Mamta Rawat · Sumit Dookia
Chandrakasan Sivaperuman *Editors*

Aquatic Ecosystem: Biodiversity, Ecology and Conservation

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Preface

The total water resources of the earth equal to 326 million cubic mile; only 2–5 % of water is fresh water, 97.5 % is salt water. Almost 69 % of fresh water resources are tied in glaciers and ice caps, about 30 % is ground water and a mere 0.27 % is surface water. Water resources are important for the survival of the planet. Aquatic biodiversity is one of the most essential characteristic of the aquatic ecosystem for maintaining its stability and means of coping with any environmental changes.

India is one of the 17 "megadiverse" countries and is composed of a diversity of ecological habitats like forests, grasslands, wetlands, deserts, and coastal and marine ecosystems. From the biodiversity point of view, India is regarded as a mega diversity country. Out of the total estimated species of the world, about 8.4 million species are reported from India. India has a wealth of wetland ecosystems distributed in different geographical regions. Most of the wetlands in India are directly or indirectly linked with major river systems such as the Ganges, Cauvery, Krishna, Godavari and Tapti. India has total of 27,403 wetlands, of which 23,444 are inland wetlands and 3,959 are coastal wetlands. Wetland systems directly and indirectly support lakhs of people, providing goods and services to them. They help check floods, prevent coastal erosion and mitigate the effects of natural disasters like cyclones and tidal waves. They store water for long periods.

Biodiversity and conservation are the key concepts in ecology during the past decades and are considered important elements in elucidating the dynamics of ecosystems disturbed by human activities. Our aquatic ecosystem comprises a major regime due to its diversity, thus needs special attention and conservation approaches. The lakes, marshes, river systems and other wetlands in the country are under threat mainly due to domestic pollution from untreated sewage, industrial pollutant and toxic effluents. India is facing an alarming danger to the loss of aquatic biodiversity, and about 55 % of aquatic species are threatened.

This book is a result of detailed observation by reputed researchers working in the field of aquatic biodiversity in India. There are 19 chapters, and each effort has been made by an expert or professional in their respective fields. The book offers novel information on aquatic biodiversity of India. We sincerely hope that this book will provide the much needed information in the field of aquatic biodiversity conservation.

Jodhpur, India — Mamta Rawat
New Delhi, India — Sumit Dookia
Port Blair, Andaman & Nicobar Islands, India — Chandrakasan Sivaperuman

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About the Editors

Dr. Sumit Dookia M.Sc., Ph.D. is working as Assistant Professor at Guru Gobind Singh Indraprastha University, New Delhi. His doctoral research work is on the Ecology of Chinkara from Great Indian Desert. He worked as research fellow at Zoological Survey of India, Jodhpur, in the research project titled "Studies on faunal communities of Great Indian Desert". He also worked in Satpura-Maikal landscape, particularly in Kanha, Pench and Satpura Tiger Reserve in Madhya Pradesh with Project Tiger Directorate, New Delhi, and Wildlife Institute of India, Dehra Dun. He authored more than 40 research papers, in journals, chapters in books, symposium and conferences.

Dr. Mamta Rawat M.Sc. Ph.D., Scientist and Head, Water and Health Program, Ecology and Rural Development Society, Jodhpur, Rajasthan, is actively engaged in research activities on various health and environmental issues of the Great Indian Desert of Rajasthan since 1999. Apart from this she has keen interest in the area of groundwater contaminations, eco-toxicology, water pollution, ecological engineering and wastewater treatment. She has received Fast Track Young Scientist Fellowship in the year 2005 from the Department of Science and Technology, Government of India. Dr. Rawat is associated with various professional and scientific societies. Presently she is an editorial board member of the *Indian Journal of Environment and Fisheries*. She has published more than 35 research papers in peer-reviewed national and international journals, conferences, seminars and symposiums, and published two books.

Dr. C. Sivaperuman M.Sc., D.B.T., Ph.D. is working as Scientist-D in Zoological Survey of India, Port Blair. He received his Master Degree in Wildlife Biology from Bharathidasan University, Tamil Nadu. His doctorate degree is in Ecology of Wetland Birds in the Vembanad-Kole Ramsar site from (Kerala Forest Research Institute, Kerala) Forest Research Institute, Deemed University, Dehra Dun. He has worked in different parts of the country in various ecosystems, which include Kerala, Rajasthan and Andaman and Nicobar Islands. He has published more than 180 research papers in national and international journals and newsletters. He also authored/edited more than 20 books in his credit. He participated and presented research papers in 40 national and international seminars and symposiums. He is life member of different scientific societies in India and other countries.

Distribution of Aquatic Macrophytes in Balasore District, Odisha

1

K.A. Sujana, R. Saravanan, and Amit Diwakar Pandey

Abstract

The qualitative survey was conducted from July 2013 to June 2014 in different aquatic environment in Balasore district of Odisha, eastern India. A total of 132 species including 129 flowering plants and 3 Pteridophyte taxa spread in 82 genera and 41 families were recorded. The most speciose families were Cyperaceae with 27 species followed by Poaceae (24). The other dominant families are Linderniaceae, Fabaceae, Onagraceae, Polygonaceae, Commelinaceae, and Scrophulariaceae. Reclamation of land and changes in land use pattern are the most serious problems observed from the study sites. Abundant growth of various macrophytes including grasses and sedges provides great value of ecological and economic importance.

