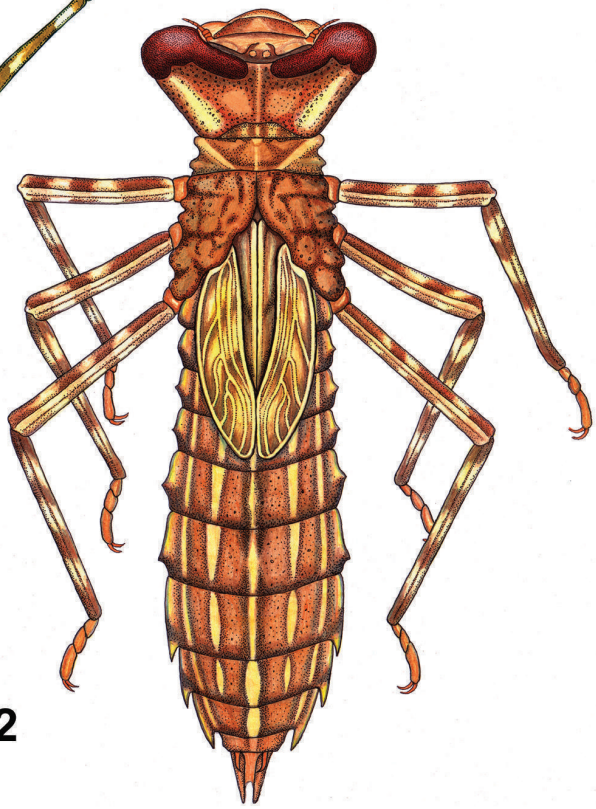
4

3

Plate 27: Aeshnidae of Himalayan Lotic Habitats.



1



2

3

Family Epiophlebiidae

Brief Characters:

The larvae are somewhat slender and elongate; with a slight petiolation at the base of the wing pad. The minute and very short antennae are with five segments. The larval body is very hard and firm covered with tubercles, but lacking any bristles. The family is extremely rare with isolated discontinuous relict distribution Japan and the Himalayas only. The family is certainly recorded from Mesozoic onwards (Nel and Jarzembowski 1996).

There are only two extant species, regarded as 'living fossils'. While the life cycle of the *Epiophlebia superstes* is better known, including adults, terrestrial phase, and egg deposition, adults of *Epiophlebia laidlawi* are not yet found. *Epiophlebia* larvae are limited on natural upper regions of fast running forest streams with water quality class I. Small larvae prefer rapids and riffles with embedded stream bottom; they are highly pollution-sensitive and live only in Epirhithron- to Metarhithron-type of biocoenotic zone. The new discovery of populations in Granite mountain streams of the Mahabharat range during the present study is one of the odonatological highlights, since *Epiophlebia lailawi* was previously known only from very few localities close to the high mountain range of the Himalayas.

Plates 28 + 29: Epiophlebiidae.

Figs. 1-9: *Epiophlebia laidlawi*, Nepal, Daman area, Sim-Khola and Simbhanjyang-Khola.
Fig. 1: Larva with length 3.0 mm.
Fig. 2: Larva with length 4.2 mm.
Fig. 3: Larva with length 5.3 mm.
Fig. 4: Larva with length 6.8 mm.
Fig. 1: Larva with length 8.3 mm.
Fig. 6: Quartultimate Larva with length 11.5 mm (sensu Asahina 1961a: 443, Plate 1, Fig. 4)
Fig. 7: Tertiultimate Larva, length 13.3 mm (sensu Asahina 1961a: 442, Plate 1, Fig.

3)

Fig. 8: Penultimate Larva, length 23.0 mm (sensu Asahina 1961a: 442, Plate 1, Fig. 2)

Fig. 9: Ultimate Larva, length 23.0 mm (sensu Asahina 1961a: 441, Plate 1, Fig. 1)

Morphological Development of the Larval Stages: Instars Larvae of *Epiophlebia laidlawi* from Nepal

The specimens of different development stages (nine sizes) are hand drawn in the same color pattern of real animals in order to provide advance knowledge on vulnerable larval stages of *Epiophlebia laidlawi*. The species is categorized into IUCN vulnerable invertebrates (1986-1990). The specimens were investigated from natural forest streams of central Nepal that ranges from 2300 to 2850 m asl. Sim Khola has high abundance compared to all other streams. The size of larvae ranges from 3.0 – 25.0 mm body length. The young larvae differ markedly in dorsal color, having dark pigmentation only on abdominal segments 2 to 5 and 9. Large larvae have generally brownish or nearly blackish appearance with dorsal metameric pattern on abdomen.

A total number of 67 larvae were investigated. Nine different size classes can be distinguished by morphological characters and different color pattern of the dorsal side. They represent different larval stages which are separated by molting. The largest four larval stages (6.-9.) were already known and extensively described by Asahina (1961a, 1961b). The distinguishing of male and female individuals by the presence of ovipositor is only possible for larger larvae from 8 mm body length onwards.

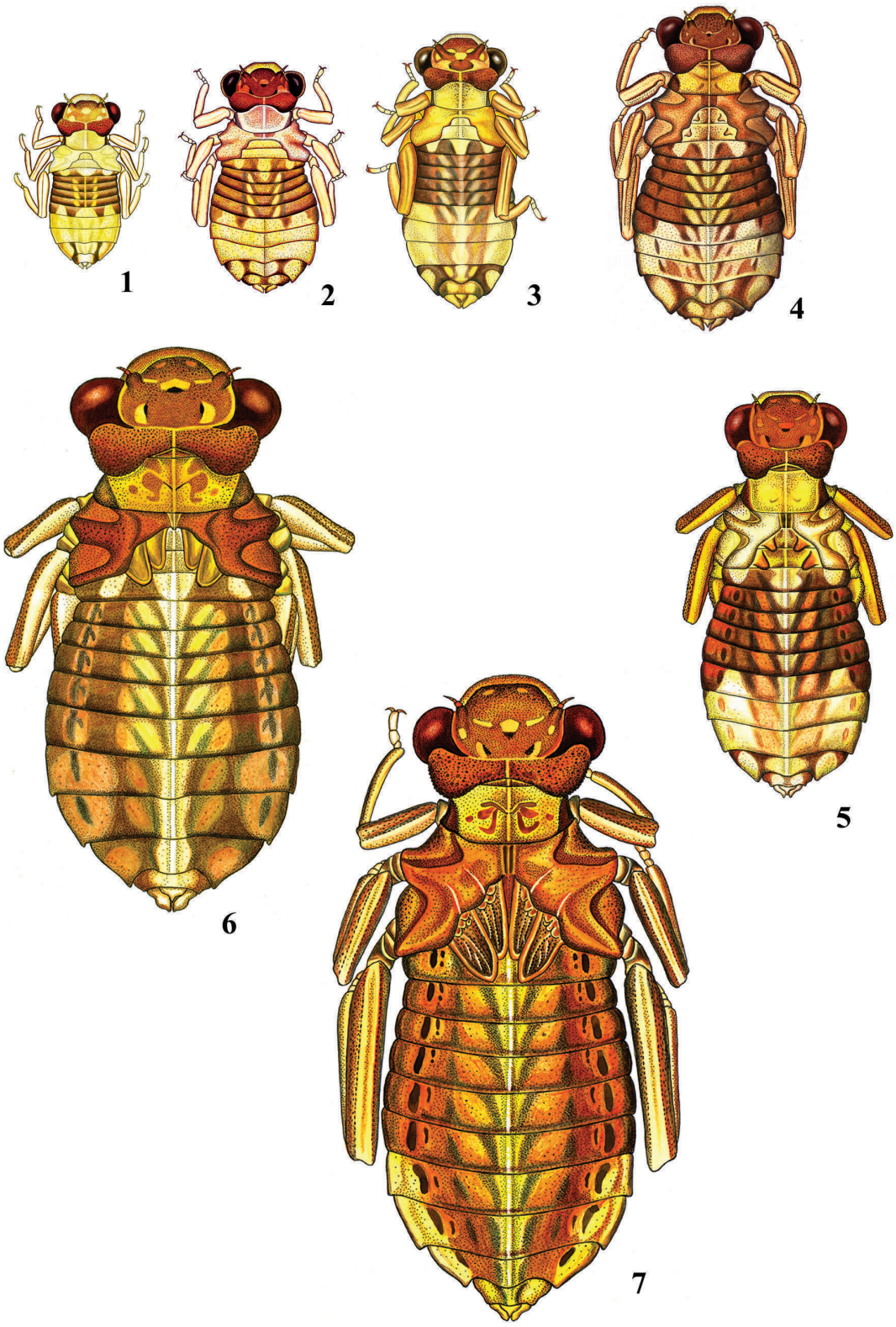
Brief Characters of the larval stages:

The description is based on the specimens from Sim-Khola and Simbhanyjang Khola.

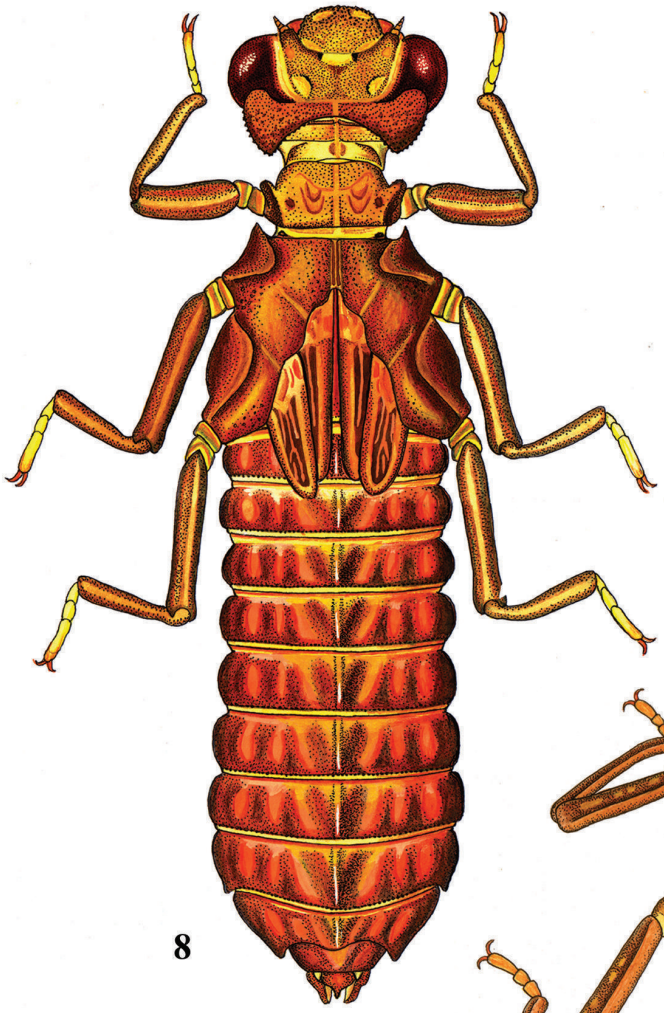
1. The Length of four specimens reaches 3.0 – 3.1 mm. The abdominal segments 2-5 are dark colored on the dorsal side with lighter paramedian longitudinal fields. The abdominal segments 1 and 6-8 have light yellow appearance.
2. The Length of 12 specimens reaches 3.8 – 4.6 mm. There is no external wing

sheath visible. The abdominal segments 2-5 are dark colored on the dorsal side with lighter paramedian fields. The abdominal segments 1 and 6-8 have light yellow appearance.

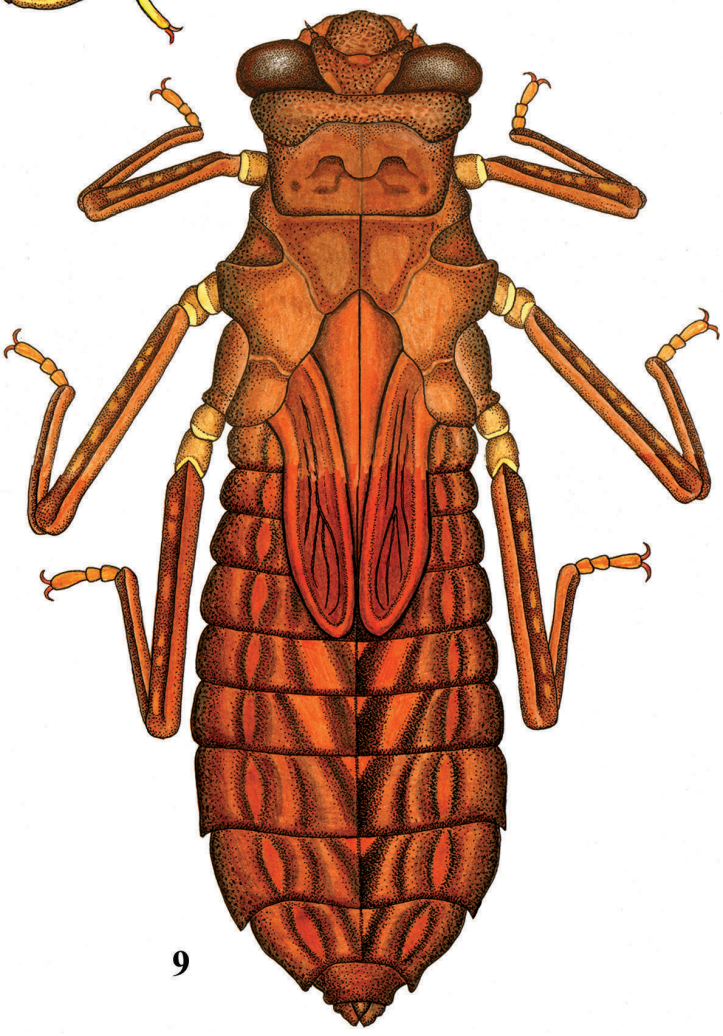
3. The Length of two specimens reaches 5.1 – 5.5 mm. There is no external wing sheath visible. The abdominal segments 2-5 are dark colored on the dorsal side with a broad lighter median field. The abdominal segments 1 and 6-8 have light yellowish brown appearance
4. The Length of five specimens reaches 6.2 – 6.8 mm. The abdominal segments 2-5 are dark colored with similar metameric pattern on dorsal abdominal segments are dark colored on the dorsal side. The fore wing and hind wing sheaths are short and stout on the second and third thoracal segment.
5. The Length of eight specimens (5♂, 3♀) reaches 8.0 – 8.3 mm. The abdominal segments 2-5 are dark colored and bear similar metameric pattern on the dorsal side. The abdominal segments 1 and 6 have dark lateral and paramedian zones interrupted by light yellow zones. The fore wing sheath length reaches and covers the segment boarder of the third thoracal segment and the first abdominal segment.
6. The Length of four specimens (1♂, 3♀) reaches 10.0 – 10.7 mm. The hind wing sheath exceeds until the first half of the first abdominal segment. The general color of the 7th to 9th abdominal segments is lighter.
7. The Length of five specimens (5♀) reaches 13.2 – 13.5 mm. The first to sixth abdominal segments are dark colored and bear dark metameric pattern on the dorsal side. The abdominal segments seven to nine are slightly lighter with yellow orange pattern at the lateral sides. The hind wing sheath exceeds until the end of the first abdominal segment.
8. The Length of the three extended specimens (2♂, 1♀) reaches 22.7-23. 0 mm. All abdominal segments are dark reddish brown and bear metameric pattern on the dorsal side. The wings are exceeding until the distal end of the 2nd abdominal segment.
9. The Length of seven specimens (2♂, 5♀) varies between 23.0 – 25.0 mm; one extended specimen has 29.0 mm. All abdominal segments are dark brown colored and bear similar metameric pattern on the dorsal side. The hind wing sheath exceeds until the distal end of the 4th abdominal segment. The general color appearance can be blackish due to iron cover.



Plates 28: Epiophlebiidae 1.



8



9

Plates 29: Epiophlebiidae 2.

Length in mm	Male	Female	Size- and Age Class	Larva Serial No.
3.0	-	-	1	1
3.1	-	-	1	2
3.1	-	-	1	3
3.5	-	-	1	4
3.5	-	-	1	5
3.8	-	-	2	6
4.0	-	-	2	7
4.1	-	-	2	8
4.1	-	-	2	9
4.1	-	-	2	10
4.1	-	-	2	11
4.1	-	-	2	12
4.2	-	-	2	13
4.2	-	-	2	14
4.2	-	-	2	15
4.2	-	-	2	16
4.3	-	-	2	17
4.3	-	-	2	18
4.3	-	-	2	19
4.6	-	-	2	20
5.1	-	-	3	21
5.1	-	-	3	22
5.3	-	-	3	23
5.3	-	-	3	24
5.3	-	-	3	25
5.5	-	-	3	26
6.1	-	-	4	27
6.2	-	-	4	28
6.2	-	-	4	29
6.3	-	-	4	30
6.3	-	-	4	31
6.3	-	-	4	32
6.5	-	-	4	33
6.5	-	-	4	34
6.8	-	-	4	35
6.8	-	-	4	36
8.0	1	-	5	37
8.0	1	-	5	38
8.1	1	-	5	39
8.1	1	-	5	40
8.2	-	1	5	41
8.2	-	1	5	42
8.3	-	1	5	43
8.3	1	-	5	44
10.0	-	1	6	45
10.2	1	-	6	46
10.5	-	1	6	47
10.7	-	1	6	48
13.2	-	1	7	49
13.2	-	1	7	50
13.3	-	1	7	51
13.5	-	1	7	52
23.0	-	1	9	53
23.8	-	1	9	54
24.0	-	1	9	55

24.2	-	1	9	56
24.5	1	-	9	57
25.0	1	-	9	58
Total number of Larvae	8	14		58

Table 77: *Epiophlebia laidlawi* Larvae from Mahabharat Mountainous Streams.

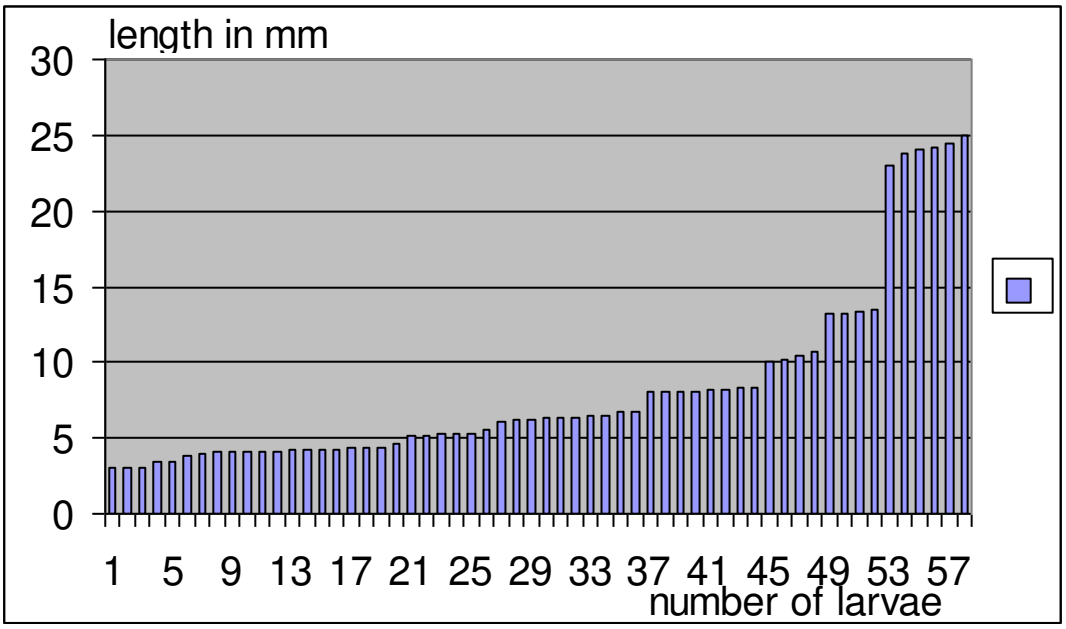


Table 77: Fig. 1: Length Frequency diagram of *Epiophlebia laidlawi* from Sim-Khola Population.

Length	Male	Female	Class	No.
3.8	-	-	1	1
10.7	-	1	5	2
11.1	1	-	5	3
13.0	1	-	7	4
14.2	-	1	7	5
22.7	1	-	8	6
23.0	1	-	8	7
23.0	-	1	8	8
29.0	-	1	9	9
Total number of Larvae	4	5		9

Table 78: *Epiophlebia laidlawi* Larvae from Indrawati Mountainous Streams.

Chapter 9. Aquatic Insects as Bioindicators (in part)

Aquatic and Semi-aquatic Bugs

9.1. Hemiptera: Heteroptera (Aquatic and Semi-aquatic Bugs)

The Order Hemiptera is first recorded from the Carboniferous/Permian onwards (Evans 1972, Grimaldi and Engel 2005) from fossil terrestrial species of the suborder Homoptera The earliest true Heteroptera are known from the Later Permian Formation of Belmont, Australia, before 250 million years (Shelling 2000, Shcherbakov 2008). The Infraorder Nepomorpha (aquatic) and Gerromorpha (semi-aquatic: on water surface) were already separated in early Mesozoic. Important recent families are present from Jurassic and Cretaceous deposits onwards. Popov (1971) has concluded that the origin of most families lies in Mesozoic times. Giant water bugs Belostomatidae of the Subfamily Lethocerinae are described Popov (1992) the Upper Jurassic, Malm, Tithonian of Bavaria, South-Germany with the large *Mesobelostomum deperditum* (Germar 1839). The same scientist also reported Belostomatidae from Lower Jurassic of Poland (Popov 1996a, 1996b). Fossil bugs closely allied to recent species occur in the Lower Cretaceous Crato Formation of Brazil (= Santana Formation) from Araripe. Nel and Waller (2006) describe the fossil *Lethocerus vetus* that is similar to the living species of this genus. Micronectidae are known from Lower Jurassic, Lias epsilon, Toarcian Formation in Dobbertin, Mecklenburg, North-Germany. A small sized bug from this locality is described as *Acromocoris similes* Yu and Povop with striking similarity to the living *Micronecta* spp. (Popov 1992). The Family Hydrometridae is present in Lower Cretaceous of Brazil with the fossil *Cretaceometra brasiliensis*, described by Nel and Popov (2000) as the oldest known fossil member of this group.

Brief Characters

All Hemiptera associated with aquatic habitats belong to the Suborder Heteroptera (true bugs). They can roughly be grouped according to their habitats. Most Gerromorpha (semi-aquatic bugs) live on the water surface, most Nepomorpha (aquatic bugs) live

submerged in fresh water and most Leptopodomorpha (shore bugs) live at the margins of water bodies. They range in length from less than 1 mm to about 80 mm. Most species are brown or black, sometimes with darker or lighter stripes. Only a few genera are brightly colored, e.g. the orange-red *Perittopus* and the metallic-blue *Enithares*.

The combined total number of aquatic and semi-aquatic species of Heteroptera approaches 4810 described and more than 1100 not yet described taxa. The Oriental Region is particularly rich; there are a high proportion of endemic genera and even subfamilies. An updated overview of Heteroptera diversity is published by Polhemus and Polhemus (2008). The taxa number is given in Table 79.