Keywords

Aquatic macrophytes • Balasore • Distribution • Odisha

Introduction

Macrophytes colonize many different types of aquatic ecosystems, such as lakes, reservoirs, wetlands, streams, rivers, marine environments, and even rapids and falls. This variety of colonized environments results from a set of adaptive strategies achieved over evolutionary time. Primary production of macrophytes can surpass that of other aquatic primary producers (Wetzel 2001; Kalff 2002). Macrophytes generally colonize shallow ecosystems where they become important components, influencing ecological processes, and they support many life-forms including several vascular hydrophytes. The value of an aquatic environment is often ignored, and many of the world's aquatic environments have been drained and converted for other profitable uses (Gopal and Zutchi 1998; UNEP-DEWA 2004; Srivastava et al. 2008). Many of these ecosystem harbors several kinds of economically useful macrophytes. Their ecological value is yet to be estimated. Studies on aquatic

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macrophytes in coastal Odisha are very sporadic and requires immediate attention. Rivers, soil moisture, and relatively shallow groundwater basins are the principal sources of water for human (Gleick 1996). One percent of the world's surface is covered by various freshwater habitats including the seasonally flooding rice paddies (Balian et al. 2008). They support life of 7 % of the estimated 1.8 million described species (Melzer 1999), including 25 % of the estimated vertebrates. Aquatic macrophytes can be used as a tool in the determination of pollution and nutrient level (Clayton and Edwards 2006), water quality and lake condition (Palmer and Bell 1992), trophic status of lakes (McCutcheon and Schnoor 2003), pollutant degradation (Nahlik and Mitsch 2006), and decontaminate wastewater (Cook 1996; Nichols 1991). Urbanization, industrialization, and bursting human population are the major threats to the freshwater ecosystem. Human interference is the main reason for the shrinkage of surface area and reduction of mean depth of the lakes of Balasore district of Odisha. For the first time, we present the aquatic macrophyte wealth of Balasore district of Odisha state, India.

Methods

Qualitative floristic survey was made in different aquatic environment including lentic (pools, ditches, lakes), lotic (streams, rivers), and wetlands seasonally through regular field visit during July 2013–June 2014 to record the aquatic macrophytic wealth of Balasore district. Angiosperm and Pteridophyte macrophytes were observed and collected including submerged, submerged anchored and floating-leaved anchored, emergent anchored, and free floating. The collected plant specimens were identified and confirmed with regional floras and regional checklist for hydrophytes. Binomial and author citation of all collected hydrophytes were checked with International Plant Names Index (http://www.ipni.org/ipni/plantnamesearchpage.do). Voucher specimens were deposited in Herbarium of Central Botanical Laboratory, Howrah.

Results and Discussion

Aquatic ecosystems perform many important environmental functions. They recycle nutrients, purify water, attenuate floods, recharge groundwater, and provide habitats for wildlife (Melzer 1999). Aquatic ecosystems are also used for human recreation and are very important to the tourism industry, especially in coastal regions. From this study, a total of 132 species including 129 flowering plants and 3 Pteridophyte species spread in 82 genera and 41 families were recorded (Table 1.1). The most speciose families were Cyperaceae with 27 species followed by Poaceae (24 taxa), Linderniaceae (7 taxa), and 5 species each for Fabaceae, Onagraceae, and Polygonaceae. Commelinaceae and Scrophulariaceae were represented by four species each. For 19 families like Alismataceae, Aizoaceae, Aponogetonaceae, Ceratophyllaceae, Sphenocleaceae, and Typhaceae, only one species each was recorded. Species richness and abundance appears to be influenced by seasonal variations. In rainy season (July–September), 112 species were collected, whereas in summer season (April–June), as many as 28 species were recorded. *Cyperus bulbosa*, *Cyperus rotundus*, *Ludwigia adscendens*, and *Ludwigia perennis* mostly grow during summer in low-depth areas near the embankment. Some species such as *Lemna gibba*, *Pistia stratiotes, Eicchorna crassipes*, and *Salvinia molesta* showed the seasonal appearance. Among 132 plant recorded, 117 taxa (89 %) are herbaceous plants. Eight shrubs (e.g., *Acanthus ilicifolius*, *Aeschynomene aspera*, *Sonneratia caseolaris*), four trees (e.g., *Barringtonia acutangula*, *Excoecaria agallocha*, *Talipariti tiliaceum*), and three climbing plants (e.g., *Dalbergia candenatensis*, *Derris scandens*, *Derris trifoliata*) were also collected from the study sites which distributed to the banks of rivers, bunds of paddy fields, and mangrove forests. Most of the species are distributed widely, and none of the endemic species or narrowly distributing plants are collected.

Data on freshwater ecosystem, inhabiting lifeforms, and species distribution and richness and comprehensive taxonomical and ecological information are needed to assess the impacts of