Taxa number of Heteroptera: Leptodomorpha, Gerromorpha, Nepomorpha			
	Species	Genera	Families
Total number	4810	343	23
Aquatic Taxa	4656	326	20
Undescribed	> 1100		
Neotropical	1289		
Oriental	1103		
Afrotopical	799		
Australasian	654		
Palearctic	496		
Nearctic	424		
Pacific	37		

Table 79: Number of Heteroptera taxa in the different zoogeographical regions (combined from Polhemus and Polhemus, 2008).

The group is characterized by forewings (hemelytra, sometimes spelled hemielytra) which are hard and leathery in the basal (anterior) portion and membraneous posteriorly (although this part is thickened in the Pleidae and Helotrephidae). In addition, they all have beak-like mouthparts. In the majority of species they are modified into a cylindrical

piercing and sucking structure (the rostrum), and feeding involves the injection of enzymes (and sometimes venom) into prey followed by extracorporeal digestion of tissue which is sucked out and swallowed. The forelegs of the Belostomatidae, Naucoridae, Nepidae and Gerridae are raptorial and variously modified for grasping prey. Some members of the Corixidae supplement feeding on small invertebrates with a secondarily herbivorous habit, and the mouthparts are adapted for rasping rather than sucking. Polymorphism in wing development (= alary) is common in many Heteroptera (e.g. Gerridae, Helotrephidae, Naucoridae and Veliidae). Adults may have fully-developed wings (= macroptery), short wings (= brachyptery), or may lack wings entirely (= aptery).

Habitats

Their habitats include moist soil, ponds, streams, rivers, rock-pools, phytotelmata (small pools of water held by living plants), water-splashed rocks, thermal springs, brackish water, inter-tidal coral reef flats and even the open ocean. The true bugs are among the most common and widespread insects found in these habitats.

9.2. Illustrated Catalogue for Nymphs and Adults

Families of the Himalayan Region and the Gangetic Plains

Altogether fourteen families of Heteroptera were collected in Nepal out of which the families Aphelocheridae, Mesoveliidae, Hebridae and Hydrometridae are for the first time recorded. Among the Nepidae, *Cercotmetus* spec. is new to the fauna of Nepal. Their abundance, distribution and habitat are briefly characterized. Nahar (2004) gave an account of 18 species from Bihar including literature records; 6 larger species of the genera *Laccotrephes*, *Ranatra*, *Lethocerus*, *Shaerodema* (= *Diplonychus*) and *Gerris* were studied and listed from Museum collections of the Zoological Survey of India. Thapa (2000) listed 10 aquatic Heteroptera for Nepal. Tirumalai (2007) included 35 species of Nepomorha for the fauna of Bihar.

Infraorder Nepomorpha

The suborder of true aquatic bugs is represented with eight families in the central part of the Ganga River System. The family Helotrephidae was found from three localities only.

Family Belostomatidae (Giant Water Bugs)

The giant water bugs constitute the largest aquatic insects and they are a homogenous group, represented with two genera in the study area. The robust and firm body is dorsoventrally flattened. The beak reaches only front legs. The head is distinctly transverse. The fore femur is thickened. Seen from above the anteclypeus (tip of head) is with a line on each side. The membrane of hemielytron has distinct veins. A pair of retractable breathing appendages is always present at tip of abdomen, but much shorter than the breathing-tube (anal-siphon) of Nepidae. The fore legs are used for hunting, middle and hind legs have brush-like arranged hairs for swimming. The color of adults is usually dark brownish on the dorsal side with often lighter yellowish-ochre ventral side. Belostomatidae are fiercely predaceous; they feed on all kinds of aquatic organisms, including large forms as young crayfishes, tadpoles, fishes or even small frogs.

The Belostomatidae are mostly found in slowly running rivers, ponds, wetland and lakes of lower elevations. They are very abundant in the Gangetic Plains in water-bodies with rich biodiversity and high ecological quality like oxbow lakes and were found in similar habitats up to the Pokhara valley in elevation of 850 m. *Lethocerus* sp. is very rare and was collected only in the Barahwa Nadi at Gaur (Rautahat district) in elevation of 75 m. A further old collection exists with the locality label “Kusma” in Kaski district. Light traps brought three further records from Ghodagori Tal (western Nepal), from Namobudha and Kathmandu University, booth Kavre district, in January, April and August 2008. Except of these five findings from Nepal, there was one observation in the middle reach of the Yamuna River. *Diplonychus* spec. is abundant in the lowlands of Terai and Lower Gangetic Plains, but occurs only in stagnant or slowly running waters with high ecological value and typical wetland benthic community.

Plate 30: Belostomatidae: *Lethocerus*.

Fig. 1: *Lethocerus* cf. *indicus*, length [without anal-siphon] 78 mm; dorsal aspect.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa 'River' east of Gaur, altitude 75 m asl; Sampling Site No. NO1 BA 021.
Fig. 2: Habitat of *Lethocerus* cf. *indicus* in Barahwa.

The habitat of the figured specimen is shown on Fig. X. It is representing an old Bagmati branch with very rich macrophytes and high benthic diversity (> 50 Taxa) of the Plesiopotamon-Type. The floating vegetation is dominated by *Eichhornia crassipes, Myriophylum submersum, Hydrilla verticilata* and *Nymphaea pubescens*. Along the banks typical floodplain palms *Borassus flabelliger* and *Phoenix sylvestris* are present. The water quality of the *Lethocerus* habitat is Class II; the Ecological (River-) Quality is Class 2. The *Lethocerus* specimen was found under the floating mat of plants, bearing its eggs attached to the ventral surface.

Plate 31: Belostomatidae: *Diplonychus annulatus*.

Fig. 1: *Diplonychus annulatus*, adult, length 27 mm.
Nepal, Pokhara Valley, Khudi Khola (effluent of Begnas Tal) east of Begnas, altitude 675 m asl; Sampling Site No. NO2 KU 021.
Fig. 2: *Diplonychus annulatus*, Nymph, length 4.5 mm.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa River east of Gaur, altutide 75 m asl; Sampling Site No. NO1 BA 021.
Fig. 3: Habitat of *Diplonychus annulatus* in Kumhrar, Patna.

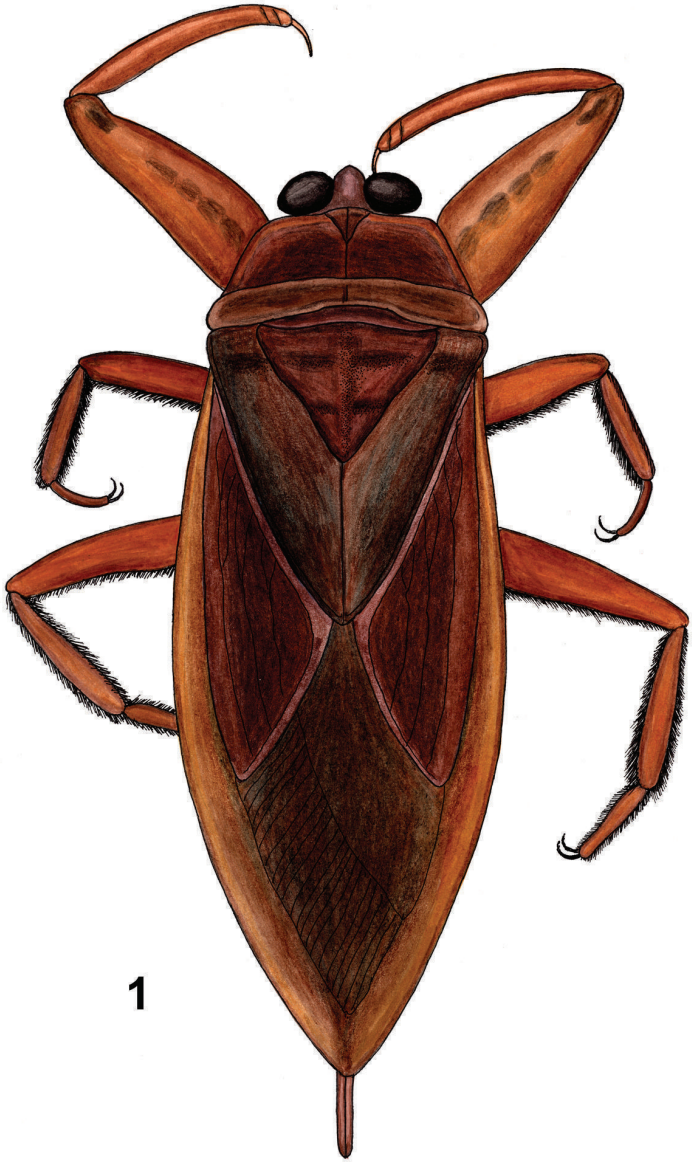
Diplonychus annulatus is very common and occurs frequently in wetlands and the Potamon biocoenotic zones of rivers and streams. Nymphs of different size are often more abundant than adults. Examples of habitats are shown on Fig. X. It is representing a eutrophic, meso-saprobic stream with very dense macrophytes and high benthic diversity

of the Epi- to Metapotamon-Type with dominance of filter-feeders like *Bellamya bengalensis*, *Lamellidens marginalis* (below Begnas Lake and Fish ponds), *Radiatula lima* (further downstream section) and the very rare Planorbid Camptoceras lineatum. The bank vegetation is dominated by *Eichhornia crassipes, Myriophylum* spp. The water quality of the *Diplonychus* habitat is Class II-III; the Ecological (River-) Quality is Class 3. Numerous specimens were found under mat of plants and in lentic pools under dominating Microlithal substrate. They were bearing eggs attached to the dorsal surface.

Plate 32: Belostomatidae: *Diplonychus rusticus*.

Fig. 1: *Diplonychus rusticus*, adult, length 17 mm.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa River north of Gaur, altutide 77 m asl; Sampling Site No. NO1 BA 011.
Fig. 2: *Diplonychus rusticus*, Nymph, length 9.5 mm.
India, Jharkhand, Chotanagpur, Subernarekha River at Lupungdih, Jamshedpur, altutide 116 m asl.
Fig. 3: Habitat of *Diplonychus annulatus* in Barahwa.

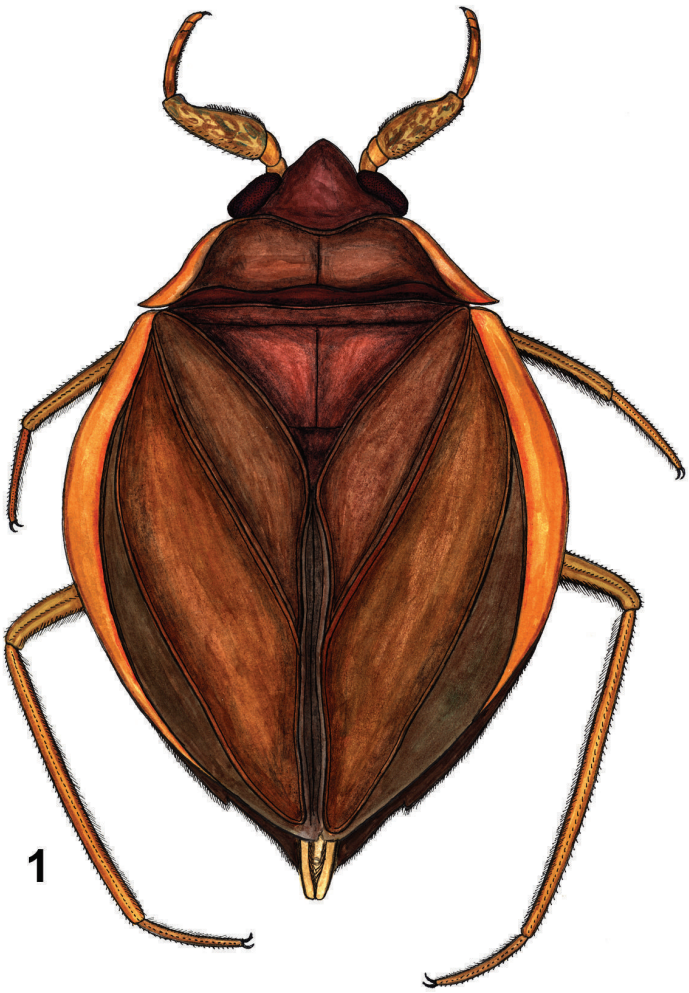
Diplonychus rusticus was found only sporadically in a few localities of lowlands. The figured adult specimen was collected together with *Diplonychus annulatus* from the headwater region of Barahwa 'River' (Fig. X) representing a reference site with unusual rich benthic diversity of more than 67 taxa pre-identified in the field. Further specimens were found in fishponds and rivers of Epi- to Metapotamon type. In the study area *Diplonychus rusticus* appears to be widespread (Thirumalai 2007), being absent from higher elevations and mountainous regions.



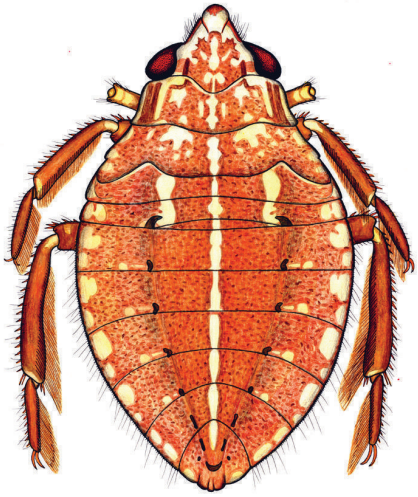
1

Plate 30: Belostomatidae: *Lethocerus.*

2



1

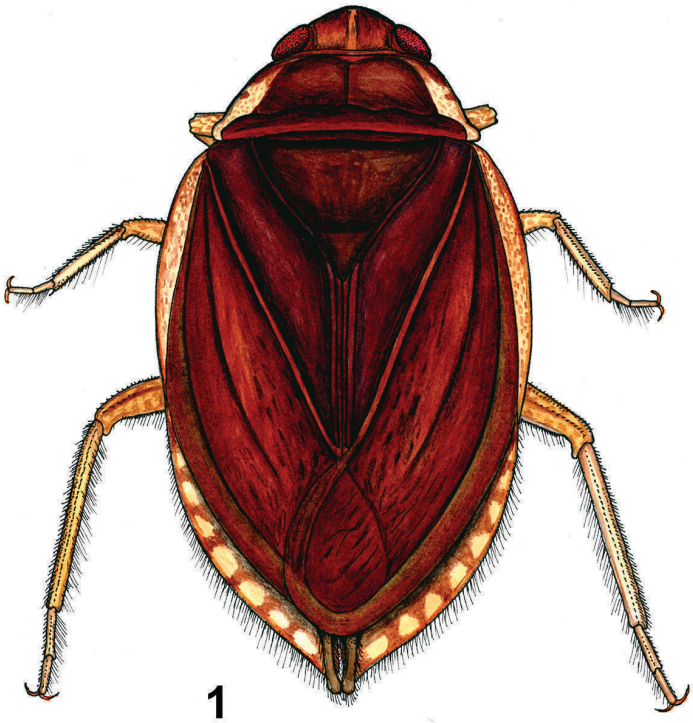


2

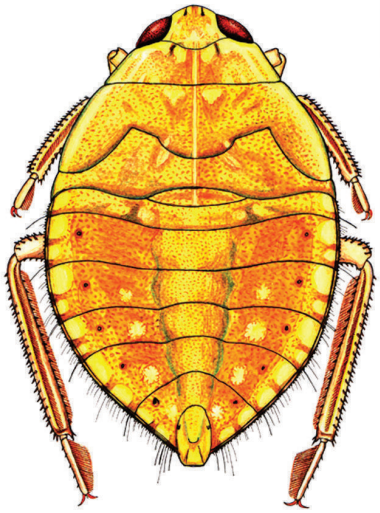
Plate 31: Belostomatidae: *Diplonychus annulatus*.

3

4



1



2

Plate 32: Belostomatidae: *Diplonychus rusticus*.

3

Family Nepidae (Water Scorpions)

The general body shape varies greatly in this peculiar family. The general body form is dorso-ventraly flattened or cylindrically elongated. There is a long breathing tube (anal-siphon) on hind end of body. The fore legs are used for hunting, middle and hind legs for walking. All species have two long, slender, non-retractile caudal filaments. Each of these has a groove on the median surface. When fitted together, the filaments constitute a respiratory breathing tube. Its tip can be placed at the surface film so that oxygen in the tracheal system may be replenished. Adults have dorsal and ventral the same coloration varying from light ochre in *Ranatra* spp. to very dark brown in *Laccotrephes* spp. Nepidae lie on the bottom or between plants in wait for their prey. The forelegs are held out in striking position and are capable of lashing with great speed. All kinds of aquatic Metazoa, and especially insects, are seized and held in this way while the body fluids are sucked out.

The Nepidae are very common in stagnant and slowly running waters of the lowlands and the middle mountains. They prefer habitats with soft muddy and sand bottom. The Nepinae are represented with *Laccotrephes* sp. (Water scorpions), which occurs in rivers, streams, ponds and even in very small temporary forest pools. It is very abundant up to elevation of 2085 m (Nagarkot). The Ranatrinae were recorded with *Ranatra* sp. and *Cercotmetus* sp. exclusively in stagnant waters of wetlands, ponds and reservoirs with very dense macrophytes. *Ranatra* sp. is scattered distributed in the lower Gangetic Plains and Terai, but locally very abundant e.g. in Jagadishpur Reservoir. In the middle mountains *Ranatra* sp. was found in a very few wetlands of ponds and small stagnant drainage ditches e.g. Khude Pokhari at Pokhara (850 m), Chaukot near Dhulikhel (1450 m). *Cercotmetus* sp. is recorded for the first time from the Ganga River System and Nepal. It was collected from Bishazari Tal in Chitwan, which has a very rich and dense macrophytes-cover, predominantly with *Trapa quadrispinosa* at the sampling date of September 25th 2006. The water body is habitat for several other rare and endangered species, e.g. the Planorbidae *Camptoceras lineatum*. This Pulmonata snail was previously known only from Manipur and Bangladesh.

Plate 33: Nepidae: *Laccotrephes*.

Fig. 1: *Laccotrephes* spp., adult, length of body 31 mm, length of anal-siphon 38 mm. Nepal, Kavre, small temporary forest pond northeast of Banepa, altutide 1675 m asl.
Fig. 2: *Laccotrephes* spp., Nymph, length of body 13 mm, length of anal-siphon 6.5 mm. Nepal, Lower Gangetic Plain, Rautahat, Barahwa River east of Gaur, altutide 75 m asl; Sampling Site No. NO1 BA 021.
Fig. 3: Habitat of *Laccotrephes* spp., in Roshi Khola at Bhandarigaon, east of Panauti, Kavre, Nepal. Altutide 1345 m asl.

Laccotrephes spp. is common in different types of stagnant and running waters from the lowlands of Gangetic plains to the Himalayan Middle Mountains in altitude of more than 1970 m asl. Preferred substrate types are Phytal of lentic habitats and Pelal, mud mixed with sand. Water scorpions are found in β- mesosaprobic, α-mesosaprobic and sometimes even in polysaprobic zones of streams and rivers. They are mostly absent from fast running forest streams and cold upper regions.

Plate 34: Nepidae: *Ranatra*.

Fig. 1: *Ranatra* spp., adult, length of body 27 mm, total length with anal-siphon 55 mm. Nepal, Lower Gangetic Plain, Rautahat, Barahwa Pond in Gaur, altutide 77 m asl.
Fig. 2: *Ranatra* spp., Nymph, total length of body with anal-siphon 21.5 mm.
From the same locality.
Fig. 3: Habitat of *Ranatra* spp., Phewa Tal near Pokhara with floating stands of *Potamogeton pectinatus*, altutide 795 m asl.

Ranatra spp. is less common than *Laccotrephes* spp. in several types of large and permanent stagnant and slowly running waters. It was found in the lowlands of Gangetic plains to the larger Himalayan Valleys in altitude of less than 1500 m asl. The occurrence of *Ranatra* spp. is confined to the presence of dense macrophytes. They are pollution

sensitive with limited distribution in oligosaprobic, β- mesosaprobic or β- to α-mesosaprobic zones of large ponds, wetlands, lakes or slowly running rivers. *Ranatra* spp. was not observed in highly polluted polysaprobic stretches of streams and rivers. Like other taxa of Ranatrinae subfamily they are mostly absent from fast running forest streams and cold upper regions.

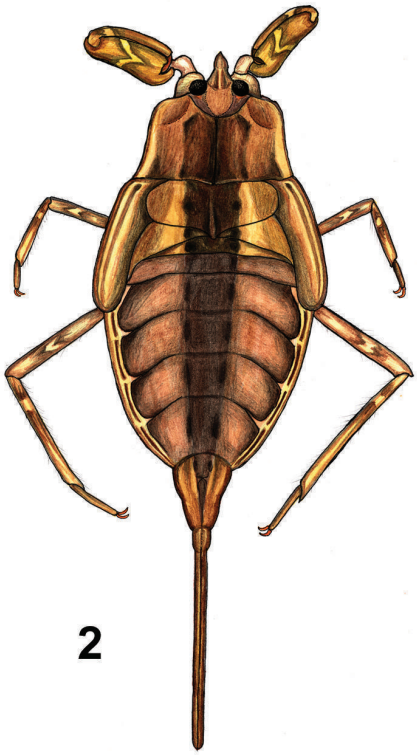
Plate 35: Nepidae: *Cercotmetus*.

Fig. 1: *Cercotmetus* spec., adult, length of body 53 mm
Nepal, Chiwan, Bishazari Tal, altutide 77 m asl.
Fig. 2: *Cercotmetus* spec., Nymph, total length of body with anal-siphon XX mm.
India, Maharashtra, Wetland, small pond east of Tahoba.
Figs. 3, 4: Habitat of *Cercotmetus* spec., small pond east of Tahoba.

Cercotmetus spp. is uniform dark brown and mostly overlooked, because its appearance is similar to a small wooden stick. Species are rare and they were found only in dense submerged macrophytes of stagnant waters. Materials were investigated from one locality each in Nepal and India. In Bishazari Tal adults were found on between Myriophyllum spp. and Utricularia spp. In Tahoba *Cercotmetus* spec. was observed numerously in Chara spp. vegetation of shallow pools. The Nymphs are much lighter than adults. They are pollution sensitive and limited to β- mesosaprobic wetlands and oxbow lakes with high diversity of benthic fauna.

Plate 33: Nepidae: *Laccotrephes*.

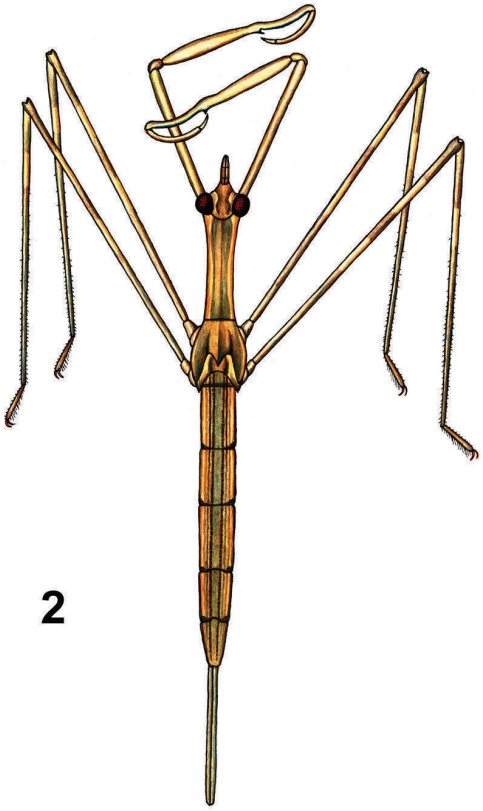
1



2

3

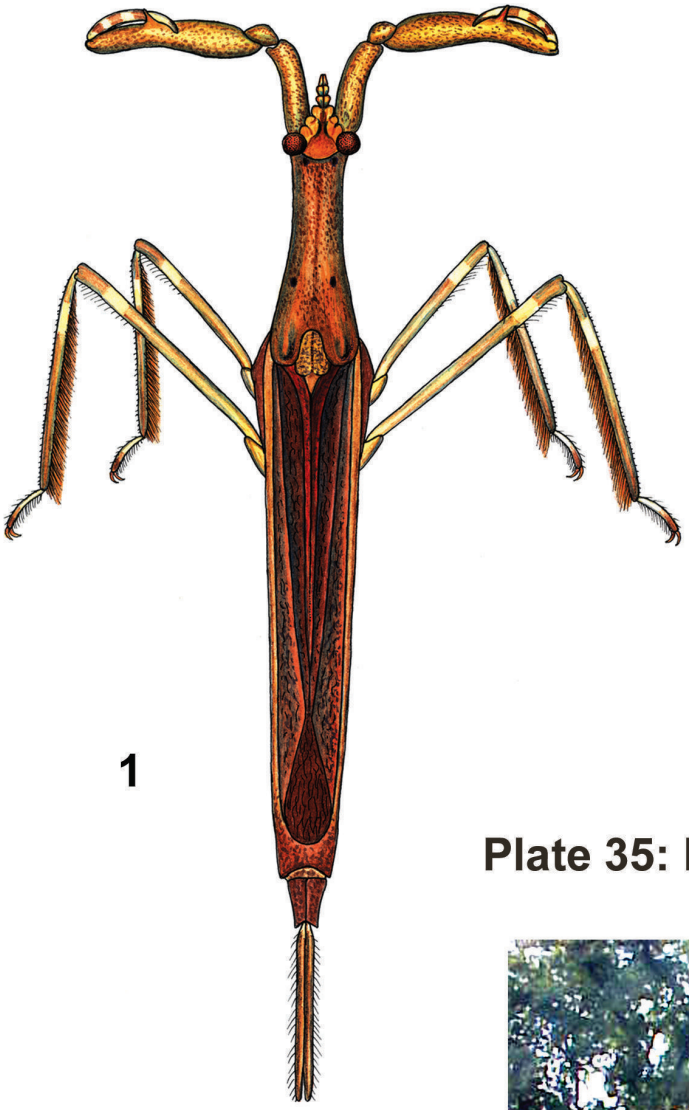
1



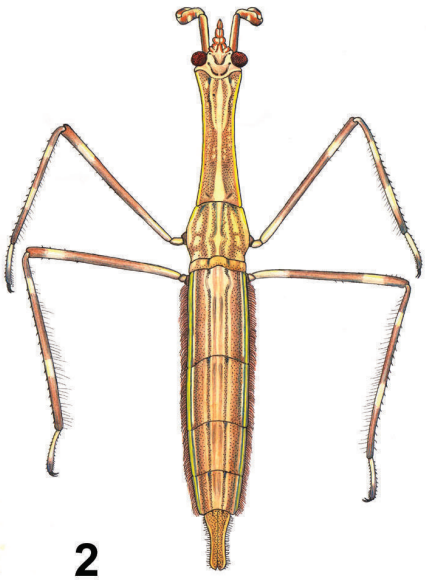
2

3

Plate 34: Nepidae: *Ranatra.*



1



2

Plate 35: Nepidae: *Cercotmetus*.

3

4

Family Naucoridae (Creeping Water Bugs)

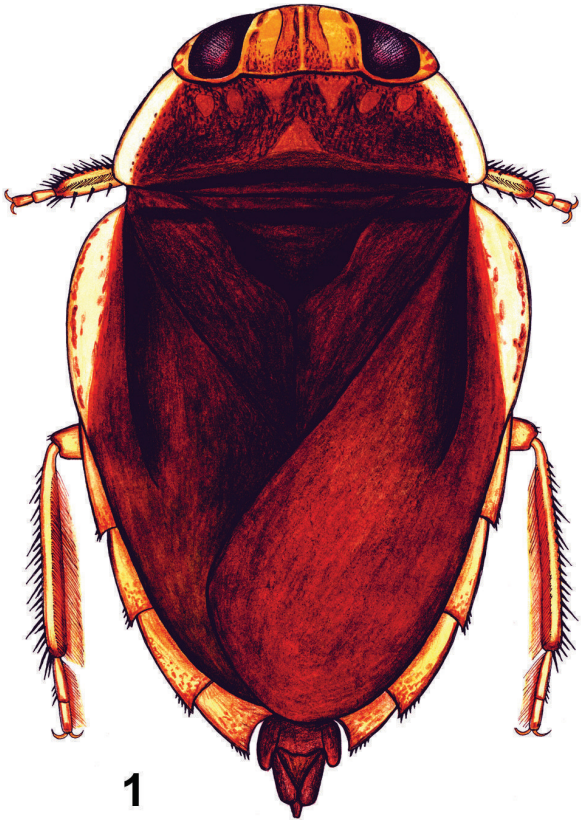
The body of the Creeping water bugs is flattened. The animals swim with dorsal side up. The fore legs originate from fore margin of prosternum. The anteclypeus is not recognizable from above. The membrane of hemielytron is without veins. The tip of abdomen is without any appendages. The body is broad and the head is exceptionally broad; the antennae are short and concealed. The Naucoridae sting viciously when handled carelessly. Their dorsal color of adults is dominated by uniform brown. They feed voraciously on a variety of aquatic Metazoa, and sting viciously when handled carelessly.

Plate 36: Naucoridae: *Heleocoris*.

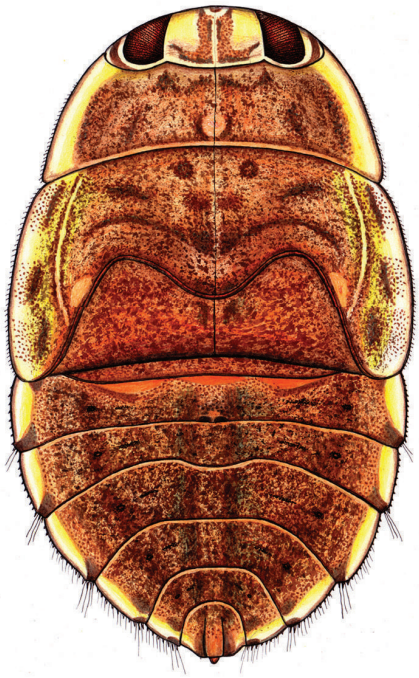
Fig. 1: *Heleocoris* spec., adult, length 12 mm
Nepal, Kavre, Chaukot Khola, small left tributary of Punyamata, altutide 1445 m asl.
Fig. 2: *Heleocoris* spec., Nymph, length 8.7 mm.
Nepal, Pokhara Valley, Kaski, Bhalam Khola at Rayalechour altutide 951 m asl.
Figs. 3: Habitat of *Heleocoris* spec., uppermost stretch of Bhalam Khola at Rayalechour.

Species of the Himalayas are part of the rheophilic fauna in lotic environments. They are not common and specimens of this family were occasionally collected from running parts in small streams of the Himalayan middle mountains. They are confined on streams of open floodplains with agricultural land-use outside from forests. Remarkable dense populations of Naucoridae were recently discovered in March 2007 in stony hill-streams of the Kali Khola (926 m), its right tributary Gharmi Khola (958 m) and Bhalam Khola at Rayalechour (951 m) at the northern border of Pokhara municipality. The family is accompanied by Gerridae and a very rich Plecoptera and Odonata fauna, including high abundance of Perlidae, Perlodidae and Euphaeidae. These habitats in open grassland have a high water current (0.8 meter/second) and the dominating substrates are medium to large size pebbles, stones and boulders with thick significant layers of filamentous green-algae. The biozoenotic region is from Epirhithral to Epipotamal. The Naucoridae reach

Plate 36: Naucoridae: *Heleocoris*.



1



2

3

their maximum abundance in water quality class I and II. One figured adult specimen is from the Chaukot Khola, a small left tributary of lower Punyamata near Panauti in Kavre district, in elevation of 1455 m. Here the Naucoridae were found in association with Nepidae *Laccotrephes* spec. and *Ranatra* spec.

Family Aphelocheiridae (Ground Water Bugs)

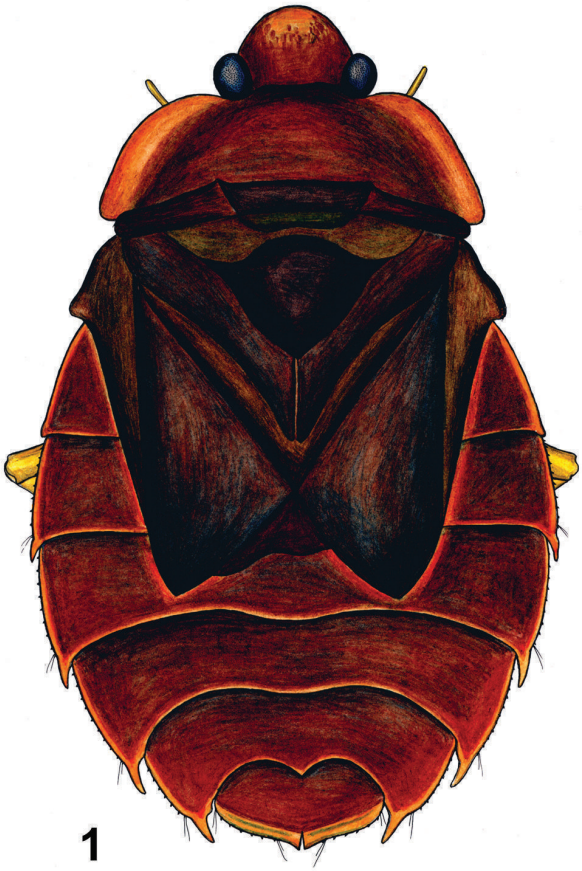
The general body form of these water bugs is much flattened. The animals can swim with dorsal side up. The fore legs originate from fore margin of prosternum. The beak very long (reaches hind legs). The head is as long as or slightly longer than wide. The fore femur is hardly thickened. Aphelocheridae adults are dark brownish on dorsal side. Similar to Naucoridae they feed voraciously on a variety of aquatic Metazoa, and sting viciously when handled carelessly.

Plate 37: Aphelocheiridae.

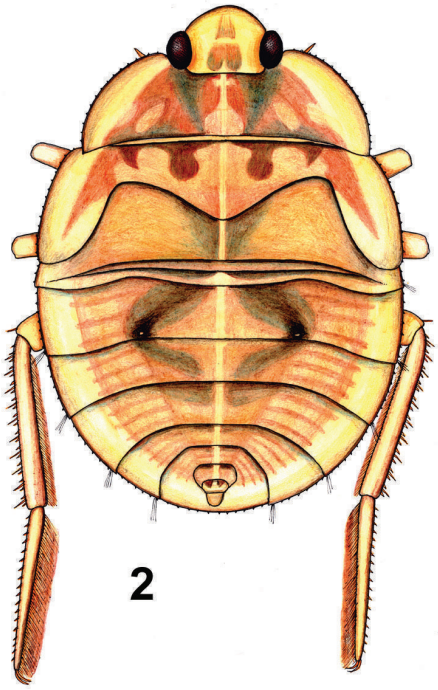
Fig. 1: *Aphelocheirus nepalensis*, Adult, length 7.5 mm
Nepal, Kathmandu Valley/Shivapuri, Bagmati at Sundarijal, altutide 1580 m asl.
Fig. 2: *Aphelocheirus* spec., Nymph, length 6.0 mm.
From the same locality.
Figs. 3, 4: Habitat of *Aphelocheirus* spec., Nepal, Pokhara Valley, Kaski, Bijaypur Khola at the confluence of Kadu Khola near Patanbesi (2.5 km east of Pokhara), altutide 805 m asl.

The Aphelocheridae are comparatively rare in the study region. They are confined to the Rhithral biocoenotic region (Meta- to Hyporhithral) of cold and unpolluted forest streams. These are the most rheophilic aquatic bugs which prefer lotic habitats of the bottom in deeper water of main channel. Localities were found within the Lesser Himalayan Crystalline (phyllites, quartzites, siltstones) of Kathmandu valley in the eco-region of the Eastern Himalayan broadleaf forest and in the Lesser Himalayan Metasediments (bedded schists, phyllites, metasandstones) of Pokhara valley in the

Plate 37: Aphelocheiridae, *Aphelocheirus nepalensis*.



1



2

3

4

Western Himalayan subtropical pine-forest. In River Bagmati at Sundarijal at the southern slope of Shivapuri mountain range *Aphelocheirus* spec. occurs abundantly in River Quality Class I. A further locality with similar environment is the Mahadev Khola 3 km upstream from Bhaktapur at the eastern border of the Kathmandu valley. This forest stream has water quality class I-II. The localities are situated in elevations of 1500 to 1600 m. These habitats have a rich invertebrate fauna with dominance of sensitive organisms like Perlidae, Perlodidae, Euphaeidae, Psephenidae, Elmidae, Blephariceridae, Potamidae *Himalayapotamon atkinsonianum*, Pomatiopsidae *Tricula montana* and Sphaeriidae *Pisidium annandalei*. In Bijayapur Khola east of Pokhara *Aphelocheirus* spec. was found in similar macro-invertebrate composition near Saptahako Dil in elevation of 810 m. The water quality class is I in this locality. In general Nymphs are more abundant and adult specimens are rarely found.

Family Pleidae (Pigmy Back Swimmers)

Together with *Microvelia* spp. and Helotrephidae this family is among the smallest aquatic bugs. The body is ovoid (seldom flat). The animals swim with ventral side up. The fore legs originate from hind margin of prosternum. Head and pronotum are separate. The antennae have three segments. The animals are very small and do not exceed more than 2.5 mm body length. The surface of hemielytrae is rough. The body is strongly arched, and the color is golden-yellow. The food of Pleidae consists mostly of small Crustaceans.

Plate 38: Pleidae.

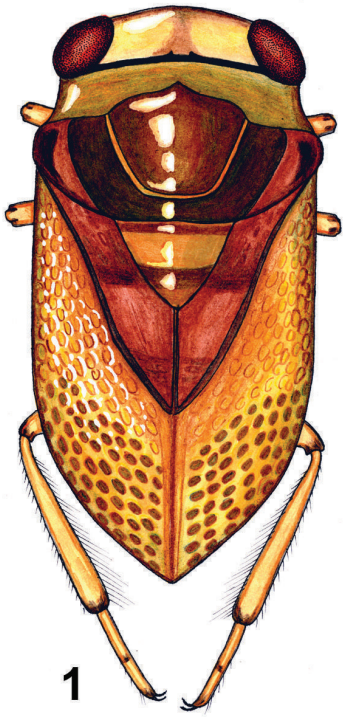
Figs. 1, 2: *Paraplea* spec., Adult, length 1.5 mm, dorsal and lateral aspect.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa River east of Gaur, altutide 75 m asl; Sampling Site No. NO1 BA 021.
Fig. 3: *Paraplea* spec., Nymph, length 1.5 mm.
Nepal, Pokhara Valley, Small wetland stream (effluent of Gude Tal) east of Bijaypur, altitude 750 m asl.

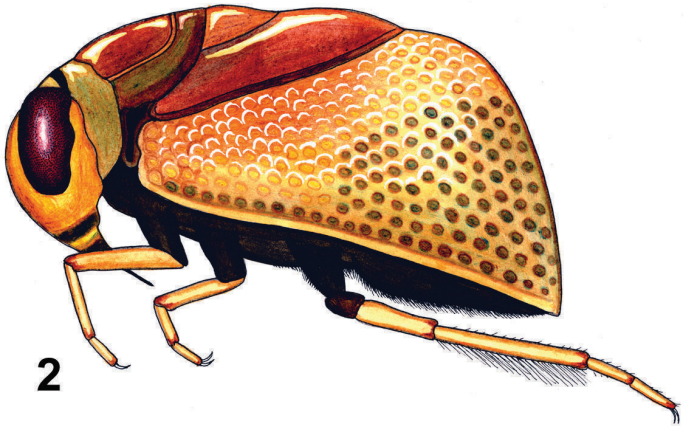
Fig. 4: Habitat of *Paraplea* spec., India, Maharashtra, Wetland, small pond east of Tahoba.

The Pleidae are represented in tropical Asia by the widely-distributed *Paraplea* (Polhemus and Polhemus 1990). Pleidae usually occur in large number of individuals forming groups in lentic zones. This family was found sporadically in slowly running parts of small rivers, streams, lake effluents and stagnant waters of wetlands from the lowlands. They prefer habitats with rich submerged vegetation and good ecological status of water quality class II or III. Localities with Pleidae are Barahwa Nadi at Gaur (Rautahat), Bishazari Tal (Chitwan), Gude Tal effluent at Pokhara (Kaski) and Asi Khola at Dhaitar, Kuntabesi (Kavre). The Pleidae family appears to be more restricted on warmer water bodies with uppermost occurrence at 900 m elevation. All investigated habitats are characterized by the presence of Sphaeriidae *Pisidium (Afropisidium) clarkeanum* or *P. (Afropisidium) nevillianum*, Salifidae *Salifa lateroculata* and Glossiphoniidae *Alboglossiphonia weberi*.

Family Helotrephidae

The general body form of these Back swimmers is ovoid similar to Pleidae but the animals appears more flat. The body height is less than in Pleidae. The animals swim with ventral side up. The fore legs originate from hind margin of prosternum. The head and pronotum are more or less fused. The antennae have one or two segments. Heloptrephidae are minute in size, being the smallest aquatic bugs. The investigated three specimens do not exceed 1.3 mm body length. They might be often overlooked due to their size or misidentified as Pleidae. The color of adult Helotrephidae is noteworthy with light yellow-ochre background on which numerous dark brown rounded spots are arranged, forming ornamental pattern.





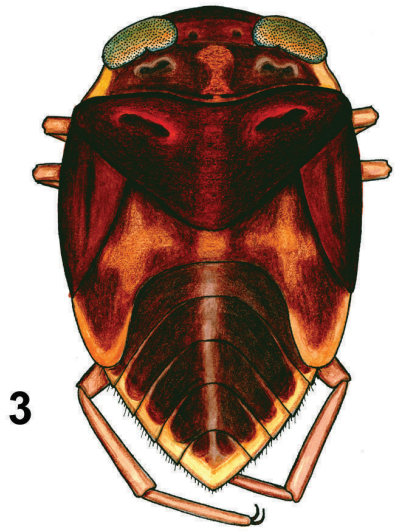


Plate 38: Pleidae, *Paraplea.*

Plate 39: Helotrephidae.

Figs. 1, 2: *Mixotrephes* spec., Adult, length 1.3 mm, dorsal and lateral aspect.
Nepal, Pokhara Valley, Ambote Khola (left tributary of Phusre Khola) southwest of Phokara, altitude 735 m asl.
Figs. 3, 4: Heletrephidae: Limnotrephinae, Tribus Limnotrephini, Adult, length 1.2 mm, dorsal and lateral aspect.
Nepal, Pokhara Valley, Phewa Tal, Forest bank and Rocks southwest of Tal Barahi Temple, Altitude: ≈ 795 m asl.
Fig. 5: Helotrephidae Nymph, length 1.3 mm, dorsal aspect.
Nepal, Lower Gangetic Plain, Kailali, Jagadishpur Reservoir.

Plate 40: Helotrephidae Habitats.

Figs 1-3: Habitats of Helotrephidae, Nepal, 1: Jagadishpur Reservoir, 2: Phewa Tal, Forest bank, 3: Natural rocks (Megalithal + Gigalithal) southwest of Tal Barahi Temple.

Family Notonectidae (Back Swimmers)

The body is elongated and ovoid (seldom flat); it appears to be slightly laterally compressed. The head and pronotum are separate. The antennae are with four segments. The size is large (up to 13 mm) compared with other back swimmers. The surface of hemielytrae is smooth. The color of the investigated material is uniform light grey to yellowish without any dark pigmentation or pattern. Nymphal food consists mostly of small crustaceans, but adults feed on much larger prey such as other aquatic insects and even small tadpoles and fishes. They can “sting” sharply with the mouth parts and produce a burning sensation.

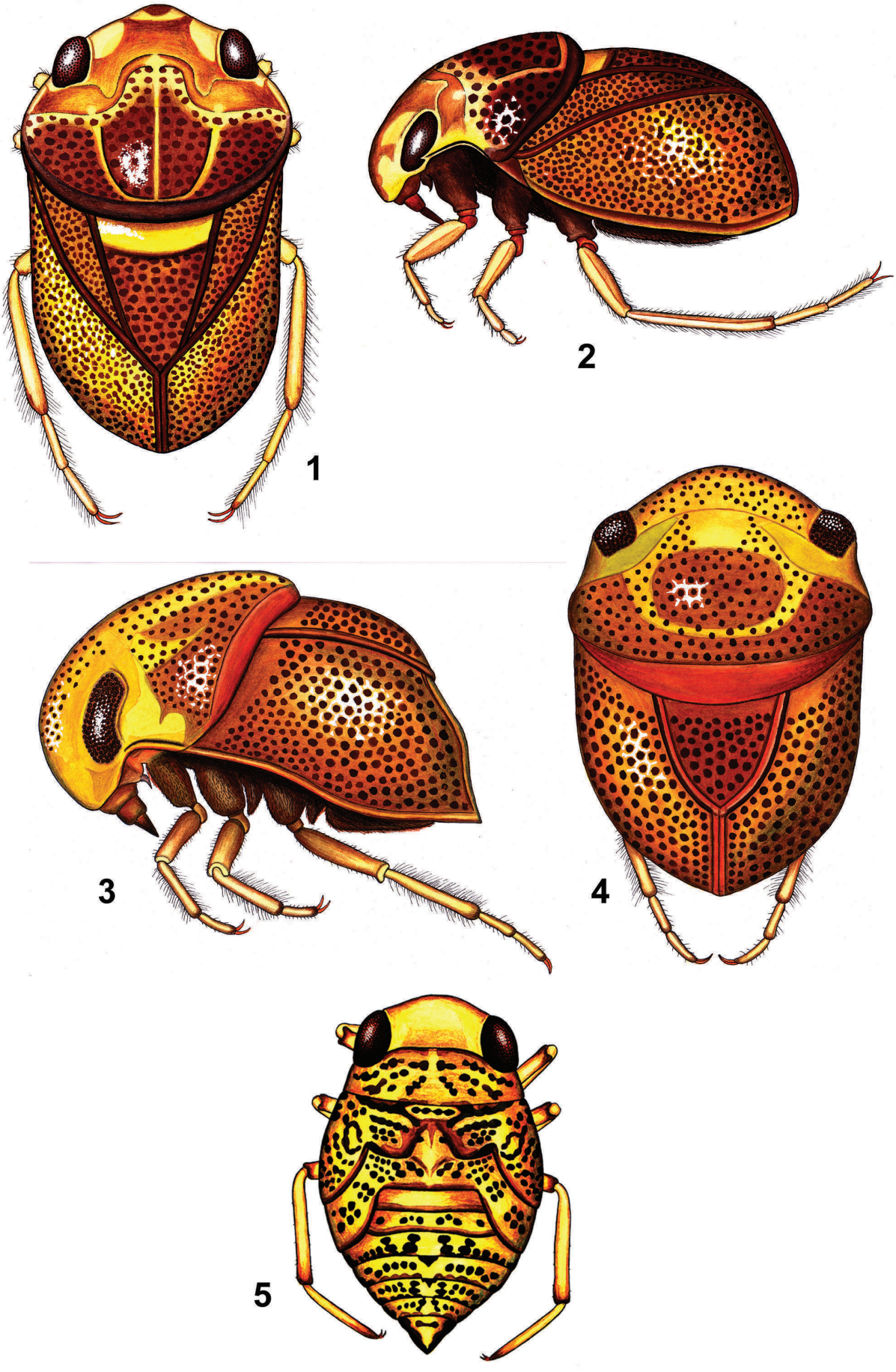


Plate 39: Helotrephidae.