Table 1.1 List of aquatic macrophytes distributed in Balasore district of Odisha

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
1.	*Acanthus ilicifolius* L.	Acanthaceae	Mangrove forests and marshy areas along backwaters	Shrub	Indo-Malesia and Australia	Chandipur
2.	*Aeschynomene aspera* L.	Fabaceae	Marshes, paddy fields, and banks of ponds	Shrub	Indo-Malesia	Balramgadi
3.	*Alloteropsis cimicina* (L.) Stapf	Poaceae	Margins of wetlands and forests, moist and dry deciduous forests, roadsides, and wastelands	Herb	Paleotropics	Mirzapur
4.	*Alternanthera philoxeroides* (Mart.) Grisb.	Amaranthaceae	Shallow water pools, ditches, and marshes and mangroves	Herb	Native of South America, now established in Indo-Malesia and Australia	Chandipur
5.	*Alternanthera sessilis* (L.) R. Br. ex. DC.	Amaranthaceae	Along sides of water courses and marshy areas	Herb	Pantropical	Nilgiri
6.	*Apluda mutica* L.	Poaceae	Moist and waste places	Herb	Tropical Asia and Australia	Nilgiri
7.	*Aponogeton natans* (L.) Engl. Krause	Aponogetonaceae	Ponds and paddy fields	Herb	Indo-Malesia to Australia	Naupalgadi
8.	*Arundo donax* L.	Poaceae	Along banks of streams and backwaters	Herb	Mediterranean region eastwards to North Africa, India-Pakistan, introduced into many parts of world	Chandipur
9.	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	Dry and moist deciduous forests, wastelands, and paddy fields	Herb	Tropics and subtropics	Balramgadi
10.	*Azolla pinnata* R. Br.	Salviniaceae	Ponds and paddy fields	Herb	Pantropical	Naupalgadi
11.	*Bacopa monnieri* (L.) Pennell	Scrophulariaceae	Ponds and paddy fields	Herb	Paleotropics	Naupalgadi
12.	*Barringtonia acutangula* (L.) Gaertn.	Lecythidaceae	Along riverbanks and water courses	Herb	Indo-Malesia to Australia	Nilgiri
13.	*Brachiaria mutica* (Forssk.) Stapf	Poaceae	Shallow water, banks of stream, backwaters and rivers	Herb	Native of America, widespread in all tropical regions	Chandipur
14.	*Bulbostylis barbata* (Rottb.) Kunth ex Clarke	Cyperaceae	Near banks of streams, sandy, and wastelands	Herb	Paleotropics and southern USA	Barnuguna chauk
15.	*Canscora diffusa* (Vahl) R. Br. Ex Roem & Schult	Gentianaceae	Along streamsides	Herb	Tropical Africa, Asia, and Australia	Jodachua
16.	*Centella asiatica* (L.) Urban	Apiaceae	Wet places in the plains	Herb	Tropical Asia and Africa	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
17.	*Centipeda minima* (L.) A. Braun & Asch.	Asteraceae	Paddy fields and along river banks	Herb	Indo-Malesia	Barnuguna chauk
18.	*Ceratophyllum demersum* L.	Ceratophyllaceae	Small ditches and ponds at lowlands, sometimes in brackish water	Herb	Cosmopolitan	Barnuguna chauk
19.	*Chloris barbata* Sw.	Poaceae	Degraded forests, wastelands, and riversides	Herb	Native of tropical Africa, spread to other tropical countries	Patrapoda
20.	*Clerodendrum inerme* (L.) Gaertn.	Verbenaceae	Scrub jungles and mangroves	Shrub	Coastal India, Sri Lanka, now naturalized on the shores of Myanmar, Australia, and China	Chandipur
21.	*Colocasia esculenta* (L.) Schott in Schott & Endl.	Araceae	Waterlogged ditches and streamside	Herb	Pantropical	Kuldiha
22.	*Commelina benghalensis* L.	Commelinaceae	Wastelands, also in deciduous forests	Herb	Africa, India, China, Japan, and Malesia	Nilgiri
23.	*Commelina clavata* C.B. Clarke	Commelinaceae	Wastelands, also in deciduous forests	Herb	Africa, India, China, Japan, and Malesia	Nilgiri, Patrapoda
24.	*Cyanotis axillaris* (L.) D. Don ex Sweet	Commelinaceae	Waterlogged ditches and streamside	Herb		Chandipur
25.	*Cynodon dactylon* (L.) Pers.	Poaceae	Along banks of backwaters, bunds of paddy fields, and wastelands	Herb	Tropical and warm temperate regions of the world	Jampara
26.	*Cyperus articulatus* L.	Cyperaceae	Marshy areas	Herb	Pantropics	Barnuguna chauk
27.	*Cyperus bulbosus* Vahl	Cyperaceae	Sandy beaches, riversides, and marshy fields	Herb	Tropical Africa, Southern Asia, Malesia, and Northern Australia	Chandipur
28.	*Cyperus cephalotes* Vahl	Cyperaceae	Permanent pools and streams	Herb	Indo-Malesia and China to Australia	Barnuguna chauk
29.	*Cyperus compressus* L.	Cyperaceae	Along banks of streams and watercourses and wastelands	Herb	Pantropical	Barnuguna chauk
30.	*Cyperus corymbosus* Rottb.	Cyperaceae	Along banks of streams	Herb	Pantropical	Barnuguna chauk
31.	*Cyperus difformis* L.	Cyperaceae	Marshy areas and paddy fields	Herb	Tropical, Subtropical, and temperate regions of the world	Karanjja