Plate 40: Helotrephidae Habitats.

1

2

3

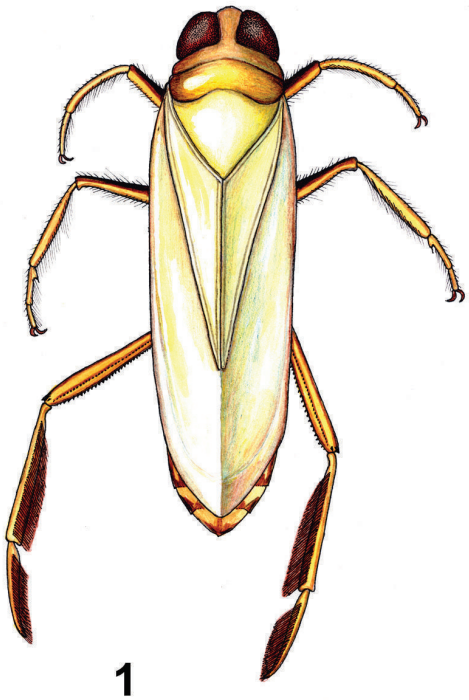
Plate 41: Notonectidae.

Figs 1, 2: *Anisops* spec.; Adult, length 8.0 mm, dorsal and lateral aspect.
Nepal, Kathmandu Valley, Jwala Pokhari in Patan, Altitude: ≈ 1200 m asl.
Fig. 3: *Anisops* Nymph, length 6.0 mm, dorsal aspect.
Nepal, Kavre, Dhulikhel, small temporary pond in open grassland in Kathmandu University, Altitude: ≈ 1450 m asl..
Figs 4-5: Habitats of Notonectidae with high abundance of *Anisops* spec., India 4: West Bengal, small pond of Subernarekha River near Jaleshwar, Altitude: 11 m asl., January 2009; 5: Bihar: Wetland Channel south of Pahari Fishpond, Altitude: ≈ 60 m asl.; Locality No. 16, April 2008.

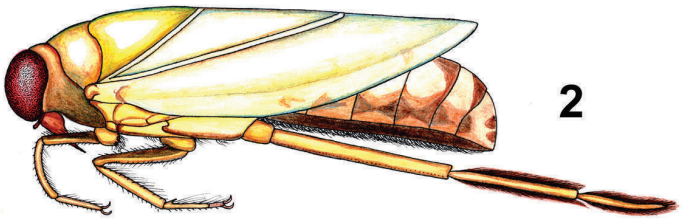
The Notonectidae are represented with mass-occurrence in stagnant waters of lakes, ponds and wetlands in the Gangetic Plains, in Nepal Terai, Pokhara valley and Kathmandu valley. They colonize water bodies with high fish population. The genus *Anisops* is very common in the study area. It tolerates high organic pollution of water quality class IV where other Heteroptera except Corixidae can not survive. Notonectidae were collected from numerous localities in the lowlands and from Kathmandu valley in Taudaha Lake, Bhaju Pokhari (Bhaktapur), Jwala Pokhari (Patan), Rani Pokhari (Kathmandu) and Nagdaha Pond. Their range exceeds from the lower Gangetic plains up to elevation of approximately 1500 m. In the Ganga River *Anisops* spec. was found numerously in lentic parts between between Macrophytes *Potamogeton crispus* growing on mud substrate.

Family Corixidae (Water Boatmen)

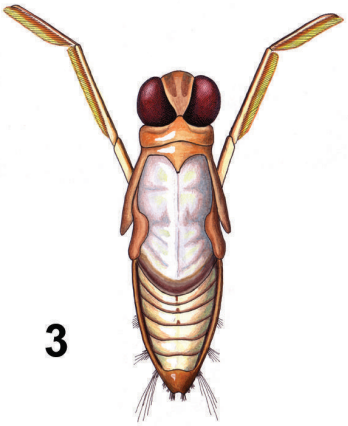
The front of head is triangular, with very short triangular beak. The fore tarsus is always 1-segmented, either conical or broadened. The scutellum is hidden by the pronotum. The body length of adults reaches 6 mm or more. The dorsal color display dark brown zebra stripes on the pronotum and very dense script-like zigzag pattern on the Membrane of hemielytron. Nymphs may have dense hairs on thoracal segments. Corixidae collect their



1



2



3

Plate 41: Notonectidae.

4

5

food from muddy bottom by sweeping the flocculent material into their mouth with their first tarsi. It consists of debris and a great variety of algae, Protozoa, and microscopic Metazoa characteristic of that habitat. In addition Corixidae feed on algal filaments by piercing each cell with their protrusible stylets and sucking out the contents.

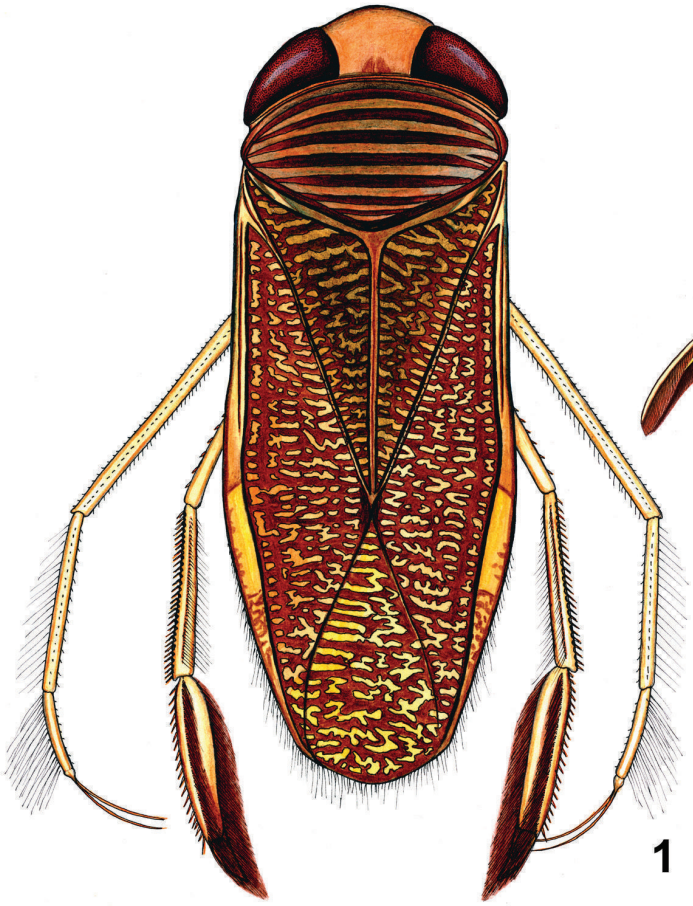
Plate 42: Corixidae.

Figs. 1: *Sigara (Tropicocorixa)* spec., Adult, length 6.0 mm, dorsal aspect.
Nepal, Pokhara Valley, Phewa Tal, wetland west of Khapaudi, Altitude: ≈ 795 m asl.
Fig. 2: *Sigara (Tropicocorixa)* spec., Nymph, length 4.0 mm, dorsal aspect.
From the same locality.
Fig. 3: Habitat Example for Corixidae with high abundance of *Sigara* spec., India: Uttar Pradesh, lentic bay of Ganga River near Chunar (Chunarghat), Locality No. 1, March 2008.

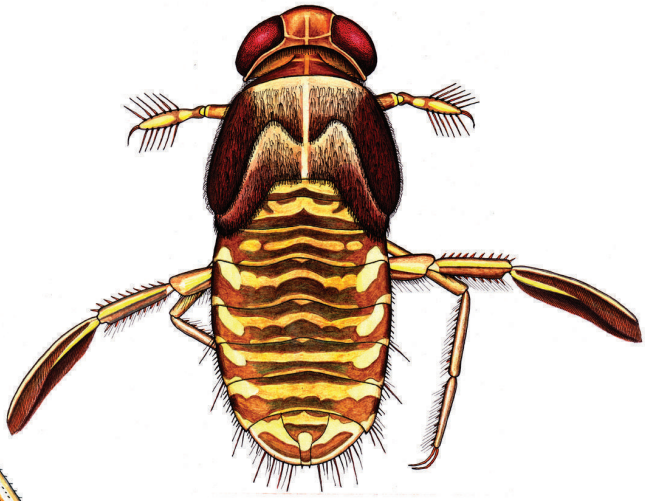
Corixidae are highly diversified in the Oriental zoogeographic region. *Sigara* spp. was found in a large variety of stagnant and running waters, mainly in floating submerged macrophytes of lentic zones. It is rather common in β- and α-mesosaprobic waters, being also collected from highly polluted streams with polysaprobic conditions, e.g. Punyamata at Shree Khandapur near Kathmandu University, Dhulikhel. Therefore the presence of the family Corixidae indicates always organic load or anthropogenic pollution. The family is absent from most cold forest streams and headwaters in the hilly and mountainous regions of Nepal.

Family Micronectidae (Pigmy Water Boatmen)

The animals differ from Corixidae visibly by their smaller size. The body length is less than 4 mm. The front of head is triangular, with very short triangular beak. The fore tarsus is always 1-segmented and conical. The scutellum is exposed and well recognizable. The dorsal color of different species is highly variable yellow, orange, ochre, and grey to dark brown. There is often a dark pattern of longitudinal stripes or dots



1



2

3

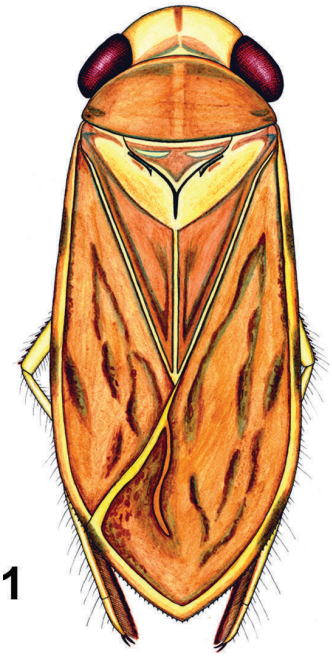
Plate 42: Corixidae.

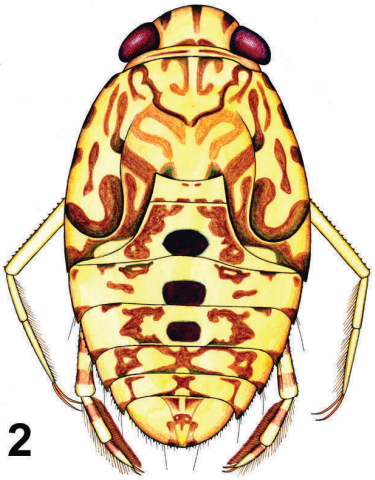
on the dorsal side. The family includes at least 27 species of genus *Micronecta* and one of genus *Synaponecta* on Indian subcontinent; they might be useful bio-indicators on species level due to high diversification. *Synaponecta* was not yet found in the numerous checked samples during the present study.

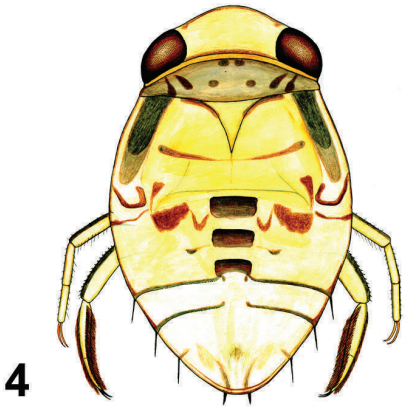
Plate 43: Micronectidae.

Fig. 1: *Micronecta* spec., Adult, length 3.8 mm, dorsal aspect.
Fig. 2: *Micronecta* spec., Nymph, length 3.0 mm, dorsal aspect.
Nepal, Kathmandu Valley, Jwala Pokhari in Patan, Altitude: ≈ 1200 m asl.
Fig. 3: *Micronecta* spec., Adult, length 2.7 mm, dorsal aspect.
Fig. 4: *Micronecta* spec., Nymph, length 2.0 mm, dorsal aspect.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa River east of Gaur, altutide 75 m asl; Sampling Site No. NO1 BA 021.
Fig. 5, 6: Habitat Examples with high abundance of *Micronecta* spec., 5: India: Bihar, lotic main channel of Ganga River near Adalatghat, Patna; Locality No. 6, April 2008; 6: India: Uttar Pradesh, lentic bay of Ganga River near Chunar (Chunarghat), Locality No. 1, March 2008.

There are about 27 species of genus *Micronecta* with 7 subgenera known from Indian subcontinent. The Micronectidae are very common in various types of stagnant and running waters. They were found in different rivers, streams, lakes, ponds and wetlands wherein they always occur in large number of individuals. Micronectidae are able to life in fast running rivers, but their occurrence is restricted on shallow lentic zones of pools near the river bank. In rivers they occur abundantly in open water where no vegetation is present and current is not too high.







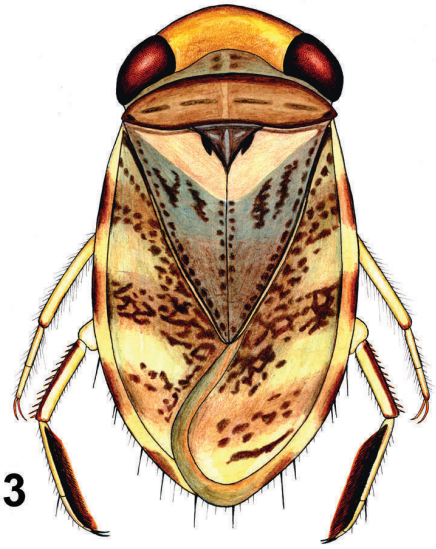


Plate 43: Micronectidae.

Infraorder Gerromorpha

This suborder is represented with four families. Due to the life style of all semi-aquatic bugs on the water surface, the animals are much more difficult to catch. The lesser representation of Gerromorpha may simply reflect that sampling of aquatic fauna is not a successful method for representation of semi-aquatic fauna. They might be often under-represented or overlooked in routine collection to assess to ecological status of river quality and water quality classes. More detailed research is required in future to cover these taxa in adequate and representative way for documentation of their presence.

Family Gerridae (Water Striders)

The length of hind femur extends well beyond the tip of abdomen. The claws are nearly always inserted distinctly before the apex on last segment. Size: 2-15 mm. The color of adults is variable light ochre to dark brown or nearly blackish with light grey lines and stripes. There is often a metameric and ornamental pattern on dorsal side. Water striders feed on a variety of small crustaceans and aquatic insects that they catch just below the surface.

The semi-aquatic long-legged Heteroptera were found skating on water surface. They prefer shadow places of pools in fast running and cooler temperate hill-streams. Gerridae are frequently occurring in unpolluted headwaters and upper regions of rivers, being rare in the lowlands and plains. Because of their high diversity and endemism in the Himalayan region, the identification up to genus or species level was possible only for some specimens. In field the animals are difficult to catch. When disturbed, they scatter nervously in all directions by fast running on the water surface. When caught by hand-net together with other insects from same Microhabitat [e.g. Veliidae, Gyrinidae], the Gerridae escape from the sample immediately. For most of the sparse collections of the present the identification has to remain on family level.

Plate 44: Gerridae.

Fig. 1: *Limnogonus* cf. *nitidus*, Nymph, length 7.2 mm, dorsal aspect.
Nepal, Lower Gangetic Plain, Rautahat, Barahwa Pond in Gaur, altutide 77 m asl.
Fig. 2: *Limnogonus nitidus*, Adult, total length 15 mm, length of body 6.0 mm, dorsal aspect.
Nepal, Kathmandu Valley, Bhaktapur, Bhajya Pond, Altitude: ≈ 1300 m asl.
Fig. 3: *Metrocoris* spec., Nymph, total length 6.8 mm, dorsal aspect.
Fig. 4: *Metrocoris* spec., Adult, total length 22 mm, length of body 6.3 mm, dorsal aspect.
Fig. 5: Gerridae., Nymph, length of body 9.5 mm, dorsal aspect.
Nepal, Kavre, Chandeshwari Forest Spring Stream northeast of Banepa, altutide 1640 m asl.

Family Veliidae (Water Striders)

The head is always with a distinct longitudinal median impressed line on dorsal surface. The length of the hind femur does not or only barely extends to the tip of abdomen. The claws are nearly always inserted distinctly before the apex on last segment. Size: 0.8-6 mm. The color of adults is very similar to Gerridae species. It is variable light ochre to dark brown or nearly blackish with light grey lines and stripes. There is often a metameric and ornamental pattern on dorsal side. The adults are usually apterous (wingless). Food are small living and dead insects that fall to the surface and small aquatic organisms that are caught just beneath the surface film.

Plate 45: Veliidae.

Fig. 1: Veliidae, Nymph, length 2.5 mm, dorsal aspect.
Nepal, Kathmandu Valley, Bhaktapur district, Manohara Khola, upper reach, Altitude: ≈ 1400 m asl.
Fig. 2: Veliidae, Adult, length 1.8 mm, dorsal aspect.
Nepal, Hetauda, Ghate Khola, Inlet of fishpond.

Fig. 3: *Microvelia leveillei*, Nymph, length 0.8 mm, dorsal aspect.
Nepal, Kavre, small temporary forest pond northeast of Banepa, altutide 1675 m asl.
Fig. 5: Habitat Example for running water species Nepal, Kathmandu Valley, Bhaktapur district, Mahadev Khola, middle reach near Kharipati.
.

Family Mesoveliidae (Water Treaders)

The length of the hind femur does not extend the tip of abdomen. All legs are of similar length. The tarsi are three-segmented, all claws are apical. Size: 2-4mm. The general color appearance is uniform ochre, light brown or bright green without any dark markings.

Plate 46: Mesoveliidae.

Fig. 1: *Mesovelia* spec., Adult, length 2.6 mm, dorsal aspect.
Fig. 2: Mesoveliidae, Adult, length 2.5 mm, dorsal aspect.
Fig. 3: Mesoveliidae, Adult, length 2.5 mm, dorsal aspect.
Nepal, Pokhara Valley, Phewa Tal – Harpan Khola wetlands west of Baskot, Altitude: 798 m asl.
Fig. 4: Mesoveliidae, Nymph, length 2.1 mm, dorsal aspect.
Nepal, Kathmandu Valley, Jwala Pokhari in Patan, Altitude: ≈ 1200 m asl.
Fig. 5: Micro-Habitat of *Mesovelia* in Phewa Tal – Harpan Khola wetlands.

The Mesoveliidae are not common in the Himalayan region of Nepal. The available few records are from stagnant water bodies of the Eastern Himalayan broadleaf forests, Western Himalayan Pine forests. In India *Mesovelia* spp. was occasionally collected from Ganga River in Bihar, large rivers in Jharkhand and Wetlands in Maharashtra.