32.	*Cyperus digitatus* Roxb.	Cyperaceae	Marshy fields	Herb	Pantropical	Barnuguna chauk
33.	*Cyperus distans* L. f.	Cyperaceae	Along banks of streams, also in wastelands and roadsides	Herb	Pantropical	Chandipur
34.	*Cyperus imbricatus* Retz.	Cyperaceae	Wetlands	Herb	Pantropical	Kuldiha
35.	*Cyperus iria* L.	Cyperaceae	Degraded deciduous forests, marshy areas, and paddy fields	Herb	Tropical Asia and East Africa, introduced in the USA and West Indies	Kuldiha
36.	*Cyperus javanicus* Houtt.	Cyperaceae	Marshy areas in degraded forests and mangrove forests, also in the plains	Herb	Pantropical	Barnuguna chauk
37.	*Cyperus malaccensis* Lam.	Cyperaceae	Banks of backwaters and ponds and mangrove forests	Herb	Paleotropics	Barnuguna chauk
38.	*Cyperus pangorei* Rottb.	Cyperaceae	Grasslands, river banks and pools	Herb	India, Sri Lanka, Nepal and Myanmar	Barnuguna chauk
39.	*Cyperus tenuispica* Steud.	Cyperaceae	Along streams, paddy fields, and marshy areas	Herb	Tropical and subtropical Africa and Asia	Haldipada
40.	*Dactyloctenium aegyptium* (L.) P. Beauv.	Poaceae	Marshy lands and open areas	Herb	Native of South America, naturalized in Paleotropics	Nilgiri
41.	*Dalbergia candenatensis* (Dennst.) Prain	Fabaceae	Mangrove swamps	Climber	Indo-Malesia, China, and Australia	Balramgadi
42.	*Derris scandens* (Roxb.) Benth.	Fabaceae	Deciduous forests, also in mangrove forests and sacred groves	Climber	Indo-Malesia	Kuldiha
43.	*Derris trifoliata* Lour.	Fabaceae	Along banks of backwaters and mangrove forests	Climber	Paleotropics	Bhitarkanika
44.	*Echinochloa colona* (L.) Link.	Poaceae	Marshes and bunds of paddy fields	Herb	Tropical Asia and Africa	Naupalgadi
45.	*Echinochloa crus-galli* (L.) P. Beauv.	Poaceae	Marshy fields	Herb	India, Southeast Asia, and Africa	Balramgadi
46.	*Echinochloa stagnina* (Retz.) P. Beauv.	Poaceae	Marshy areas	Herb	Tropical Asia and Africa	Barnuguna chauk
47.	*Eclipta prostrata* (L.) L., Mant.	Asteraceae	Paddy fields and moist localities	Herb	Pantropical	Naupalgadi
48.	*Eichhornia crassipes* (Mart.) Solms. in A. & C. DC.	Pontederiaceae	Ponds and wet lowlands	Herb	South America, now naturalized in the Paleotropics	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
49.	*Eleocharis acutangula* (Roxb.) Schult.	Cyperaceae	Marshy areas in grasslands	Herb	Pantropical	Balramgadi
50.	*Eleocharis dulcis* (Burm. f.) Trimen ex Hensch.	Cyperaceae	Marshy areas and mangroves	Herb	Paleotropics	Balramgadi
51.	*Eleocharis spiralis* (Rottb.) Roem. & Schult.	Cyperaceae	Wet areas in grasslands and mangroves	Herb	Paleotropics	Naupalgadi
52.	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae	Streams, banks of backwaters, and waste places	Herb	Southeast Asia, India, and Africa	Naupalgadi
53.	*Excoecaria agallocha* L.	Euphorbiaceae	Banks of backwaters and mangrove forests	Tree	Indo-Malesia to Australia and Pacific islands	Balramgadi
54.	*Fimbristylis argentea* (Rottb.) Vahl	Cyperaceae	Wet or moist sandy grounds, grasslands and in rice fields	Herb	South and Southeast Asia	Balramgadi
55.	*Floscopa scandens* Lour.	Commelinaceae	Marshy areas	Herb	Indo-Malesia	Kuldiha
56.	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Marshy areas in grasslands and paddy fields	Herb	Pantropical	Balramgadi
57.	*Glinus oppositifolius* (L.) A. DC.	Molluginaceae	Open areas, lakeshores, and stream banks	Herb	Pantropical	Balramgadi
58.	*Heliotropium indicum* L.	Boraginaceae	Along lakeshores and paddy fields during summer	Herb	Pantropical	Balramgadi
59.	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	Stagnant ponds	Herb	Asia, Europe, and Africa	Balramgadi
60.	*Hydrolea zeylanica* (L.) Vahl	Hydrophyllaceae	Wet sandy areas near water bodies	Herb	Pantropical	Karanja
61.	*Hygrophila schulli* (Buch.-Ham.) M. R. & S. M. Almeida	Acanthaceae	Paddy fields and other moist localities	Herb	India, Myanmar, and Indo-China	Balramgadi
62.	*Ipomoea aquatica* Forssk.	Convolvulaceae	Ponds and lakes	Herb	Pantropics	Balramgadi
63.	*Ipomoea carnea* Jack. ssp. *fistulosa* (Mart. ex Choisy) Austin	Convolvulaceae	In marshy areas along the banks of streams and paddy fields, also grown as hedge plant	Shrub	Native of America, now Pantropical	Panchalingeswar
64.	*Isachne globosa* (Thunb.) O. Ktze.	Poaceae	Wetlands	Herb	Tropical Asia	Balramgadi
65.	*Isachne miliacea* Roth	Poaceae	Marshy fields, wetlands, along the streams, and paddy fields	Herb	India, China and Southeast Asia	
66.	*Ischaemum indicum* (Houtt.) Merr.	Poaceae	Moist areas	Herb	America, Australia, and Southeast Asia	Balramgadi
67.	*Kandelia candel* (L.) Druce	Rhizophoraceae	Mangrove swamps	Tree	Indo-Melasia and China	
68.	*Kyllinga bulbosa* P. Beauv.	Cyperaceae	Marshy areas	Herb	Paleotropics	Balramgadi