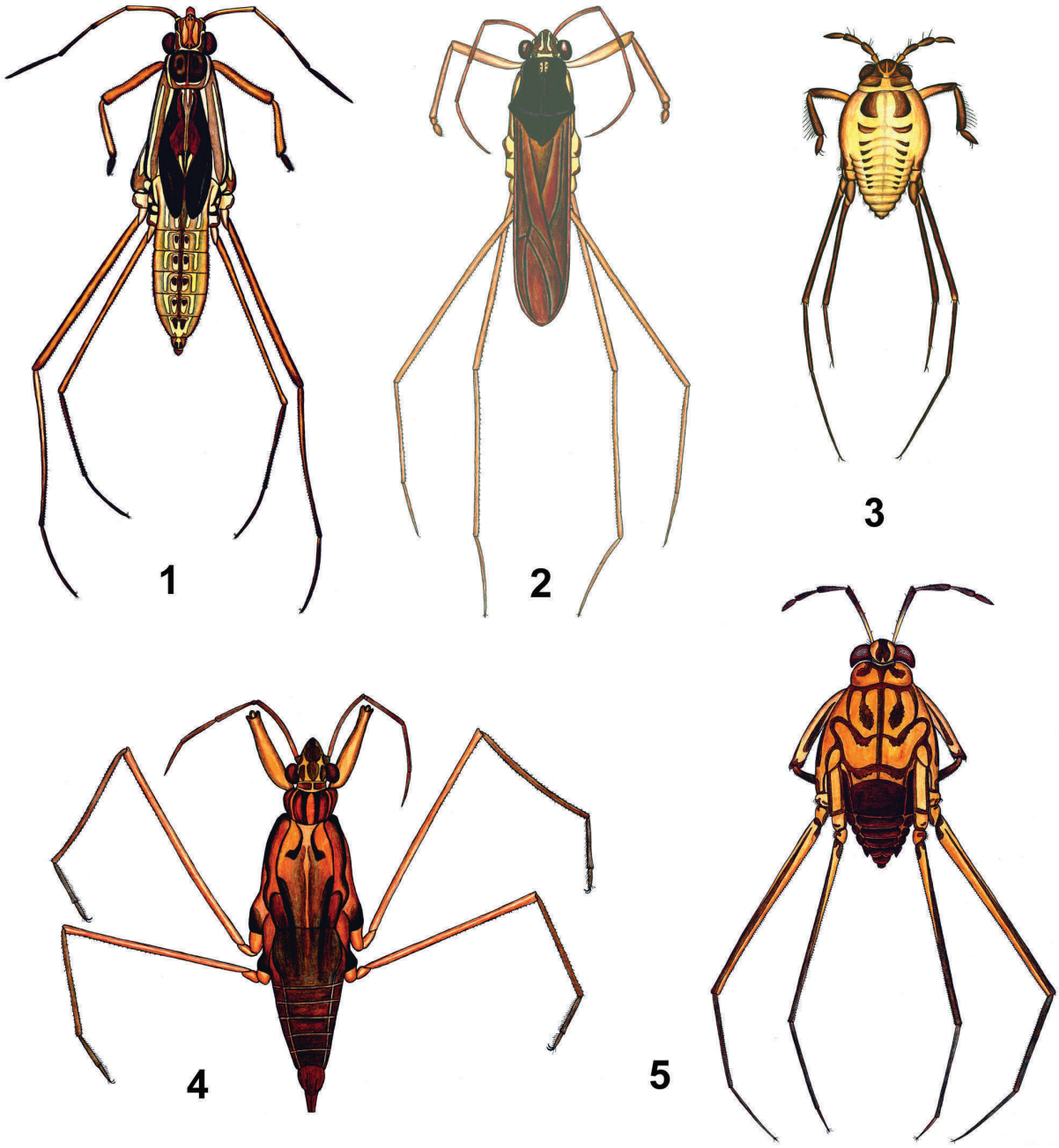
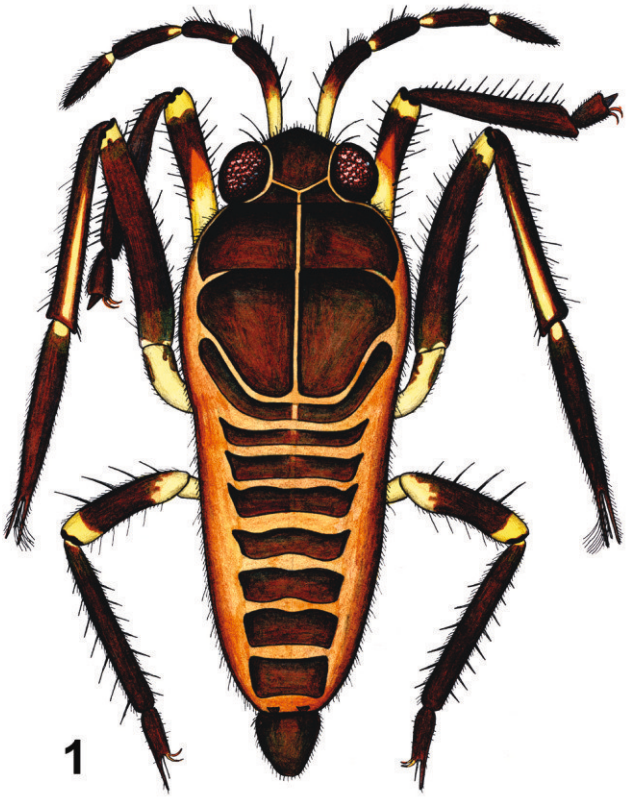
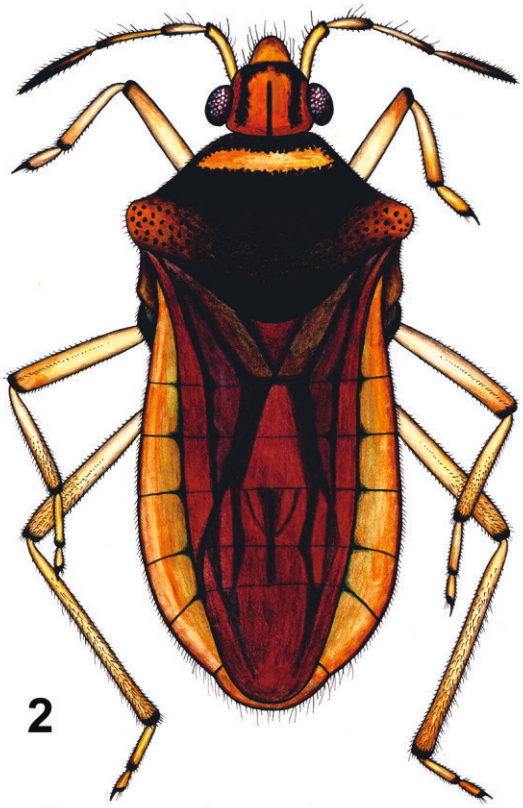


Plate 44: Gerridae.

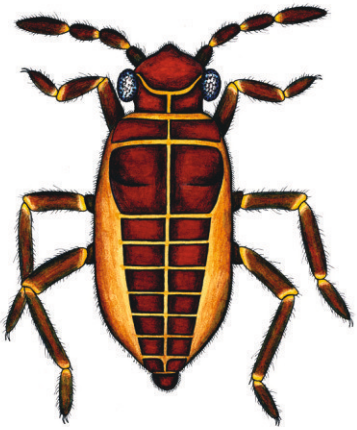
Plate 45: Veliidae.



1



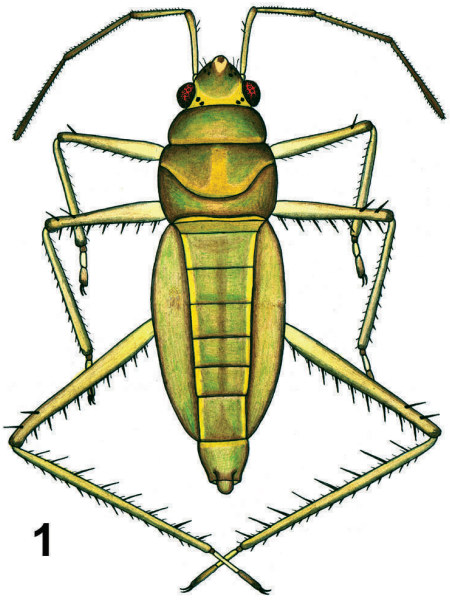
2



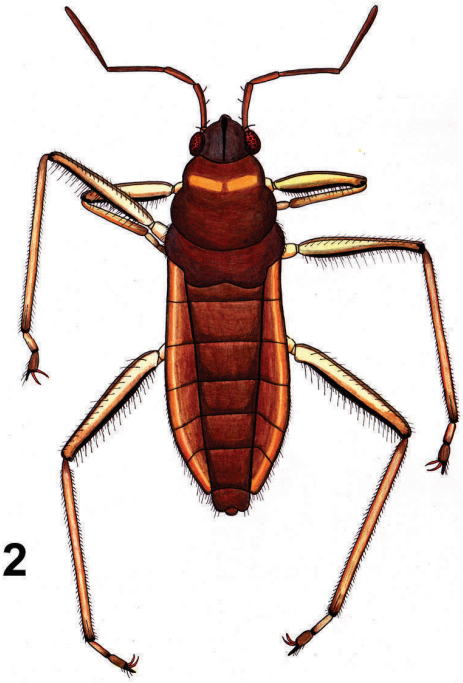
3

4

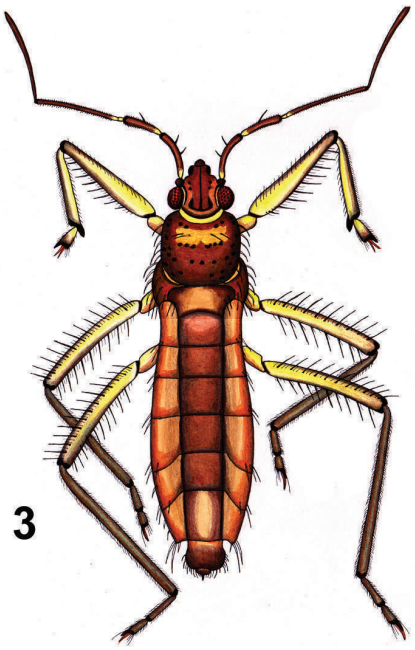
Plate 46: Mesoveliidae.



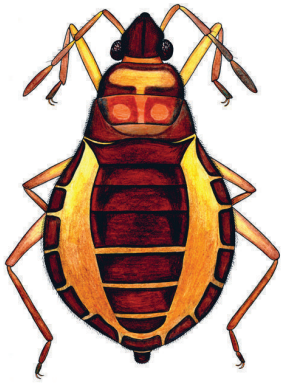
1



2



3



4

5

Family Hebridae (Velvet Water Bugs)

The head bears ventro-laterally a pair of prominent vertical plates (bucculae) covering the base of rostrum. The tarsi are two-segmented with claws apical. Size: 1-3mm. Their body is covered with a dense, velvety, water-resistant pile. The general color appearance is uniform ochre-brown to dark red-brown without any markings. They are similar in their morphology to terrestrial Hemiptera. Hebridae feed on small insects.

Hebridae were for the first time recorded from Nepal, they occur numerously in clean and unpolluted section of Phokara Valley streams, preferring Akal and Micrilithal substrates along the banks. In Ambote Khola, which has water quality class I and Ecological River Quality 1, *Nieserius* spec. inhabits the same habitat with *Mixotrephes* spec. and *Rhagovelia* spec. The studied and figured specimens were collected from a reference site (unpolluted and undisturbed) stream in the Western Kumaon Himalayan Valleys of Uttaranchal in India.

Family Hydrometridae (Marsh Traders, Water Measurers)

The head is more than three times longer than wide¸ the eyes are far removed from posterior margin of head. The claws are inserted apical on last tarsal segment.
Size: 7-10mm. The body is uniform in color varying from light brown, dark brown to nearly blackish. Hydrometridae feed on all types of small Metazoa at or near the surface film.

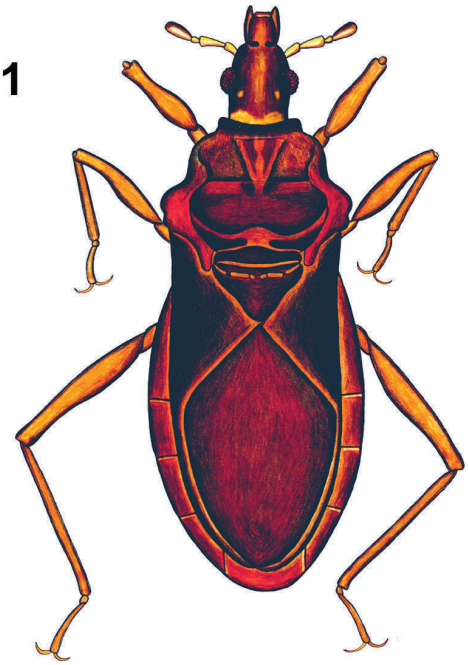
The Hydrometridae were prior to the present study unknown from Nepal. The record from the uppermost Punyamata watershed is the first finding in the study area. The locality is in the Nagarkot forest east of Rohini Banjyang at the border of Bhaktapur district in elevation of 1950 m. An adult specimen of *Hydrometra* spec. was collected in March 2005 from a spring wetland of the Jaljale Khola in a larger spring pool at the bank in Juncaceae grassland vegetation. The habitat is a lentic part of the spring stream with a rich diversity of Coleoptera, Odonata and Diptera, Sphaeriidae *Pisidium atkisonianum*,

Pomatiopsidae *Tricula montana*, Planorbidae *Gyraulus convexiusculus*, *Segmentina calatha*, amphibious Megascolecidae *Perionyx* spec. and rare occurrence of Tubificidae *Spirosperma* spec. Further habitats are the wetlands of Harpan Khola in the Phewa Tal basin, where *Hydrometra* spec. was found between dense Macrophytes in small effluents of old meanders around Baskot. In Phusre Khola [the effluent of Phewa Tal] *Hydrometra* spec. is abundant on open mudflats along the banks.

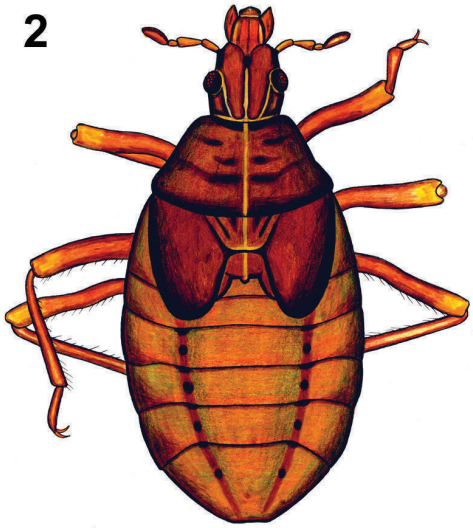
Plate 47: Hebridae, Hydrometridae.

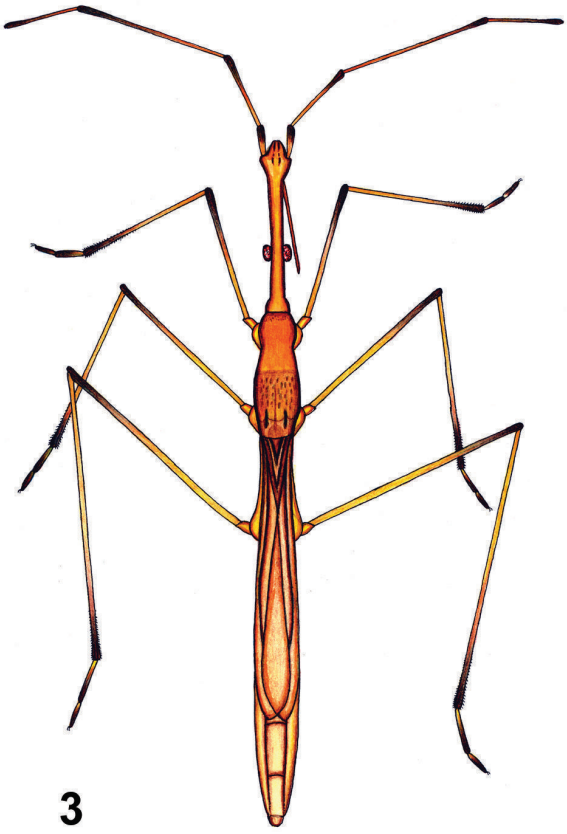
Fig. 1: *Nieserius* spec., Adult, length 3.0 mm, dorsal aspect.
Fig. 2: *Nieserius* spec., Nymph, length 2.2 mm, dorsal aspect.
India, Uttaranchal, Headwater, Sampling Site: IO5 SO 061.
Fig. 3: *Hydrometra* spec., Adult, length 12.0 mm, dorsal aspect.
Nepal, Kavre, Jaijale Khola (uppermost Punyamata), Rohini Banjyang, Nagarkot Hills, Altitude: 1950 m asl.
Figs 4, 5: Habitat of *Hydrometra* spec., in Jaijale Khola (uppermost Punyamata), Rohini Banjyang; 4: Helocrenon = Spring wetland; 5: Limnocrenon = Spring pool.

1



2





3

4

5

Plate 47: Hebridae, Hydrometridae.

Chapter 10. Aquatic Insects as Bioindicators (in part)

Aquatic Roaches

10.1. Blattodea: Aquatic Cockroaches [Synonyms: Blattoptera, Blattaria, Blattariae]

The Order Blattodea including fossil ancestors is one of the oldest still existing groups of insects. "Blattoid" insects were already highly diversified in the Paleozoic and cockroaches were representing the dominating terrestrial insects in the Carboniferous and Permian (Wichard et al. 1995, Beier 1967, 2004), although in the more recent evolutionary view the true modern cockroach origin is dated back in the Triassic/Jurassic. Gullan and Cranston (2005: 188) concluded: "The many early fossils allocated to Blattodea that possess a well-developed ovipositor are considered best as belonging to a blattoid stem group, that is, from prior to the ordinal diversification of Dictyoptera." The oldest members are represented by *Eoblattina temporis* (35 mm length) from the late Carboniferous, Stephanian, in 305 million years old deposits from Commentry in France. The largest fossil member *Arthropleura pustulatus* (90 mm length) was discovered from 300 million years old coal deposits of northeastern Ohio in North-America (Ohio State University 2001, 2009). They are now considered as Eublattoidea of the early Dictyoptera because of the following reasons: "Contrary to the popular belief, this specimen [= *Eoblattina temporis*], while sharing many features in common with extant roaches would be more accurately termed a "roachoid". They possessed a long ovipositor unlike the roaches of the present, a feature that carried through until the late Jurassic. Contrasting with the Carboniferous roachoids, the true roaches have a fossil history that extends only to the Early Cretaceous, or nearly 200 million years later." Thus like in Dragonflies modern Odonata evolved from Paleozoic Odonatoptera, the living cockroaches [Blattodea] can be derived from Paleozoic/Mesozoic Eoblattoidea ancestors.

The living Blattodea are represented worldwide with more than 3500 (? – 4000) described species (Wichard et al. 1995, Mandal 2003) which are mainly distributed in warm humid tropical zones. All are herbivorous and feed on leaf litter, a small number of the Family Blaberidae, mainly Subfamily Epilamprinae are well adapted to the

semi-aquatic life in the Littoral-zone of freshwaters. Epilamprinae have 34 accepted genera (+ 4 genera incertae sedis) out of which the genus *Rhabdoblatta* Kirby, 1903, has the highest number of species.

Fossil aquatic cockroaches are found from Mesozoic. The Santana formation in North-Eastern Brazil is famous for providing an undisturbed fossil accumulation. It is dated to Cretaceous [Aptian, Cenomanian] 108-92 million years ago, when the South Atlantic was a long narrow shallow sea. The insect fauna comprises Odonata (adults 264, larvae 120), Heteroptera, Orthoptera and Blattodea (terrestrial + aquatic). The aquatic cockroach fossils are of excellent preserved condition and may well represent Epilamprinae closely allied to the living forms. An hitherto unnamed adult winged male specimen is shown with number C.BLT-07 (Reference: http://www.devoniandepot.com/Crato/blattodea_cockroaches.htm).

Aquatic cockroaches are hitherto known only from South Asia, South-East Asia and Japan. Information about findings in the literature is rare and most of important few papers were published in the years 1900 to 1921, when the present taxa were still regarded as members of the Order Orthoptera. The concerned scientist are Annandale (1900, 1906), Green (1902), Shelford (1907, 1909) and Takahashi (1921). Furthermore findings of aquatic Epilamprinae in a Malaysian stream were done by Bishop (1973) who identified three genera. In the more recent taxonomical literature of aquatic macro-invertebrates Blattodea are briefly mentioned only by Ward (1992, p. 28), Hutchinson (1993, p. 569) and Dudegon (1999, pp. 511-512).

From the Indian subcontinent the first published record (Annandale 1906, p. 105) of aquatic cockroaches was coming from India in Jharkhand. Annandale collected a female larva on March 4th 1905 “while turning over stones in a small jungle stream on a hill near Chakardharpur in Chota Nagpur”. During the present study aquatic cockroaches were found in Maharashtra and Nepal. The latter ones appear to be new for the country and the Himalayan region. Mandal (2003, 2006) did not mention the presence of *Rhicnoda* species for the fauna of Sikkim and Arunachal Pradesh.

10.2. Illustrated Guide

Investigated Materials:

Rhicnodona natatrix Shelford, 1907

Material: 13 specimens from 5 localities.
Nepal: 6 juveniles (larvae), Mahabarat range, Makwanpur district, Daman, Sim-Khola middle reach, November 2007.
Nepal: 1 adult ♀, Pokhara Valley, Seti watershed, N03WK03, March 2007.
Nepal: 1 juvenile (larva), Shivapuri National Park, Bagmati watershed, GO 01, May 2007.
India: 2 juvenile (larva), Pench National Park, forest stream, spring region, November 2008.
India: 2 adult ♀, 1 juvenile (larva), Pench National Park, Ambakori Totladoah, November 2008.

Plate 48: Blaberidae: *Rhicnoda natatrix*.

Fig. 1: *Rhicnoda natatrix*, adult ♀, length, 22.5 mm, India, Maharashtra, Pench: Ambakhori-Totladoah forest stream.
Fig. 2: *Rhicnoda natatrix*, juvenile (larva), length, 10.0 mm, Nepal, Makwanpur, Sim-Khola, middle reach.

Rhicnoda rugosa Brunner von Wattenwyl, 1865

Material: 3 specimens from 3 localities.
Nepal: 1 juvenile (larva), Pokhara Valley, Seti watershed, N03WK03, March 2007.
Nepal: 1 adult ♀, Shivapuri National Park, Bagmati watershed, GO 02, May 2007.
Nepal: 1 adult ♂, 1 juvenile (larva), Shivapuri National Park, Bagmati watershed, Dhobi Khola DH 01, May 2007.

Plate 49: Blaberidae: *Rhicnoda rugosa*.

Fig. 1: *Rhicnoda rugosa*, , adult ♂, length 36.5 mm, Nepal, Shivapuri, Dhobi-Khola.
Fig. 2: *Rhicnoda rugosa*, adult ♀ length, 23.0 mm, Nepal, Seti Nadi, Tributary in Pokhara Valley

Locality/Species	*Rhicnoda natatrix* [length]	*Rhicnoda rugosa* [length]
Sim-Khola	8.5 mm juvenile 9.5 mm juvenile 10.0 mm juvenile 10.5 mm juvenile 10.5 mm juvenile	
Seti-Watershed N03WK03	9.0 mm juvenile	23.0 mm ♀ adult
Shivapuri GO 01	8.5 mm juvenile	
Shivapuri GO 02		10.5 mm juvenile
Shivapuri DH 01	10.5 mm juvenile	36.5 mm ♂ adult
Pench forest stream, spring region	14.0 mm juvenile 19.5 mm ♀ adult	
Pench, Ambakori Totladoah	18.0 mm ♀ adult 18.5 mm ♀ adult 22.5 mm ♀ adult	
Total number of specimens	13	3

Table 80: Investigated Specimens of *Rhicnoda* spp. from Nepal and India.

The identification of the material collected from Nepal turns out the sympatric occurrence of *Rhicnoda natatrix* Shelford, 1907 and *Rhicnoda rugosa* (Brunner von Wattenwyl, 1865) in the Shivapuri hills of the Bagmati watershed at the northern slope of Kathmandu Valley. These localities in natural mixed forest dominated by *Pinus roxburgii* are in 1600-1700 meter altitude. Remarkable is the occurrence of *Rhicnoda natatrix* in the Mahabarat range in 2450 meter altitude because this is also one of the known best habitats the Himalayan relict dragonfly *Epiophlebia laidlawi*.

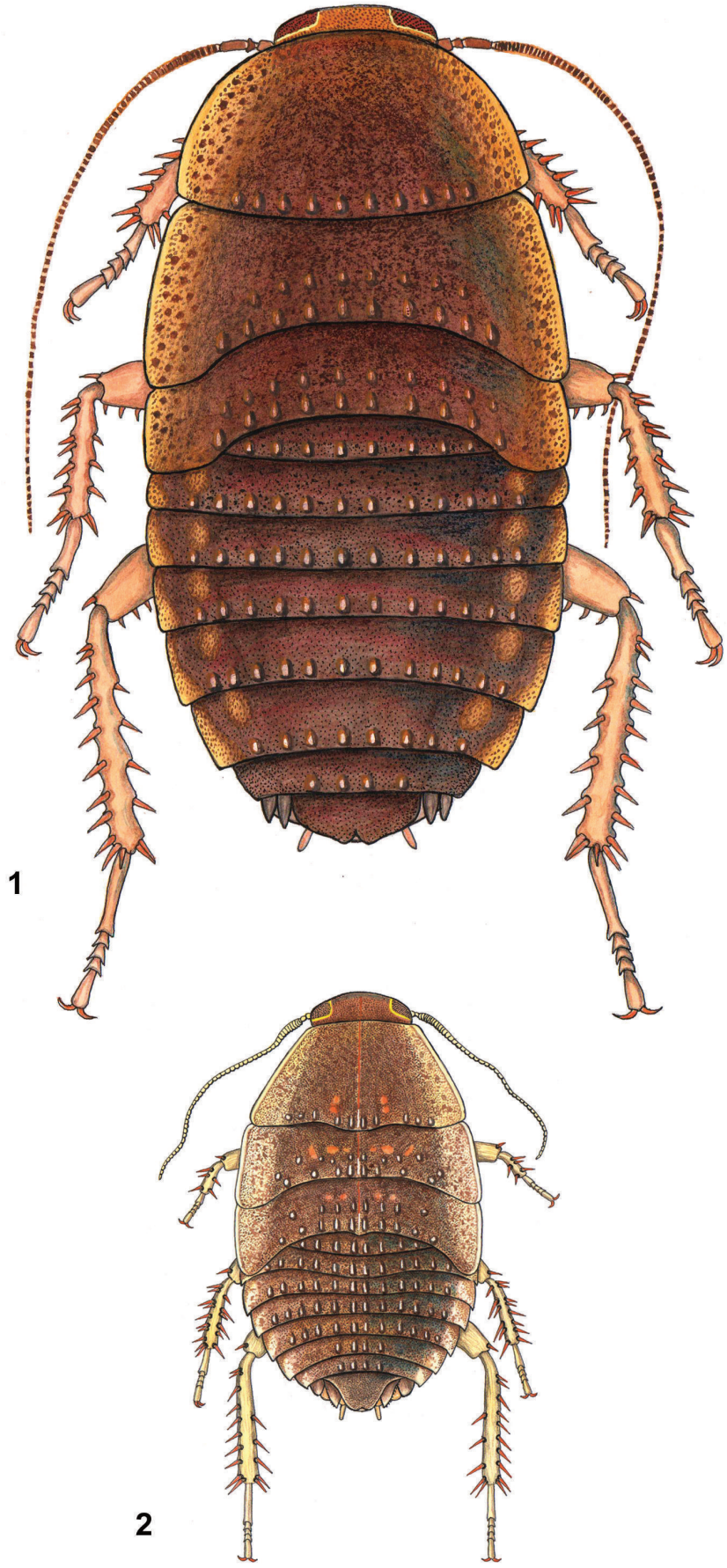
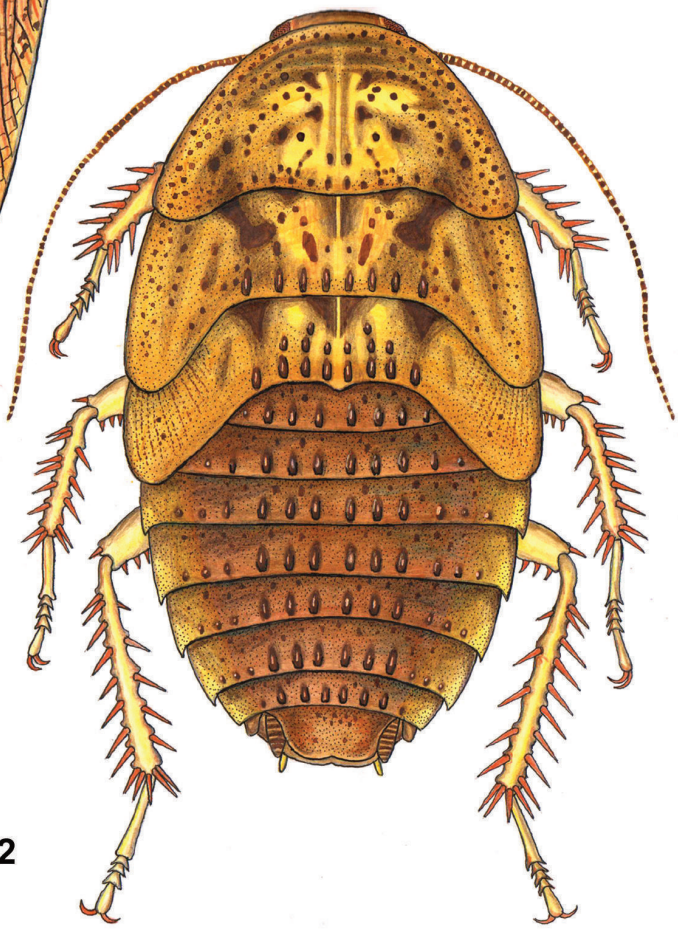


Plate 48: Blaberidae: *Rhicnoda natatrix*.

1



2

Plate 49: Blaberidae: *Rhicnoda rugosa*.

This locality of Sim-Khola is a natural forest stream in dense mixed forest dominated by *Quercus semecarpifolia* and *Pinus wallichiana*. Booth localities in the Pench National Park in Maharashtra are situated in dense pristine mixed forests (Jungle) of 450 meter altitude. All mentioned water bodies are representing undisturbed natural small to medium sized streams with water quality class I and I-II; and ecological river-quality 1.

Locality	*R. natatrix*	Biocoenotic Zone, Typology	Taxa No.	Water Quality Class NEPBIOS	Water Quality Class GRS-BIOS	Water Quality Class HKHBIOS	Locality No.
Sim Khola midstream	X	Metarhitron	29	I	I	I	54
First Tributary of Sim Khola	X	Epirhithron	42	I	I	I	55
Tributary of Ghatte Khola*	X	Epirhithron	10	I	I	I	Additional Sampling Site
Pench, forest spring stream	X	Hypocrenon	12	I	I	I	19
Ambakhori -Totladoah forest stream	X	Metarhithron-Hyporhithron	11	III	II	IV	20
Average			20.8	1.4	1.2	1.6	

Table 81: Characteristics of different stream habitats with *Rhicnoda natatrix* in Nepal and India. The lower number of taxa is caused by different time schedule, sampling methods, weather conditions and availability of preservation. One stream in Nepal marked with * was roughly sited during the Multi-habitat Sampling on August 13th, 2006 under cool, rainy weather and dark conditions. It is included here, because the locality (altitude: 1930 m asl., Rasuwa district) provides additional information for the Central Nepal region.

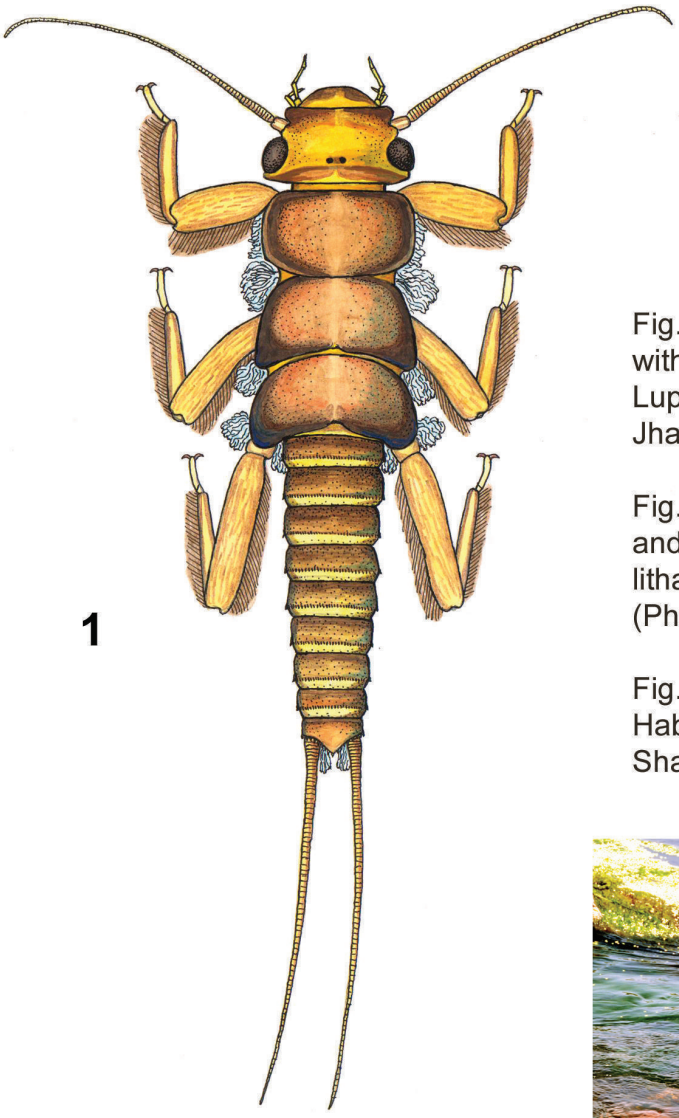
Ecological field-observations:

Aquatic cockroaches were observed numerously in the field. Due to their fast movement, specimens are difficult to collect by hand pick-up. Only a small reference material was preserved for further studies and identification.

*Rhicnoda natatr*ix was found benthic and under stones of the shoreline. Specimens were observed swimming and diving. They were moving quickly into and out of water during daytime. The micro-habitats are downstream from rapids and waterfalls. Only larvae and wingless (= aptery) females were seen. The winged (= macroptery) male specimen of *Rhicnoda rugosa* was collected from the shoreline outside the water under large boulders. The two species can be easily distinguished in the field by their dorsal color pattern. *Rhicnoda natatrix* is uniform-colored dark red-brown or pinkish brown. *Rhicnoda rugosa* has always a central metameric color pattern with light marginal fields and much darker median stripe. This is already visible in the larvae and allows readily making preliminary field identification.

The habitats of the two species are different but overlapping along the water courses. *Rhicnoda natatrix* appears aquatic to semi-aquatic species. *Rhicnoda rugosa* is a terrestrial species of humid forest habitats that can also enter semi-aquatic zones and tolerate short duration under water.

Plate 50: Perlidae: *Gibosia.*



1

Fig. 1: *Gibosia* spec.length 11.0 mm without cerci, Subernarekha River at Lupungdih d/s. Jamshedpur, Jharkhand, 116 m asl.

Fig. 2: Microhabitat, Lithal in Riffles and Rapids (Macrolithal, Mega-lithal, Gigalithal)
(Photo: Dr. Gopal Sharma).

Fig.3: River view of Lowland Habitat (Photo: Dr. Gopal Sharma).

3

2

References:

Allan, J.D. (1995): Stream Ecology – Structure and function of running waters. xii+388 pp., Chapman & Hall, London.

Amoros, C. and A. L. Roux (1988) Interactions between water-bodies within the floodplain of large rivers: function and development of connectivity. – Proceedings of the 2nd International Seminar of "International Association of Landscape Ecology" pp. 125-130.

Andrew, R. J. and T. R. Mitra (2008): Indian Odonatological Bibliography. – Occasional Publication by the South Asian Council of Odonatology (SACO), Hislop College, Nagpur, India. No. 1/2008 for the 18th International Symposium of Odonatology, Nagpur, India, pp. 1-40.

Andrew, R.J., Subramanian, K.A. and A.D. Tiple (2008): Common Odonates of Central India. The 18th Symposium of Odonatology, Hislop College, Nagpur, India, 5th-9th November 2008, Ebook, pp. 1-50.

Annandale, N. (1900): Notes on Orthoptera in the Siamese Malay State. – Entomological Records 12: 75.

Annandale, N. (1907): Notes on the Freshwater Fauna of India. No. III. An Indian Aquatic Cockroach and Beetle Larva. – Journal & Proceedings of the Asiatic Society of Bengal, New Series, Vol. 2 (4): 105-107.

Asahina, S. (1961a): Is Epiophlepia laidlawi Tillyard (Odonata, Anisozygoptera) a good species? – Internationale Revue der gesamten Hydrobiologie 46 (3): 441-446.

Asahina, S. (1961b): The Taxonomic Characteristics of the Himalayan Epiophlebia-Larva (Insecta, Odonata) – Proceedings of the Japanese Academy 37 (1): 42.

Aschauer, A.; Zieritz, I; Wimmer, R.; Deutsch, K. and A. Chovanec (2006): WGEV Datenband Fliessgewässer 2006, Methodik. 16 pp., Umweltbundesamt Wien. www.umweltbundesamt.at/fileadmin/site/umweltthemen/wasser/Datenband_FG06/1_Methodik.pdf

Bechly, G. (1999): Phylogeny and systematics of fossil dragonflies (Insecta: Odonatoptera) with special reference to some Mesozoic outcrops. Ph.D thesis, Eberhard-Karls-University Tübingen, x+755 pp., Tübingen.

Beier, M. (1967): Schaben (Blattariae). Die Neue Brehm-Bücherei. Heft 379: 1-38, A. Ziemsen Verlag, Wittenberg Lutherstadt.

Bishop, J.E. (1973): Limnology of a small Malayan River Sungai Gombak. – Monographiae Biologicae 22: 1-485, Dr. W. Junk B.V., Publishers, The Hague.

Blanford, W.T. (1870): Zoogeographical division of India, based to a great extent on a study on the distribution of land mollusca. – Journal of the Asiatic Society of Bengal 39 (2): 336.

Bohn, H. (2003): Ordnung Blattoptera, Schaben. – In: Dathe, H.H. (ed.): Lehrbuch der Speziellen Zoologie. Band 1: Wirbellose Tiere. 5. Teil: Insecta, pp. 197-223.

Bouchard, R.W., Jr. (2004): Guide to aquatic macroinvertebrates of the Upper Midwest. Water Resources Center, University of Minnesota, St. Paul, MN. 208 pp, Chapter 13 Diptera (Aquatic & Semiaquatic True Flies), pp. 159-183.

Cairns Jr., J. and J.R. Pratt (1993): A History of Biological Monitoring Using Benthic Macroinvertebrates, pp. 10-27, In: Rosenberg, D.M. and V.H. Resh (eds.): Freshwater Biomonitoring and Benthic Macroinvertebrates, ix+488 pp., Chapman & Hall, New York.

Chapman, D. (1992): Water Quality Assessment. A guide to the use of biota, sediments and water in environmental monitoring, xx+585 pp., Chapman & Hall, London.

Chaudhary, D.N., Singh, A.K. and G. Sharma (2008): Danapur Military Cantonment (IBA): The largest breeding site of Asian Openbill in Bihar. – MISTNET Indian Bird Conservation Network 9 (2): 6-8.

Chen, P.P., Nieser, N. And H. Zettel (2005): The aquatic and semi-aquatic bugs of Malesia. Fauna Malesiana handbooks: 5.

Chinery, M. (2004): Pareys Buch der Insekten, Kosmos Naturführer, pp. 1-327, Stuttgart, ISBN 3-440-09969-5.

Cook, C.D.K. (1996): Aquatic and Wetland Plants of India. A reference book and identification manual for the vascular plants found in permanent and seasonal fresh water in the subcontinent of India south of the Himalayas, iii+385 pp., Oxford University Press.

Dudegon, D. (1999): Tropical Asian Streams: Zoobenthos, Ecology and Conservation. Hong Kong University Press, HKU, pp. 291-316.

Evans, J.W. (1972): Fossil Insects. – Hunter Natural History 4 (2): 122-123.

Graf, W., Malicky, H. and A. Schmidt-Kloiber (2006): Key to Trichoptera (Caddisflies). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-56.

Graf, W., Sivec, I. and A. Schmidt-Kloiber (2006): Key to Plecoptera (Stoneflies). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-26.

Green, E.E. (1902): Aquatic Orthoptera in Ceylon. – Entomological Mon. Mag. 38: 214-215.

Grimaldi, D. and M.S. Engel (2005): Evolution of the Insects. – Cambridge Evolution Series No. 1, 772 pp.; Cambridge University Press.

Gullan, P.J. and P.S. Cranston (2005): The insects: An outline of entomology. With illustrations by K. Hansen McInnes. Insect Systematics: Phylogeny and Classification, pp. 177-200, Insect Biogeography and Evolution, pp. 201-216, Blackwell Publishing Ltd.

Hartmann, A. (2006): Key to Odonata (Dragonflies & Damselflies). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-13.

Hartmann, A. (2007): Field Key for selected Benthic Invertebrates from the HKH Region, Draft Version February 2007, 34 pp. ASSESS HKH, Vienna.

Hora, B. (1993): Bäume der Welt. Eine Enzyklopädie, 288 pp. DRW-Verlag Stuttgart, ISBN 3-87181-205-06.

Huber, T., Graf, W. and A. Schmidt-Kloiber (2006): Key to Coleoptera (Beetles). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-4.

Huber, T., Graf, W. and A. Schmidt-Kloiber (2006): Key to Heteroptera (Bugs). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-4.

Hutchinson, G.E. (1993): A treatise on Limnology. Volume 4. The zoobenthos. John Wiley & Sons, New York, Chichester etc. i-xx, 1-944, illustr.

Inoue, K. and M. Sugimura (2008): Vivid life of Dragonflies in high vision camera including the whole life history of the living fossil Epiophlebia superstes. – Abstract Papers XVIII Int. Symposium Odonatology, p. 32, Nagpur, India.

Jairajpuri, D.S. and M.S. Jairajpuri (1990): Promoting Taxonomy: Why and How? – Taxonomy in Environment & Biology: 129-132, Zoological Survey of India, Calcutta.

Janeček, B. (2006): Key to Diptera (Two-winged Flies). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-48.

Jha, B.R. (2006): Fish Ecological Studies and its Application in Assessing Ecological Integrity of Rivers in Nepal. Thesis Submitted in fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Environmental Science and Engineering, School of Science, Kathmandu University, xvii+301 pp.

Jha, B.R. and S. Aava (2008): Variation in time and gear in the fish assemblage of the rivers flowing through Chitwan National Park and its latest update. – In: Moog, O., Hering, D., Sharma, S., Stubauer, I. and T. Korte (eds.): Proceedings of the Scientific Conference Rivers in the Hindu Kush-Himalaya – The Ecology & Environmental Assessment, pp. 97-104. ISBN 978-3-00-024806-1.

Kawai, T. (2001): An Illustrated Book of Aquatic Insects of Japan. Tokai University Press.

Kawai, T. and T. Kazumi (2005): Aquatic Insects of Japan: Manual with Keys and Illustrations. Tokai University Press, 1342 pp.

Khanal, S. (2001) Effects of human disturbances in Nepalese rivers on benthic invertebrate fauna. - PhD Dissertation. – Applied Natural Science, Department of Sanitary Engineering and Water Pollution Control, Institute of Water Provision, Water Ecology and Waste Management, BOKU – University of Natural Resources and Applied Life Sciences, Vienna, Austria.

Kment, P. and Z. Jindra (2008): Review of the family Gelastocoridae (Heteroptera: Nepomorpha) of south-eastern Asia. – In: Grozeva, S. and N. Simov (eds): Advances in Heteroptera Research. Festschrift in Honour of 80th Anniversary of Michail Josifov: 189-213.

Lötschert, W. (1995): Palmen Botanik Kultur Nutzung, 2., durchgesehene und ergänzte Auflage, 139 pp. Ulmer, Stuttgart, ISBN 3-8001-6532-5.

Malz, H. and H. Schröder (1979): Fossile Libellen – biologisch betrachtet. – Kleine Senckenberg-Reihe Nr. 9: 1-46 (Fossil Dragonflies – Biological view [in German]).

Mandal, S.K. (2003): Insecta: Blattariae. – The Zoological Survey of India, State Fauna Series 9, Fauna of Sikkim (Part 2): 227-237.

Mandal, S.K. (2006): Blattaria (Dictyoptera). – The Zoological Survey of India, State Fauna Series 13 (Part-2), Fauna of Arunachal Pradesh: 175-190.

Mason, C.F. (1981): Biology of Freshwater Pollution. 250 pp., Longman, Harlow.

Meier, M. (1974): Blattariae (Schaben). – In: Beier, M. (ed.): Handbuch der Zoologie. Eine Naturgeschichte der Stämme des Tierreiches. IV. Band: Arthropoda – 2. Hälfte: Insecta, pp. 1-127, Berlin.

Menon, A.G.K. (1990): Zoogeography of India. – Taxonomy in Environment & Biology: 59-75, Zoological Survey of India, Calcutta.

Merritt, R.W. and K.W. Cummins (1996): An Introduction to the Aquatic Insects of North America, Third Edition, xiii+862 pp. Kendall/Hunt Publishing Company, Iowa, ISBN 0-7872-1761-1.

Mitra, A. (2005): Life history pattern and larval development of Neurothemis fulvia Drury (Odonata: Libellulidae) from Dehra Dun valley, India: A comparative analysis with two other species of the genus. – Ann. For. 13 (2): 311-322.

Mitra, A. (2006): Current Status of the Odonata of Bhutan: A Checklist with Four New Records. – Bhutan Journal RNR 2 (1): 136-143.

Mitra, A. (2007): Larval and Adult Behavioural Patterns of some Odonate Species from Dehradun Valley. – In: Tyagi, B.K. (ed.): Odonata: Biology of Dragonflies. Scientific Publishers (India), pp. 323-341.

Mitra, A. (2008): Dragonfly Fauna of Bhutan – An Annotated and updated Check-List with ten new records. – Abstract Papers XVIII Int. Symposium Odonatology, p. 39, Nagpur, India.

Mitra, A. and P. Thinley (2008): Odonata of the Bumdelling Wildlife Sanctuary, Trashi Yangtse, Eastern Bhutan with the Description of two new Species. – Abstract Papers XVIII Int. Symposium Odonatology, p. 40, Nagpur, India.

Mitra, T.R. (2003): Ecology and biogeography of Odonata with special reference to Indian fauna. – Records of the Zoological Survey of India, Occasional Paper No. 202: 1-41.

Mitra, T.R. (2003): Ecology and biogeography of Odonata with special reference to Indian Fauna. – Records of the Zoological Survey of India, Occasional Paper No. 202: 1-41+Plate 1-4.

Moog, O. 1991: Biologische Parameter zum Bewerten der Gewassergute von Fliebgewassern. Landschaftswasserbau 11, 235-266. TU Wien.

Moog, O. 1993: Makrozoobenthos als Indikator bei okologischen Fragestellungen. Landschaftwasserbau 15, 104-143, TU Wien

Moog, O. 1995: Fauna Aquatica Austriaca.- Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Wien.

Moog, O. 2002: Fauna Aquatica Austriaca, Edition 2002. – Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Vienna.

Morse, J.C., Yang, L. and L. Tian (2003): Aquatic Insects of China useful for Monitoring Water Quality, 570 pp. Hohai University Press, ISBN 7-5630-0240-5.

Nahar, S.C. (2004): Aquatic Insects. – Zool. Surv. India, State Fauna Series 11: Fauna of Bihar (Including Jharkhand), Part-1: 195-213, Kolkata.

Needham, J. G. and P. R. Needam (1984) A guide to the study of Fresh-Water Biology. Fifth edition, revised and enlarged, Holden-Day, Inc., Oakland, pp. 1-108.

Nel, A, and Y.A. Popov (2000): The oldest known fossil Hydrometridae from the Lower Cretaceous of Brazil (Heteroptera: Gerromorpha). – Journal of Natural History 34 (12): 2315-2322.

Nel, A. and A. Waller (2006): A giant water bug from the Lower Cretaceous Crato Formation of Brazil (Heteroptera: Belostomatidae: Lethocerinae). – Zootaxa 1220: 63-68.

Nel, A. and E.A. Jarzembowski (1996): Description and revision of the dragonflies ('Anisozygoptera') from the Lower Cretaceous of England (Odonata: Stenophlebiidae, Campterophlebiidae?, Epiophlebiidae, Euthemistidae). – Cretaceous Research 17 (1): 87-96.