69.	*Kyllinga brevifolia* Rottb. var. *stellulata* (Sur.) Hooper in Saldanha & Nicolson	Cyperaceae	Forest margins	Herb	Indo-Malesia and Australia	Naupalgadi
70.	*Kyllinga bulbosa* P. Beauv	Cyperaceae	Marshy areas, wastelands, and roadsides	Herb	Paleotropics	Naupalgadi
71.	*Kyllinga nemoralis* (J. R & G. Forst.) Dandy ex Hutch. & Dalz.	Cyperaceae	Waste places, degraded forest areas, and grasslands	Herb	Pantropical	Balramgadi
72.	*Kyllinga odorata* Vahl ssp. *cylindrica* (Nees ex Wight) Koyama	Cyperaceae	Marshy areas in degraded deciduous forests, also in the plains	Herb	Paleotropics	Naupalgadi
73.	*Lemna gibba* L.	Lemnaceae	Stagnant waters	Herb	Cosmopolitan	Naupalgadi
74.	*Limnophila aquatica* (Roxb.) Alston	Scrophulariaceae	Flooded paddy fields, ponds, etc	Herb	Indo-Malesia and East and South China	Naupalgadi
75.	*Limnophila chinensis* (Osbeck) Merr.	Scrophulariaceae	Water logged areas	Herb	Paleotropics	Naupalgadi
76.	*Limnophila indica* (L.) Druce	Scrophulariaceae	Along banks of streams and marshy areas	Herb	Pantropical	Naupalgadi
77.	*Limnophyton obtusifolium* (L.) Miq.	Alismataceae	Marshy areas	Herb	Pantropical	Naupalgadi
78.	*Lindernia anagallis* (Burm. f.) Pennell	Linderniaceae	Banks of streams and marshy areas	Herb	Indo-Malesia	Balramgadi
79.	*Lindernia antipoda* (L.) Alston in Trimen	Linderniaceae	Sides of streams, reservoirs and marshy areas	Herb	Tropical and subtropical Asia and Australia	Balramgadi
80.	*Lindernia crustacea* (L.) F.v. Muell.	Linderniaceae	Moist deciduous forests and wastelands	Herb	Africa, America, and tropical and subtropical Asia	Balramgadi
81.	*Lindernia hyssopioides* (L.) Haines	Linderniaceae	Marshy areas	Herb	Southeast Asia, Malesia, and China	Naupalgadi
82.	*Lindernia ruellioides* (Colsm.) Pennell	Linderniaceae	Wet areas in semievergreen forests, also in the plains	Herb	Tropical and subtropical Asia	Balramgadi
83.	*Lindernia tenuifolia* (Colsm.) Alston in Trimen	Linderniaceae	Along banks of backwaters and mangroves	Herb	Indo-China and Indo-Malesia	Balramgadi
84.	*Lindernia viscosa* (Hornem.) Merr.	Linderniaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia and China	Kuldiha
85.	*Lobelia alsinoides* Lam.	Campanulaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia	Pancharjuna Nalla
86.	*Lobelia heyneana* Schult.	Campanulaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia, China, and Africa	Kuldiha

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
87.	*Ludwigia adscendens* (L.) H. Hara	Onagraceae	Ponds and ditches	Herb	Continental Asia, Malesia, and Australia	Kuldiha
88.	*Ludwigia hyssopifolia* (G. Don) Exell	Onagraceae	Marshy places	Herb	Pantropical	Kuldiha
89.	*Ludwigia octovalvis* (Jacq.) P.H. Raven	Onagraceae	Marshy places	Herb	Pantropical	Kuldiha
90.	*Ludwigia perennis* L.	Onagraceae	Waterlogged areas in grasslands	Herb	Tropical Africa, Asia, and Australia	Chandipur
91.	*Ludwigia peruviana* (L.) H. Hara	Onagraceae	Marshy areas	Shrub	Originally from America, now naturalized throughout the Old World	Panchalingeswar
92.	*Marsilea polycarpa* Hook. & Grev.	Marsileaceae	Pools and streams	Herb	Pantropical	Chandipur
93.	*Monochoria vaginalis* (Burm. f.) Presl	Pontederiaceae	Paddy fields and wet lowlands	Herb	India to China, Malesia, and Japan	Chandipur
94.	*Najas graminea* Del.	Najadaceae	Pools and streams	Herb	Pantropical	Chandipur
95.	*Najas indica* (Willd.) Cham.	Najadaceae	Streams, ditches, and ponds	Herb	Tropical Asia and Africa	Chandipur
96.	*Nelumbo nucifera* Gaertn.	Nelumbonaceae	Freshwater ponds and lakes, also grown as an ornamental plant	Herb	South and East Asia to far eastern Russia and to Australia	Balramgadi
97.	*Nymphaea nouchali* Burm. f.	Nymphaeaceae	Ponds and pools in plains	Herb	Indo-Malesia and tropical Africa	Balramgadi
98.	*Nymphaea pubescens* Willd.	Nymphaeaceae	Freshwater pools, lakes, and flooded paddy fields	Herb	Indo-Malesia	Naupalgadi
99.	*Nymphaea rubra* Roxb. ex Salisb.	Nymphaeaceae	Ponds	Herb	Native of Europe	Naupalgadi
100.	*Nymphoides hydrophylla* (Lour.) O. Ktze	Menyanthaceae	Ditches and ponds	Herb	Indo-Malesia and South China	Jaleswar
101.	*Oryza rufipogon* Griff.	Poaceae	Marshy grasslands	Herb	India, Sri Lanka, and tropical Australia	Balramgadi
102.	*Oryza sativa* L.	Poaceae	Cultivated	Herb	Widely cultivated	Balramgadi
103.	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae	Ponds and streams	Herb	Indo-Malesia to Pacific Islands and East Asia	Naupalgadi
104.	*Pandanus fascicularis* Lam.	Pandanaceae	Mangrove forests and sea coasts	Shrub	Tropical and subtropical Asia	Naupalgadi
105.	*Panicum repens* L.	Poaceae	Wetlands, marshy areas of grasslands, and wastelands	Herb	Tropics and subtropics of both hemispheres	Balramgadi

106.	*Paspalum scrobiculatum* L.	Poaceae	Marshes, ponds, wetlands, and other waterlogged areas	Herb	India and Pakistan	Mirzapur
107.	*Persicaria barbata* (L.) H. Hara	Polygonaceae	Along streamsides	Herb	Paleotropics	Balramgadi
108.	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	Moist localities in semievergreen forests	herb	Pantropical	Kuldiha
109.	*Persicaria pulchra* (Blume) Soják	Polygonaceae	Marshy areas	Herb	Indo-Malesia and Africa	Balramgadi
110.	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Mangrove swamps and marshy areas	Herb	Paleotropics	Naupalgadi
111.	*Phyla nodiflora* (L.) Greene	Verbenaceae	Coastal sandy areas, paddy fields, and streamsides	Herb	Tropics and subtropics	Naupalgadi
112.	*Pistia stratiotes* L.	Araceae	Ponds and tanks	Herb	Tropics and subtropics	Karanja
113.	*Polygala arvensis* Willd.	Polygalaceae	Moist deciduous forests, also in the plains	Herb	Indo-Malesia to Australia	Kuldiha
114.	*Polygala chinensis* L.	Polygalaceae	Moist deciduous forests, also in the plains	Herb	Indo-Malesia and China	Balramgadi
115.	*Polygonum barbatum* L.	Polygonaceae	Along streamsides	Herb	Paleotropics	Balramgadi
116.	*Polygonum pubescens* Blume	Polygonaceae	Marshy areas	Herb	Indo-Malesia and East Asia	Jodachua
117.	*Pycreus polystachyos* (Rottb.) P. Beauv.	Cyperaceae	Marshy areas in grasslands	Herb	Widely distributed in the tropical and subtropical regions	Naupalgadi
118.	*Sacciolepis interrupta* (Willd.) Stapf	Poaceae	Wetlands	Herb	Tropics of Southeast Asia and Africa	Balramgadi
119.	*Salvinia molesta* D. S. Mitchell	Salviniaceae	Ponds and streams	Herb	Pantropical	Naupalgadi
120.	*Schoenoplectiella articulata* (L.) Lye	Cyperaceae	Marshy areas in grasslands and wet fallow fields	Herb	Indo-Malesia	Naupalgadi
121.	*Sesbania javanica* Miq.	Fabaceae	Bunds of paddy fields	Shrub	India	Balramgadi
122.	*Sesuvium portulacastrum* (L.) L.	Aizoaceae	Near mangrove swamps along sea coasts	Herb	Pantropical	Naupalgadi
123.	*Sonneratia caseolaris* (L.) Engl.	Rhizophoraceae	Along backwaters and mangrove forests	Tree	Indo-Malesia and Australia	Naupalgadi
124.	*Sphenoclea zeylanica* Gaertn.	Sphenocleaceae	Along water courses and mangrove forests	Herb	Pantropical	Balramgadi
125.	*Sporobolus indicus* (L.) R.Br.	Poaceae	Moist and dry deciduous forests	Herb	Pantropical	Kuldiha
126.	*Talipariti tiliaceum* (L.) Fryxell	Malvaceae	Along streamside and banks of tidal streams and mangrove forests, also grown as live fence	Tree	Pantropics	Balramgadi
127.	*Typha angustata* Bory & Chaub.	Typhaceae	Marshy fields	Herb	Cosmopolitan	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
128.	*Utricularia caerulea* L.	Lentibulariaceae	Grasslands and marshy areas	Herb	Paleotropics	Balramgadi
129.	*Utricularia polygaloides* Edgew.	Lentibulariaceae	Wet or waterlogged sandy areas near seashores	Herb	India and Sri Lanka	Naupalgadi
130.	*Vallisneria natans* (Lour.) Hara	Hydrocharitaceae	Pools and ponds	Herb	Pantropical	Naupalgadi
131.	*Myriostachya wightiana* (Nees ex Steud.) Hook.f.	Poaceae	Wetlands	Shrub	Indo-Malesia	Naupalgadi
132.	*Sacciolepis mysuroides* (R. Br.) A. camus	Poaceae	Ditches and marshes	Herb	Tropical Asia and Australia	Balramgadi

developmental activities on freshwater ecosystem. Increasing sedimentation in the aquatic environments due to both natural and man-made causes affect water quality and clarity (Cook 1996). Addition of silt during rainy season, run-off of garbage from human settlement, and draining of wastewater into the lake from industries have resulted shrinkage of this habitat (Nichols 1991). For rural people, this environment is to a certain extent functions as a bio-resource in a sustainable way. *Aponogeton natans*, *Alternanthera sessilis*, *Ipomoea aquatica*, *Marsilea polycarpa*, *Persicaria barbata*, and *Sesbania javanica*, common leafy greens, are available throughout the year, and they are harvested from the wetlands and marshy areas for human consumption. *Ipomoea carnea*, an aggressive alien-invasive weed, is collected from the bunds of the ponds and ditches for fencing of agriculture lands. Flowers of sacred plants *Nymphaea nouchali* and *Nelumbo nucifera* are sold in the market; matured seeds are eaten raw or roasted and made into flour to make nutritious meal. The presence of *Ipomoea carnea*, *Pistia stratiotes*, *Eichhornia crassipes*, and *Salvinia molesta* is a clear indication of invasion of alien species in this perennial ecosystem. *Centella asiatica*, *Bacopa monnieri*, and *Eclipta prostrata* were used in different medicinal formulations. *Arundo donax*, *Cyperus corymbosus*, *Cyperus digitatus*, *Cyperus pangorei*, *Pandanus fascicularis*, and *Typha angustata* were used for basketries and mat-making purposes. However, a detailed study about the suitability of these plants for human consumption as supplemental food or as feed for the cattle has to be carried out as these are growing in water that is dangerously polluted both industrially and biologically.