Nesemann, H. (2006): Aquatic non-insect macro-invertebrate fauna and their role in bio-monitoring of the Ganga River System (With Illustrated Key Including 679 Figures). Dissertation Submitted for the partial fulfilment of the requirements for the Master of Science by Research degree in Environmental Science, Department of Environmental Science and Engineering, School of Science, Kathmandu University, 135 pp.+68 Plates.

Nesemann, H., Sharma, S., Sharma, G., Khanal, S.N., Pradhan, B., Shah, D.N. and R.D. Tachamo (2007): Aquatic Invertebrates of the Ganga River System: Volume 1 – Mollusca, Annelida, Crustacea (in part), 263 pp. Published by Hasko Nesemann, Kathmandu, Nepal, ISBN 978-99946-2-674-8.

Nesemann, H., Tachamo, R.D., Shah, D.N., Sharma, Subodh (2008): Morphological Development of Epiophlebia laidlawi, a Relict Himalayan Dragonfly. – Abstract Papers XVIII Int. Symposium Odonatology, p. 43, Nagpur, India.

Nesemann, H., Tachamo, R.D., Shah, D.N., Sharma, Subodh, Sharma, Gopal and R.K. Sinha (2008): Illustrated Larva Catalogue to the common Odonata Families of the Ganga River System, Northern Indian Subcontinent. – Abstract Papers XVIII Int. Symposium Odonatology, p. 45, Nagpur, India.

Ofenböck, T., Moog, O. and S. Sharma (2008): Development and application of the HKH Biotic Score to assess the river quality in the Hindu Kush-Himalaya region. – In: Moog, O., Hering, D., Sharma, S., Stubauer, I. and T. Korte (eds.): Proceedings of the Scientific Conference Rivers in the Hindu Kush-Himalaya – The Ecology & Environmental Assessment, pp. 17-32. ISBN 978-3-00-024806-1.

Okudaira, M., Sugimura, M., Ishida, S,, Kojima, K., Ishida, K., Aoki, T. (2005): Dragonflies of the Japanese Archipelago in Color. Hokkaido University Press.

Omair, M., Naylor, B. Wiley, M.J., Reddy, S.G., Sinha, R.K. and G. Sharma (2005): Biological and Chemical Characteristics of the River Ganga (Ganges). – The Journal of International Institute. The University of Michigan, Ann Arbor, Michigan, USA, 12: 16.

Pennak, R.W. (1978a): Fresh-Water Invertebrates of the United States, pp. 1-803, Chapter 28 Odonata (Dragonflies, Damselflies) pp. 551-566.

Pennak, R.W. (1978b): Fresh-Water Invertebrates of the United States, pp. 1-803, Chapter 29 Hemiptera (Bugs) pp. 567-585.

Polhemus, J.T. and D.A. Polhemus (2008): Global diversity of true bugs (Heteroptera; Insecta) in freshwater. – Developments in Hydrobiology, Volume 198: 379-391, Springer, Netherlands.

Popov, Y.A. (1971): Historical Development of the Hemipteran Infraorder Nepomorpha (Heteroptera). pp. 1-240, Proceedings of the Paleontological Institute of the USSR, Academy of Science, Moscow, Nauka Publishers [in Russian].

Popov, Y.A. (1992): Jurassic bugs (Hemiptera: Heteroptera) from the Museum of Natural History in Vienna. Die jurassischen Wanzen (Hemiptera: Heteroptera) des Naturhistorischen Museums in Wien. – Annalen des Naturhistorischen Museums in Wien 94 (A): 7-14.

Popov, Y.A. (1996a): The first record of a fossil water bug from the Lower Jurassic of Poland (Heteroptera: Nepomorpha: Belostomatidae). – Polish Journal of Entomology 65: 101-105.

Popov, Y.A. (1996b): The first find of a fossil water bug from the Lower Jurassic of Poland (Heteroptera: Nepomorpha: Belostomatidae). – Polskie Pismo Entomologiczne 66: 195-201.

Pradhan, B. (1998) Water Quality Assessment of the Bagmati River and Its Tributaries, Nepal. PhD Dissertation. – Applied Natural Science, Department of Sanitary Engineering and Water Pollution Control, Institute of Water Provision, Water Ecology and Waste Management, BOKU – University of Natural Resources and Applied Life Sciences, Vienna, Austria, 198 pp.

Prabhakar, A.K. and S.P. Roy (2008): Taxonomic diversity of shell fishes of Kosi region of North-Bihar. – The Ecoscan. An International Biannual Journal of Environmental Sciences 2 (2): 149-156, Ranchi.

Rai A.K. (2000): Limnological characteristics of subtropical Lakes Phewa, Begnas, and Rupa in Pokhara Valley, Nepal. Limnology **1**, 33-46.

Rai, A.K., Shrestha, B.C., Joshi, P.L., Gurung, T.B. and M. Nakanishi (1995): Bathymetric maps of Lakes of Phewa Lake, Pokhara, Nepal. – Memoirs of the Faculty of Science. Kyoto University (Series of Biology) 16: 49-54.

Resh, V.H. and J.K. Jackson (1993): Rapid Assessment Approaches to Biomonitoring Using Benthic Macroinvertebrates, pp. 195-223, In: Rosenberg, D.M. and V.H. Resh (eds.): Freshwater Biomonitoring and Benthic Macroinvertebrates, ix+488 pp., Chapman & Hall, New York.

Rozkosny, R. and K. Brabec (2006): Diptera. Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-8.

Sharma S. (1996) Biological assessment of water quality in the rivers of Nepal. PhD Dissertation. – Applied Natural Science, Department of Sanitary Engineering and Water Pollution Control, Institute of Water Provision, Water Ecology and Waste Management, BOKU – University of Natural Resources and Applied Life Sciences, Vienna, Austria, 257 + cxxxiv pp.

Sharma, S. (1998): An Inventory of Nepal's Aquatic Insects used as Biological Indicators of Water Pollution, 117 pp. Funded by University Grants Commission, New Beneshwar, Kathmandu.

Sharma, G., Sinha, R. K., Kumar, R. and D. K. Kedia (2008) Water Quality Vis-à-vis Zooplankton Diversity of Damodar River System in Jharkhand and West Bengal, India. Souvenir-08: 31-38, Ranchi.

Sharma, S. and O. Moog (2005) A reference based "Nepalese Biotic score" and its application in the midland hills and lowland plains for the river quality assessment and management. Ch. 41, pp 356-362, IBDC Book, Army Printing Press, Lucknow.

Sharma, S. and T. Ofenböck (1996): New Discoveries of Epiophlebia laidlawi Tillyard, 1921 in the Nepal Himalaya (Odonata, Anisozygoptera: Epiophlebiidae) – Opuscula zoologica fluminensia 150: 1-11.

Sharma, S., Moog, O., Nesemann, H. and B. Pradhan (2009): Application of Nepalese Biotic Score and its extension for river water quality management in Central Himalaya, pp. 1-10, Symposium on "Environment Energy and Water in Nepal: Recent Researches and Direction for Future" 31 March-01 April 2009, Kathmandu, Nepal.

Shcherbakov, D.E. (2008): On Permian and Triassic insect faunas in relation to biogeography and the Permian-Triassic crisis. – Paleontological Journal 42 (1): 15-31.

Shelford, R. (1907): Aquatic Cockroaches. – Zoologist (London) 1907: 221-226.

Shelford, R. (1909): Notes on some amphibious cockroaches. – Records of the Indian Museum 3: 125-127, Calcutta.

Shelling, A.A. (2009): An Australian Fossil Insect Bed Resulting from Cataclysmic Destruction. – Institute for Creation Research. http://www.icr./article/australian-fossil-insect-bed-resulting-fro-catacl (assessed April 29, 2009).

Sinha, R.K. and G. Sharma (2001): The gastropod Stenothyra ornate Annandale and Prashad, 1921, A New Record From River Ganga in Bihar. – Journal of the Bombay Natural History Society, 98 (3): 485-487.

Sinha, R.K. and G. Sharma (2003a): Current status of Ganges dolphin, Platanista gangetica in River Son and Kosi in Bihar. – Journal of the Bombay Natural History Society, 100 (1): 27-37.

Sinha, R.K. and G. Sharma (2003b): Faunal diversity of the River Sarda, Uttar Pradesh, India. – Journal of Ecophysiology and Occupational Health. 3 (2003): 103-116.

Sinha, R.K. Prasad, K., Sharma, G. and R. Dalwini (2001): Ecological Restoration of the River Ganga. – International Journal of Ecology and Environmental Science 27: 127-135.

Sinha, R.K., Das, N.K., Singh, N.K., Sharma, G. and S.N. Ashan (1993): Gut content of the Gangetic dolphin, Platanista gangetica. – Investigation of Cetacea XXIV: 317-321.

Sinha, R.K., Das, N.K., Singh, N.K., Sharma, G. and S.N. Ashan (1992): Food and feeding – behaviour of the Gangetic dolphin, Platanista gangetica. – Proc. Sum. Inst. On Breeding Management and Disease Control of Wild Animals. BVC, RAU, Patna: 461-466.

Sinha, R.K., Nesemann, H. and G. Sharma (2003): New records of Physa (Gastropoda: Physidae) from Indian subcontinent. – Club Conchylia Informationen 34 (5/6): 3-11, Vienna and Ludwigsburg.

Sinha, R.K., Smith, B.D., Sharma, G. Prasad, K., Choudhury, B.C., Sapkota, K., Sharma, R.K. and S.K. Behera (2000): Status and Distribution of the Ganges Susu (Platanista gangetica) in the Ganges River System of India and Nepal. – Biology and Conservation of Freshwater Cetaceans in Asia. – In: Reeves, R.R., Smith, B.D. and T. Kasuya (eds.): Occasional Papers of the IUCN Species Survival Commission, Gland, Switzerland, 23: 54-61.

Soldán, T. and E. Bauernfeind (2006): A key to larvae of families, subfamilies and genera of mayflies (order Ephemeroptera) of Indian Subcontinent (except for Sri Lanka). Regional capacity building workshop on Macro-invertebrate Communities to evaluate the ecological status of rivers in the Hindu Kush Himalayan Region. August 20th to September 9th 2006, Kathmandu University, Dhulikhel, Nepal, pp. 1-36.

Srivastava, V.D. (1990): Taxonomy of Freshwater Insects. – Taxonomy in Environment & Biology: 257-269, Zoological Survey of India, Calcutta.

St. Quentin, D. and M. Beier (1968): Odonata (Libellen). – In: Beier, M. (ed.): Handbuch der Zoologie. Eine Naturgeschichte der Stämme des Tierreiches. IV. Band: Arthropoda – 2. Hälfte: Insecta, 2. Teil: Spezielles 4 (2) 2/6: 1-39, Berlin.

Storrs, A. and J. Storrs (1998): Trees & Shrubs of Nepal and the Himalayas. xxiv+367 pp. Book Faith India, Delhi, ISBN 81-7303-098-7.

Subba Rao, N.V. (1990): Taxonomy and Evolution. – Taxonomy in Environment & Biology: 85-97, Zoological Survey of India, Calcutta.

Subramanian, K.A., Ali, S. and Ramachandra, T.V. (2008): Odonates as Indicators of Riparian Ecosystem health – A Case Study from South Western Karnathaka, India. – Abstract Papers XVIII Int. Symposium Odonatology, p. 59, Nagpur, India.

Takahashi, R. (1921): Orthoptera and water. – Transactions of the Sapporo Natural History Society 8: 85-100.

Thapa, V.K. (2000): An Inventory of Nepal's Insects, Volume III (Hemiptera, Hymenoptera, Coleoptera & Diptera). IUCN Nepal Biodiversity Publication Series: 4, xi+471 pp. + IV maps, ISBN 92-9144-049-3.

The Ohio State University (2001): Largest Fossil Cockroach found; site preserves incredible detail. – Research News, Nov. 7, 2001, The Ohio State University. http://researchnews.osu.edu/archive/bigroachpics.htm

Thirumalai, G. (2001): Insecta: Aquatic and Semi-Aquatic Hemiptera. – Zoological Survey of India, Conservation Area Series 11, Fauna of Nilgiri Biosphere Reserve: 111-127.

Thirumalai, G. (2007): A Synoptic List of Nepomorha (Hemiptera: Heteroptera) from India. – Records of the Zoological Survey of India, Occasional Paper No. 273: 1-84.

Thirumalai, G. and R. Suresh Kumar (2006): Insecta: Hemiptera (Aquatic and Semi Aquatic). – Zoological Survey of India, Conservation Area Series 27, Fauna of Biligiri Rangaswamy Temple Wildlife Sanctuary: 59-82.

Thirumalai, G. and R.M. Sharma (2005): Insecta: Hemiptera (Aquatic and Semi Aquatic). – Zoological Survey of India, Conservation Area Series 24, Fauna of Melghat Tiger Reserve: 341-357.

Thirumalai, G., Sharma, R.M. and K. Chandra (2007): A Checklist of Aquatic and Semiaquatic Hemiptera (Insecta) of Madhya Pradesh. – Records of the Zoological Survey of India 107 (Part-4): 71-91.

Thirumalai, G., Sharma, R.M. and M.P. Sreedharan Namboodiri (2006): Insecta: Aquatic and Semi-Aquatic Hemiptera. – Zoological Survey of India, Conservation Area Series 25, Fauna of Tadoba Tiger Reserve: 233-253.

Thirumalai, G., Suresh Kumar, R. and R.M. Sharma (2004): Insecta: Aquatic and Semi-Aquatic Hemiptera. – Zoological Survey of India, Conservation Area Series 20, Fauna of Pench National Park: 233-250.

Tillyard, R.J. (1921): On an Anisozygopterous larva from the Himalayas (Order Odonata). – Records of the Indian Museum 22: 93-109 + plate XIII

Trueman, J.W.H. and R. J. Rowe (2001): Odonata. Dragonflies and damselflies. Version 01 January 2001. http://tolweb.org/Odonata/8266/2001.01.01 in The Tree of Life Web Project, http://tolweb.org/

Van Tol, J. (2008): Catalogue of the Odonata of the World. National Museum of Natural History (Naturalis), Leiden. The Netherlands, http://www.odonata.info

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing 1980: The River Continuum Concept. – Canadian Journal of Fisheries and Aquatic Sciences 37 (1): 130-137.

Vick, G.S. (1989): List of the dragonflies recorded from Nepal, with a summary of their altitudinal distribution (Odonata). Opusc. Zool. Flumin. 43, 1-21.

Walker, I.R. (1993): Paleolimnological Biomonitoring Using Freshwater Benthic Macroinvertebrates, pp. 306-343, In: Rosenberg, D.M. and V.H. Resh (eds.): Freshwater Biomonitoring and Benthic Macroinvertebrates, ix+488 pp., Chapman & Hall, New York.

Wallace, A.R. (1876): Geographical Distribution of Animals. 2 Vols., Hafner Publishing Co., London New York.

Ward, J.V. (1992): Aquatic Insect Ecology. 1. Biology and Habitat. John Wiley & Sons, Inc. New York, pp. 1-438.

Welch, E.B. and T. Lindell (1992): Ecological effects of Wastewater. Applied limnology and pollutant effects. 2nd eds., x+425 pp., Chapman & Hall, London etc.

Wichard, W., Arens, W. and G. Eisenbeis (1995): Atlas zur Biologie der Wasserinsekten. Gustav Fischer, Jena.

Xylander, W.E.R. and K.K. Günther (2003): Ordnung Odonata, Libellen. – In: Dathe, H.H. (ed.): Lehrbuch der Speziellen Zoologie. Band 1: Wirbellose Tiere. 5. Teil: Insecta, pp. 121-142.

Yule, C.N. and Y. Hoi Sen (2004): Freshwater Invertebrates of the Malaysian Region. pp. 1-860, Selangor.

Zessin, W. (2008): Overview of the Dragonflies of the Palaezoic. – Abstract Papers XVIII Int. Symposium Odonatology, p. 79, Nagpur, India.

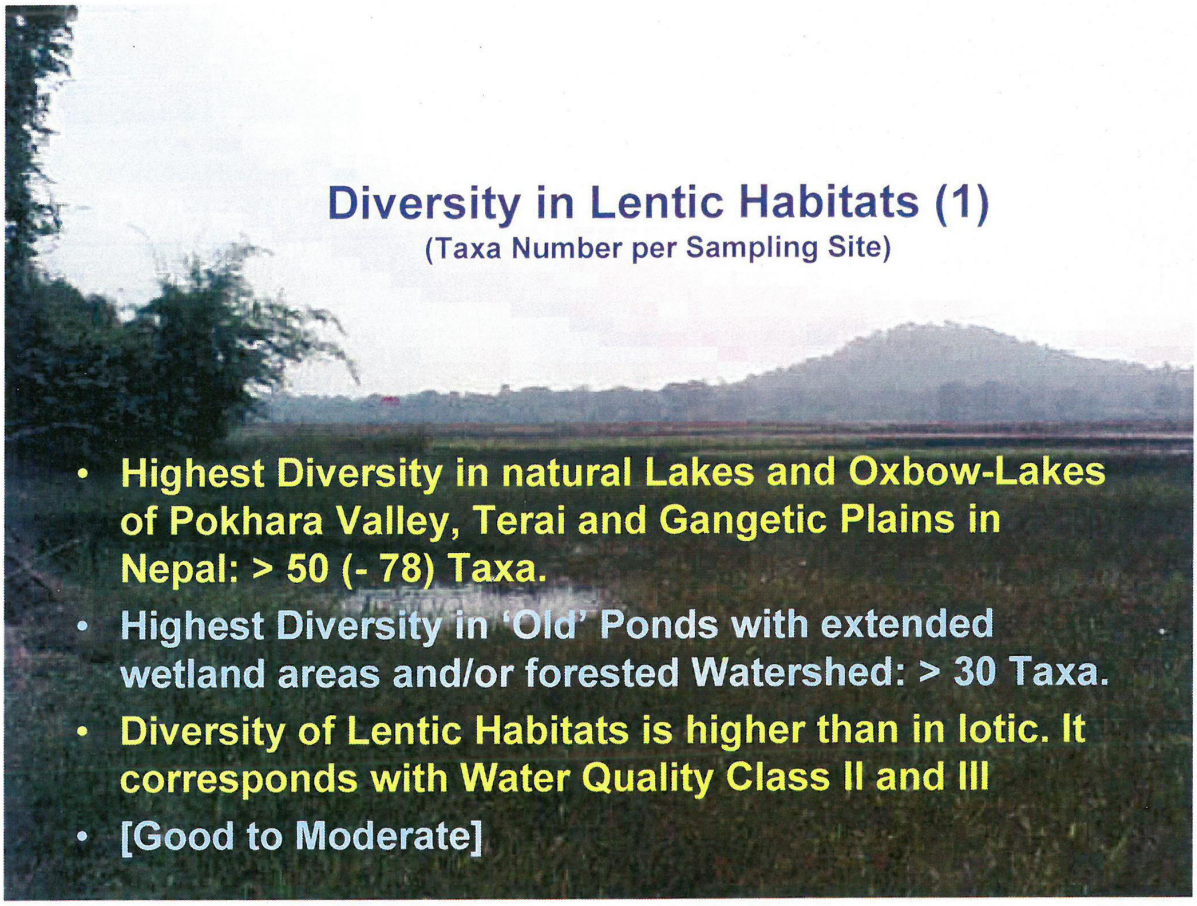
Zessin, W. (2008): Some Aspects concerning the Biology of Palaeozoic Dragonflies (Odonatoptera). – Abstract Papers XVIII Int. Symposium Odonatology, p. 77, Nagpur, India.

Zessin, W. (2008): The oldest Dragonflies (Odonatoptera). – Abstract Papers XVIII Int. Symposium Odonatology, p. 78, Nagpur, India.

Zhang, Junfeng (2000): The discovery of aeschnidiid nymphs (Aeschnidiidae, Odonata, Insecta). – Chinese Science Bulletin 45 (11): 1031-1038.

Zhang, Junfeng and Haichun Zhang (2001): New findings of larval and adult aeschnidiids (Insecta: Odonata) in the Yixian Formation, China. – Cretaceous Research 22 (4): 443-450.