Conclusions

Studies on aquatic plants are crucial in this ever-changing environment; in India, to assess life-forms and the aquatic environment. In-depth knowledge on macrophyte biology will pave the way for formulation of new management techniques and enhance the efficacy of the present management practices of the aquatic ecosystem. Inhabitants around the aquatic environments are unaware of the importance and role of flora and fauna. Anthropogenic activities such as building construction, accumulation of garbage, encroachment, industrialization, and mining of clay or soil are escalating around the wetlands. Further studies on the impacts of pollutants, nutrient load, microphyte wealth, seed germination strategies, and water quality and ecological quantitative studies are needed to efficiently conserve these important ecosystems and its invaluable biota. Assessment of biota and continuous monitoring and preservation of natural resources are important activities to safeguard the biological wealth of freshwater ecosystems.

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References

Balian EV, Segers H, Leveque C, Martens K (2008) The freshwater animal diversity assessment: an overview of the results. Hydrobiologia 595:627–637

Clayton J, Edwards T (2006) Aquatic plants as environmental indicators of ecological condition in New Zealand lakes. Hydrobiologia 570:147–151

Cook CDK (1996) Aquatic and wetland plants of India. Oxford University Press, New York, pp 1–385

Gleick PH (1996) Water resources. In: Schneider SH (ed) Encyclopaedia of climate and weather. Oxford University Press, New York, pp 817–823

Gopal B, Zutchi DP (1998) Fifty years of hydrobiological research in India. Hydrobiologia 384:267–290

Kalff J (2002) Limnology. Prentice Hall, Upper Saddle River, New Jersey, 592 p

McCutcheon SC, Schnoor JL (2003) Overview of phytotransformation and control of wastes. In: McCutcheon SC, Schnoor JL (eds) Phytoremediation: transformation and control of contaminants. Wiley, New York, pp 3–58

Melzer A (1999) Aquatic macrophytes as tool for lake management. Hydrobiologia 395:181–190

Nahlik AM, Mitsch WJ (2006) Tropical treatment wetlands dominated by free-floating macrophytes for water quality improvement in Costa Rica. Ecol Eng 28:246–257

Nichols SA (1991) The interaction between biology and the management of aquatic macrophytes. Aquat Bot 41:225–252

Palmer MAS, Bell SL (1992) Butterfield I. A botanical classification of standing water in Britain: applications for conservation and monitoring. Aquat Conserv Mar Freshw Ecosyst 2:125–143

Srivastava J, Gupta A, Chandra H (2008) Managing water quality with aquatic macrophytes. Rev Environ Sci Biotechnol 7:255–266

UNEP-DEWA (2004) Freshwater in Europe. Facts figures and maps. Division of Early Warning and Assessment (DEWA), United Nations Environment Programme, Geneva, 6, pp 1–5

Wetzel RG (2001) Limnology: lake and river ecosystems. Academic, San Diego, 998 p

2

Aquatic Resources: A Case Study of Udaipur 'City of Lakes', Rajasthan

Hemant Mangal and Sandhya Pathania

Abstract

Aquatic resources refer to water and its multiple roles as a natural resource and in supporting all human, animal and plant life. It has a meaning that is broader than that of water resources alone, in that it encompasses all the possible roles for water, including human survival needs, supporting aquatic ecosystems and as an essential component of economic development. It considers both the quantity of available water and its quality for its intended uses. Aquatic resources also encompass the linkage between fresh water systems and the downstream coastal areas into which it drains, where it sustains biologically rich and commercially important coast as ecosystems. This chapter highlights the aquatic resources of Udaipur City, and the study is based on secondary data collected from various government and nongovernment organizations.

Keywords

Aquatic • Biodiversity • Lakes • Rajasthan

Introduction

The total water resources of the earth equal to 326 million cubic mile; only 2–5 % of water is fresh water; 97.5 % is salt water. Almost 69 % of fresh water resources are tied in glaciers and ice caps, about 30 % is ground water and a mere 0.27 % is surface water (www.drinkingwater.com). Water resources are important for the survival of a planet. As water is a prime resource, a basic need, it is essential to realise its full potential. It has always played a very important role in human life since its existence. All human activities are affiliated to water. Water is a supreme economic wealth besides its biological importance. It serves as an ideal medium for biochemical reactions so necessary for life. Thus water sustains life and regulates all important economic activities because of which it has been termed as the richest of all economic resources. Nearly 70 % of the

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world's population that is concentrated in the river valleys and deltas, around lakes and in the coastal areas speaks volumes of utility of aquatic resources for man. It seems that water is abundant, but usable water is very limited and creates a serious conservation problem in many places where it is needed. While plants and animals living in oceans are called marine resources, those living in flowing water like rivers as well as inland standing water like reservoirs and ponds are called aquatic resources (fresh water resources). This chapter highlights the present scenario of aquatic resources in Udaipur City, Udaipur being the Kashmir of Rajasthan, Lake City or Venus of India.

Methods

This chapter has been prepared with the help of secondary data collected from various government and nongovernment organizations and various websites. Maps are prepared on Corel Draw.

Study Area

Site Udaipur City is located in the southern part of Rajasthan. It is actually lying in the centre of a bowl-shaped basin surrounded by the Aravalli hills and is drained by the Ayad river.

Location Its latitudinal location is from 23° 9′ to 25° 28′ N and longitudinal extension is from 73° 1′ to 75° 49′ E. Its geographical region is 12,499 km^2 and is about 577 m above sea level. Udaipur evolved as a result of a decline in political power. The decision to site the new capital was favoured by a number of factors including having the temple of Eklingji close by, its isolated position caused by a hilly and forest-covered terrain, availability of water in abundance and the area having a quality of defence, to name a few. The increase in the municipal area of the town was primarily in response to the increase in population. Except for the two consecutive decades, 1891–1901 and 1901–1911, when the population recorded decline due to natural calamities, it has otherwise registered a steady and continuous growth, except that of 1941–1951 when it had the highest growth due to various reasons of which the post partition being the most significant. Besides this the growth rate in Udaipur City had been in accordance with Udaipur's economic and cultural growth. Udaipur being an important tourist centre has a floating population of considerable size (Fig. 2.1).