Summarized Results and Conclusions



Diversity in Lentic Habitats (1)

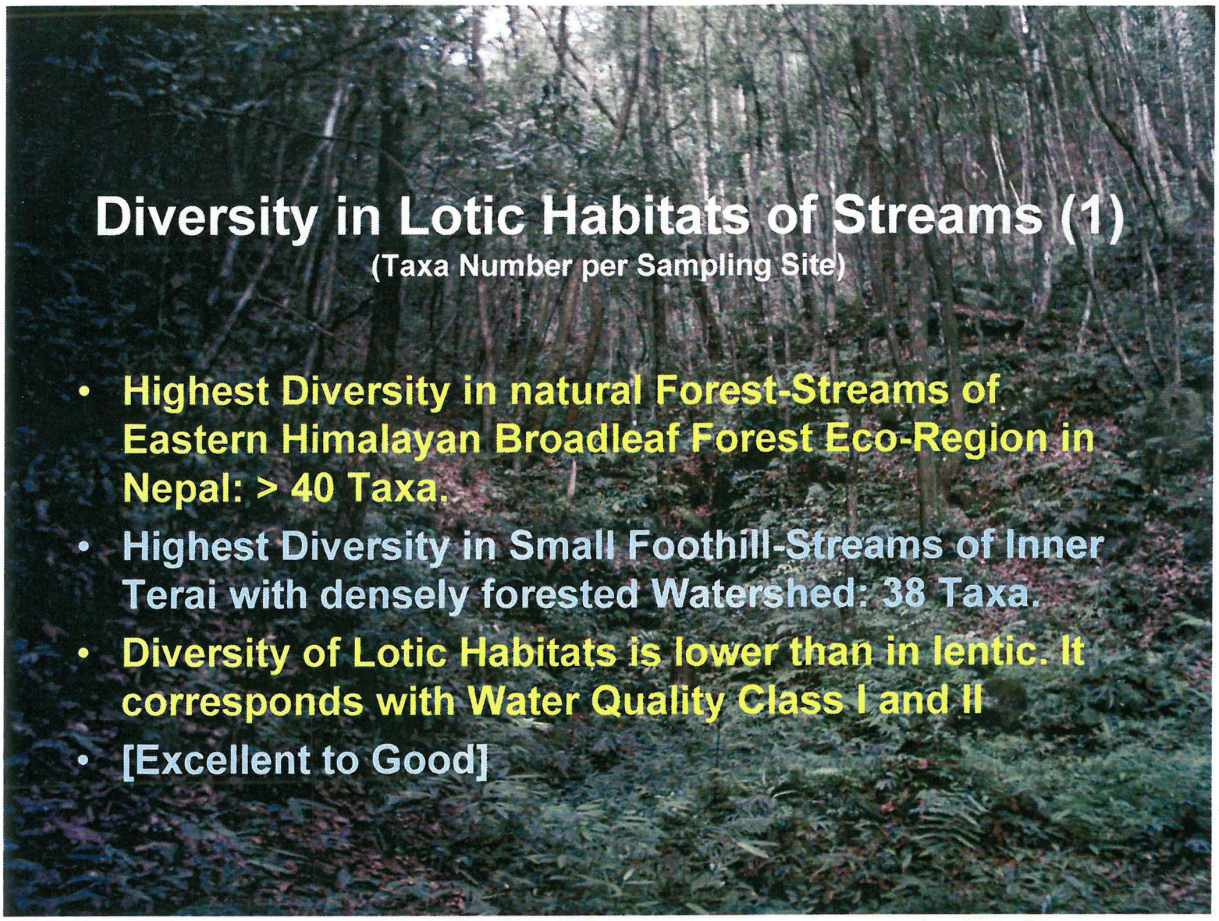
(Taxa Number per Sampling Site)

- Highest Diversity in natural Lakes and Oxbow-Lakes of Pokhara Valley, Terai and Gangetic Plains in Nepal: > 50 (- 78) Taxa.
- Highest Diversity in 'Old' Ponds with extended wetland areas and/or forested Watershed: > 30 Taxa.
- Diversity of Lentic Habitats is higher than in lotic. It corresponds with Water Quality Class II and III
- [Good to Moderate]

Diversity in Lentic Habitats (2)

Sampling Sites with highest number of identified Taxa

Identified Taxa	Sampling Site	Typology	Ecological Quality Class NEPBIOS ASPT Value	Ecological Quality Class GRS-BIOS ASPT Value	Ecological Quality Class HKHBIOS ASPT Value
78	Phewa Tal including connected wetlands	Large Eulimnion + Littoral	III Moderate (4.53)	II Good (5.439)	III Moderate (4.71)
67	Bishazari Tal Chitwan	Plesiopotamon	II Good (5.07)	II Good (5.56)	II Good (5.42)
56	Jagadishpur Reservoir Kapilvastu Dist.	Plesiopotamon	III Moderate (4.42)	III Moderate (4.42)	II Good (5.13)
38	Taudaha Large Pond, Kirtipur Monsoon	'Old' Pond + Swamps, Littoral	II Good (5.125)	II Good (5.21)	III Moderate (4.65)
33	Khapaudi, Phewa Chisapani	Large Eulimnion + Littoral	III Moderate (4.46)	II Good (5.125)	III Moderate (4.85)
31	Tahoba Large Pond + Wetlands	'Old' Pond + Swamps, Littoral	III Moderate (4.529)	III Moderate (4.76)	II Good (5.57)



Diversity in Lotic Habitats of Streams (1)

(Taxa Number per Sampling Site)

- Highest Diversity in natural Forest-Streams of Eastern Himalayan Broadleaf Forest Eco-Region in Nepal: > 40 Taxa.
- Highest Diversity in Small Foothill-Streams of Inner Terai with densely forested Watershed: 38 Taxa.
- Diversity of Lotic Habitats is lower than in lentic. It corresponds with Water Quality Class I and II
- [Excellent to Good]

Diversity in Lotic Habitats of Streams (2)

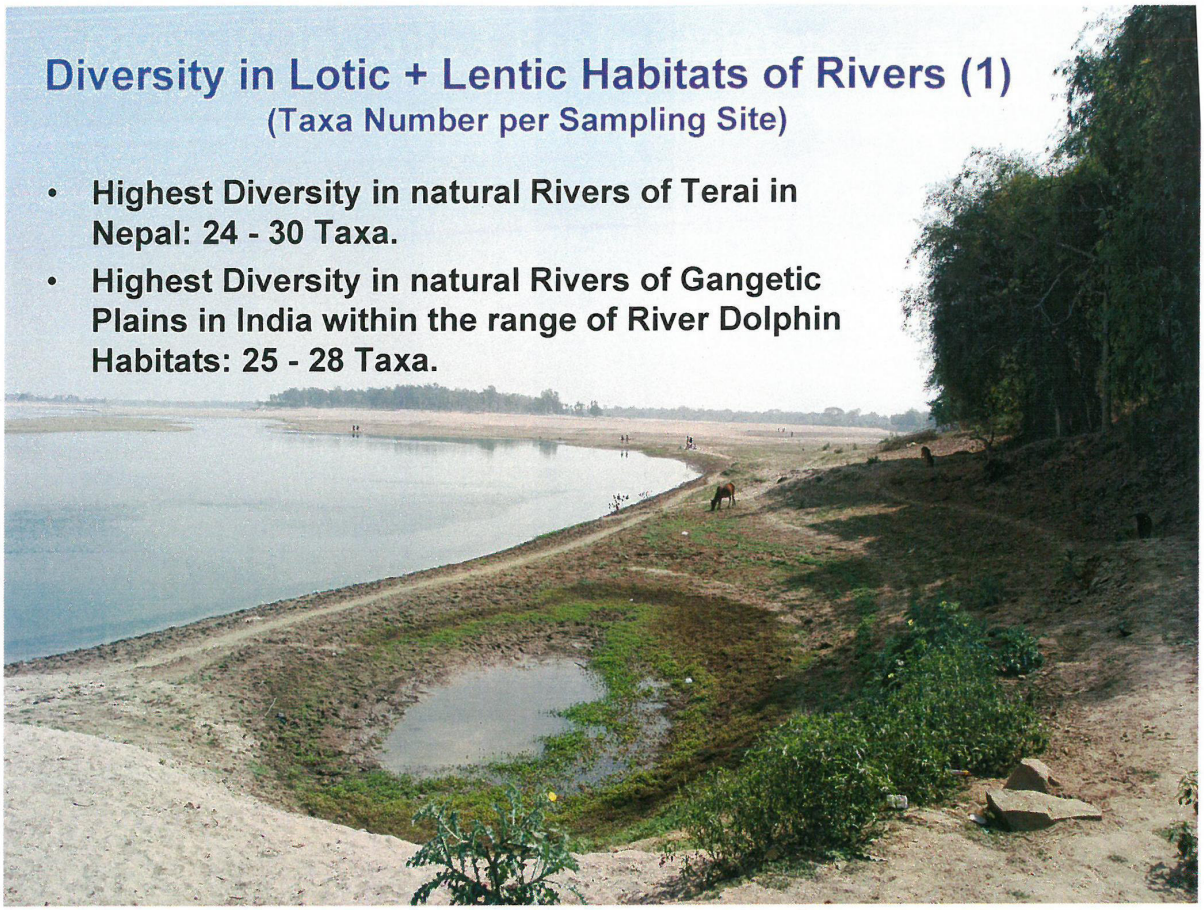
Sampling Sites with highest number of identified Taxa

Identified Taxa	Sampling Site	Typology	Ecological Quality Class NEPBIOS ASPT Value	Ecological Quality Class GRS-BIOS ASPT Value	Ecological Quality Class HKHBIOS ASPT Value
42	First Tributary of Sim-Khola	Epirhithron	I Excellent (6.96)	I Excellent (7.10)	I Excellent (7.15)
40	Sim-Khola below Simbhanjyang	Metarhithron	I Excellent (7.18)	I Excellent (7.16)	I Excellent (7.26)
38	Ghatte Khola, Hetauda	Hyporhithron/ Epipotamon	II Good (5.28)	II Good (5.18)	II Good (5.68)
31	Middle Simbhanjyang Khola	Metarhithron	I Excellent (7.13)	I Excellent (7.04)	I Excellent (7.59)
29	Sim-Khola, (midstream)	Metarhithron	I Excellent (7.72)	I Excellent (7.65)	I Excellent (8.33)
28	Third Tributary of Sim-Khola	Epirhithron	I Excellent (7.50)	I Excellent (6.95)	I Excellent (7.43)

Diversity in Lotic + Lentic Habitats of Rivers (1)

(Taxa Number per Sampling Site)

- Highest Diversity in natural Rivers of Terai in Nepal: 24 - 30 Taxa.
- Highest Diversity in natural Rivers of Gangetic Plains in India within the range of River Dolphin Habitats: 25 - 28 Taxa.



Diversity in Lotic + Lentic Habitats of Rivers (2)

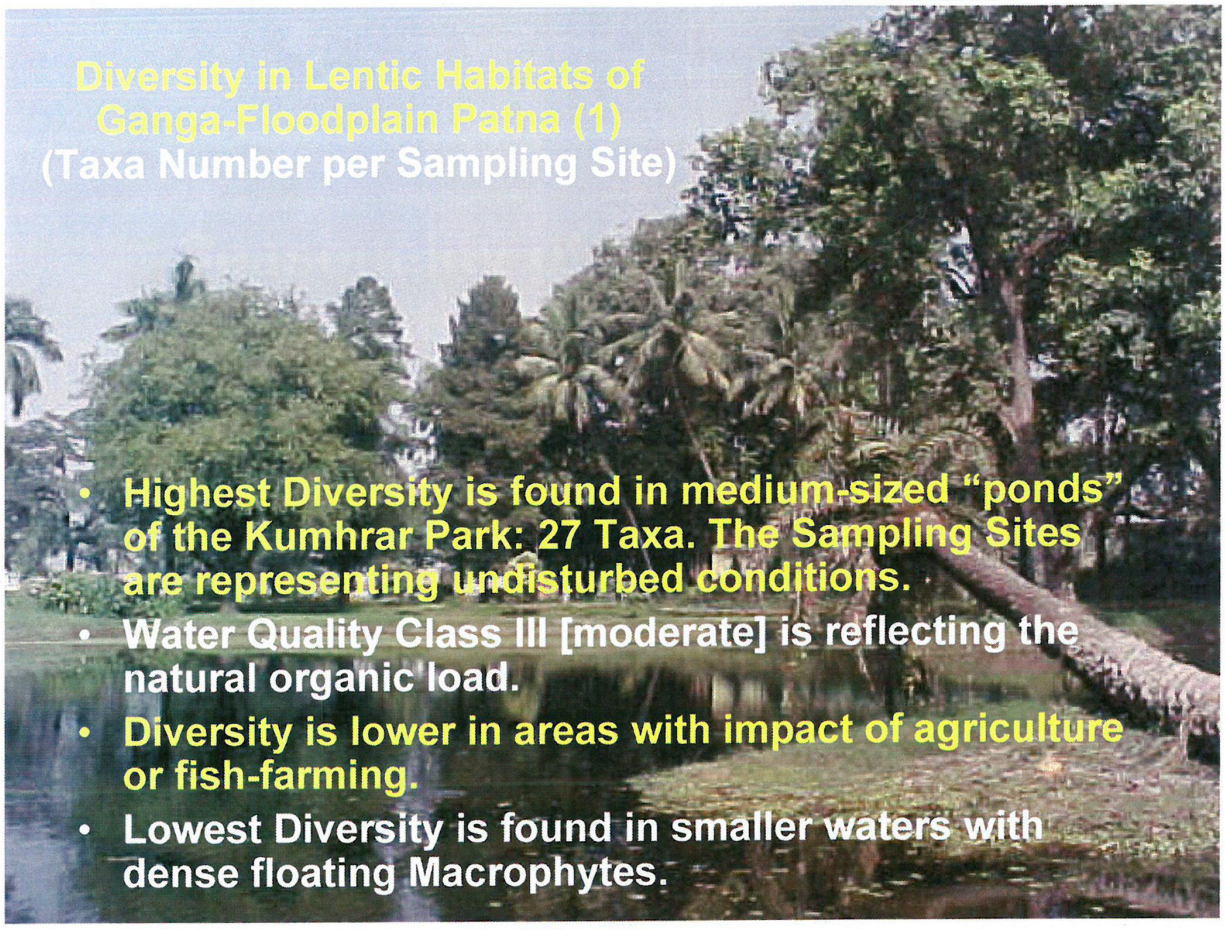
(Taxa Number and Water Quality Class)

- Diversity is lower in Gangetic Plains than in Terai. It reflects the naturally more uniform substrate dominated by Psammal, Pelal and Silt.
- High Diversity of Rivers is not clearly corresponding with any particular Water Quality Class.
- Sampling Sites with highest Diversity are representing Water Quality Classes I, II and III.
- [Excellent , Good, Moderate]

Diversity in Lotic + Lentic Habitats of Rivers (3)

Sampling Sites with highest number of identified Taxa

Identified Taxa	Sampling Site	Typology	Ecological Quality Class NEPBIOS ASPT Value	Ecological Quality Class GRS-BIOS ASPT Value	Ecological Quality Class HKHBIOS ASPT Value
30	Karnali River, Chisapani	Large Hyporhithron	I Excellent (6.57)	I Excellent (6.00)	I Excellent (7.28)
28	Ganga River, lentic. Pelal Chunarghat	Metapotamon	III Moderate (4.00)	II Good (5.52)	III Moderate (4.54)
27	Punpun River Phytal, lentic Gaurichak	Metapotamon	III Moderate (4.94)	II Good (5.428)	III Moderate (4.91)
26	Ganga River, Patna, Old Palace, Lithal	Metapotamon	III Moderate (4.36)	II Good (5.79)	III Moderate (4.73)
25	Punpun River Psammal, Pelal Gaurichak	Metapotamon	III Moderate (4.80)	II Good (5.20)	III Moderate (4.54)
24	Karnali River, Manau Ghat	Epipotamon	I Excellent (6.00)	II Good (5.66)	I Excellent (7.58)



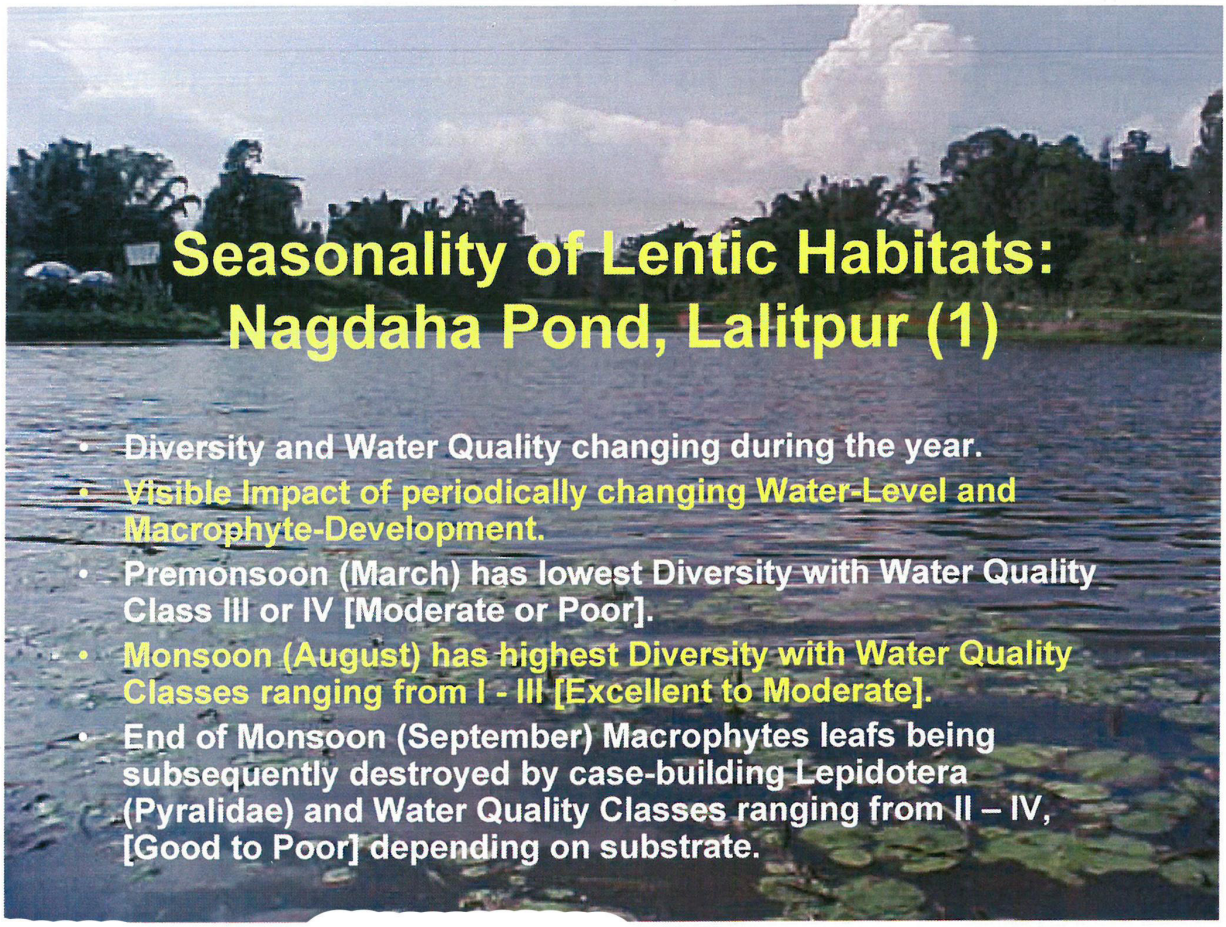
Diversity in Lentic Habitats of Ganga-Floodplain Patna (1)
(Taxa Number per Sampling Site)

- Highest Diversity is found in medium-sized "ponds" of the Kumhrar Park: 27 Taxa. The Sampling Sites are representing undisturbed conditions.
- Water Quality Class III [moderate] is reflecting the natural organic load.
- Diversity is lower in areas with impact of agriculture or fish-farming.
- Lowest Diversity is found in smaller waters with dense floating Macrophytes.

Diversity in Lentic Habitats of Ganga-Floodplain (2)

Sampling Sites with highest number of identified Taxa

Identified Taxa	Sampling Site	Typology	Ecological Quality Class NEPBIOS ASPT Value	Ecological Quality Class GRS-BIOS ASPT Value	Ecological Quality Class HKHBIOS ASPT Value
27	Kumhrar "Bivalvia"pond	Wetland. Plesio-Potamon	III Moderate (4.50)	III Moderate (4.66)	III Moderate (4.40)
27	Kumhrar, Central *Phonix sylvestris* pond	Wetland. Plesio-Potamon	III Moderate (4.83)	III Moderate (4.85)	III Moderate (4.53)
19	Fishpond north of Pahari	Wetland. Plesio-Potamon	III Moderate (4.36)	III Moderate (4.76)	IV Poor (3.94)
18	Wetland-Channel at Pahari	Wetland. Paleo-Potamon	IV Poor (3.81)	III Moderate (4.60)	IV Poor (3.54)
18	Bairia *Eichhornia crassipes* pond	Wetland. Paleo-Potamon	III Moderate (4.55)	III Moderate (4.57)	IV Poor (3.75)
8	Bairia, *Trapa natans* pond	Wetland. Paleo-Potamon	II Good (5.00)	II Good (5.00)	IV Poor (3.63)



Seasonality of Lentic Habitats: Nagdaha Pond, Lalitpur (1)

- Diversity and Water Quality changing during the year.
- Visible Impact of periodically changing Water-Level and Macrophyte-Development.
- Premonsoon (March) has lowest Diversity with Water Quality Class III or IV [Moderate or Poor].
- Monsoon (August) has highest Diversity with Water Quality Classes ranging from I - III [Excellent to Moderate].
- End of Monsoon (September) Macrophytes leafs being subsequently destroyed by case-building Lepidotera (Pyralidae) and Water Quality Classes ranging from II – IV, [Good to Poor] depending on substrate.

Seasonality of Lentic Habitats: Nagdaha Pond, Lalitpur (2)

Sampling Date	Identified Taxa	Habitat Type Choriotope Substrate	Ecological Quality Class NEPBIOS ASPT Value	Ecological Quality Class GRS-BIOS ASPT Value	Ecological Quality Class HKHBIOS ASPT Value
02. March 2007	13	Psammal Phytal	III Moderate (4.00)	IV Poor (3.80)	IV Poor (3.82)
03. July 2007	24	Pelal, Lithal Phytal	III Moderate (4.37)	I Excellent (6.56)	II Good (5.14)
19. August 2007	28	Pelal, Lithal Phytal	III Moderate (4.64)	II Good (5.08)	III Moderate (4.05)
09. September 2008	17	Macrolithal, Megalithal	III Moderate (4.46)	II Good (5.14)	II Good (4.87)
09. September 2008	18	Psammal, Phytal	IV Poor (3.55)	III Moderate (4.75)	III Moderate (4.07)
09. September 2008	25	Pelal, Phytal	III Moderate (4.06)	III Moderate (4.59)	III Moderate (4.48)

Aquatic Insecta in Lowlands, Stagnant waters and Middle Mountains

What is new?

- 27 families with 60 taxa of Odonata, Heteroptera and Blattodea described and figured.
- Identification characters and ecological habitat observations.
- First key based on material mainly from Nepal and India for the Ganges River Basin.

Summary

1. Highest Diversity in Lentic Habitats of Orientalis followed by Streams of Middle Mountains with Palearctic Impact and densely forested Watershed.

2. Maximum Diversity per Sampling Site in Water Quality Class II and III in Lentic Habitats: Eulimnion and Plesiopotamon.

3. Maximum Diversity per Sampling Site in Water Quality Class I in Lotic Habitats: Epirhithron and Metarhithron.

4. Maximum Diversity per Sampling Site in Water Quality Class II and III in Gangetic Plain Rivers: Metapotamon.

5. First identification Materials for three taxonomical Units of the Study Area on Family and Genus Level: Aquatic Stages of Odonata, Heteroptera, Blattodea.

Thanks and Acknowledgements to:

- Kathmandu University, Nepal
- Patna University, India
- Tribuvan University, Nepal
- BOKU University, Austria
- Natural History Museum Vienna, Austria
- Senckenbergmuseum Frankfurt Main, Germany

APPENDIX

Curriculum vitae

Name: Hasko Friedrich Nesemann

Nationality: European Union, Federal Republic of Germany

Date and place of birth: 27. 07. 1964, Höchst am Main, Hessen, Germany

Matural status: unmarried

Parents: Dr. Georg Nesemann, Microbiologist, Annemarie Nesemann

School education: Primary school: Volksschule Lorsbach im Taunus, Grammar school: Main-Taunus-Gymnasium Hofheim am Taunus. School-leaving examination: 2.6. 1983

Practica period: March-April 1980, Natural History Museum Senckenberg, Frankfurt am Main, Malacological Department.

Vocational Training: Agriculture, 1983-1985 in Osterstedt (Schleswig-Holstein) and Butjadingen (Niedersachsen), vocational school and final examination: 15. July 1985

Military service duty: 1986-1987 (15 month) in Wetzlar (Hessen).

Study: 1985 Agriculture, Technical University Munich (Bavaria), 1986 Agriculture, University of Agricultural Sciences BOKU, Vienna, Austria, 1995 Study of "Applied hydrobiology and zoology" University of Agricultural Sciences BOKU, Vienna, Austria, 2001-2009 Environmental Science at Kathmandu University, Dhulikel, Nepal in Collaboration with Patna University (Bihar) India.

Acadamic Degrees: 2004 Bachelor of Science (B.Sc. Honors) 2006 Master of Science by Research (M.S.), 2009 Doctor of Philosophy (Ph.D.) in Environmental Sciences at Kathmandu University, Dhulikhel, Nepal.

Occupational activities:

November 1989- August 2001: Assistant at the Department for Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences BOKU, Vienna, Austria.
October 2001-June 2004, October 2008-June 2009: Research Scholar at the Department of Zoology, Environmental Biology Laboratory, Patna University, Patna (Bihar) India.
July 2004-April 2007: Research Scholar at the Department of Biological and Environmental Sciences, Kathmandu University, Dhulikhel, Nepal.

Dhulikhel, Nepal 4. August 2009

Hasko Friedrich Nesemann