Though demographically it is a class I city, functionally it is only a medium-sized regional city without having any major or metropolitan function (Bhattacharya 2000). Till 2011 Udaipur continues to develop and expand its commercial, administrative, educational, cultural, recreational and tourist interests. Thus, this throws light on the fact that with the rapid increase in population, the area of city is also increasing.

Aquatic Resources of Udaipur City

Rain water remains reserved in nature in various forms called water reservoirs. They can be broadly classified into surface sources and underground sources.

Surface Water Sources

Udaipur, famous as 'City of Lakes', includes rivers, lakes and ponds that are surface water sources, namely, Fateh Sagar, Pichhola Lake, Swaroop Sagar, Nandeshwar Talab, Badi, Madar, Choti Madar, Ayad river, etc. Figure 2.2 gives a clear picture of all the surface water sources of Udaipur City (Babel and Gupta 1994). Besides these, there were 121 baovries of which 83 have dried up.

Ayad

Berach the main tributary of river Banas rises originates from the Girwa ranges of Aravalli situated to the north of Udaipur City. It is called Ayad river from its fountainhead through Bedla up to Udai Sagar Lake, in which it falls. It is the principal river of the Udaipur basin. Beyond Udai Sagar up to Dabok village, the river passes through a distance of about 75.5 km and is named

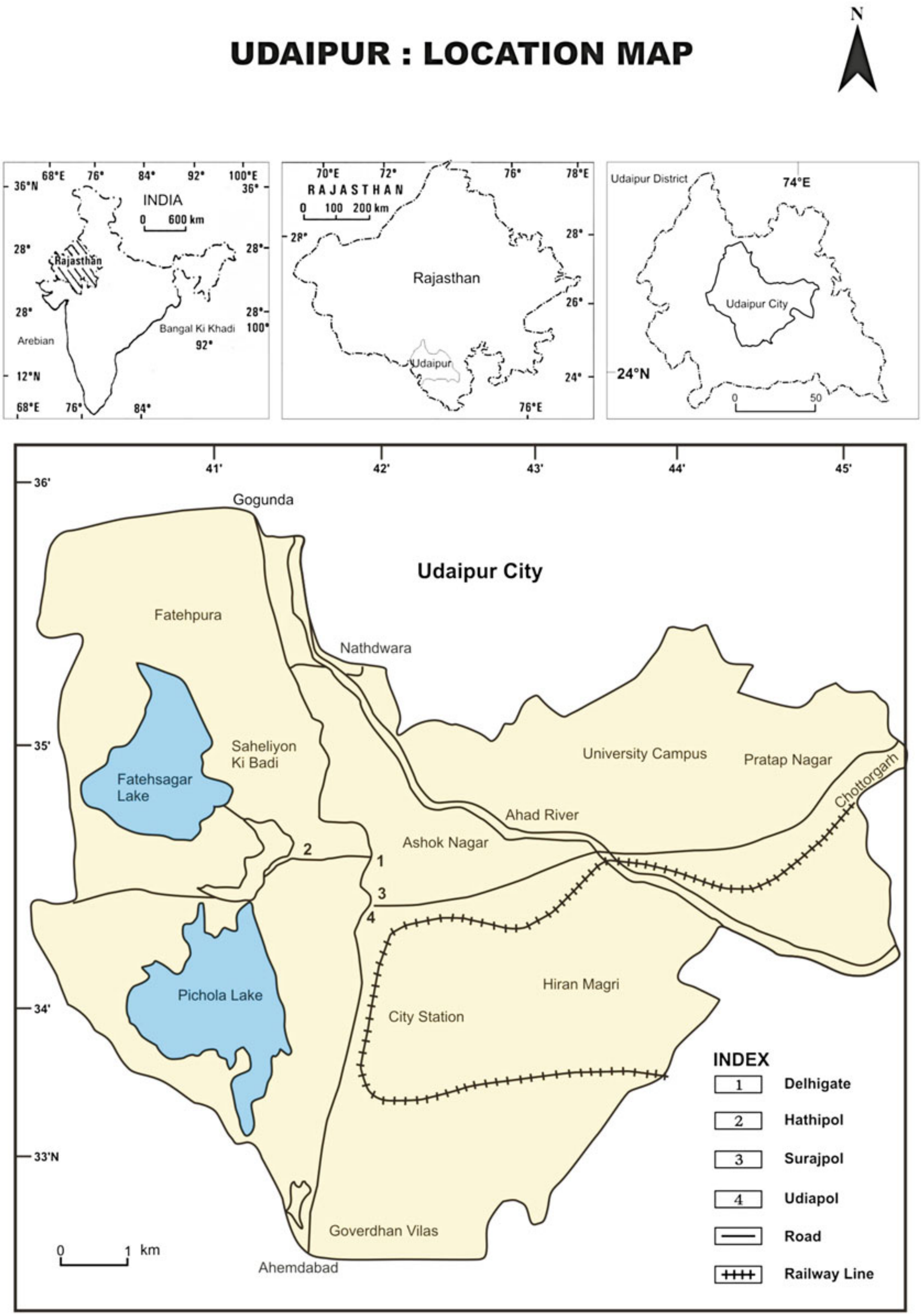

Fig. 2.1 Map of Udaipur City with major water bodies

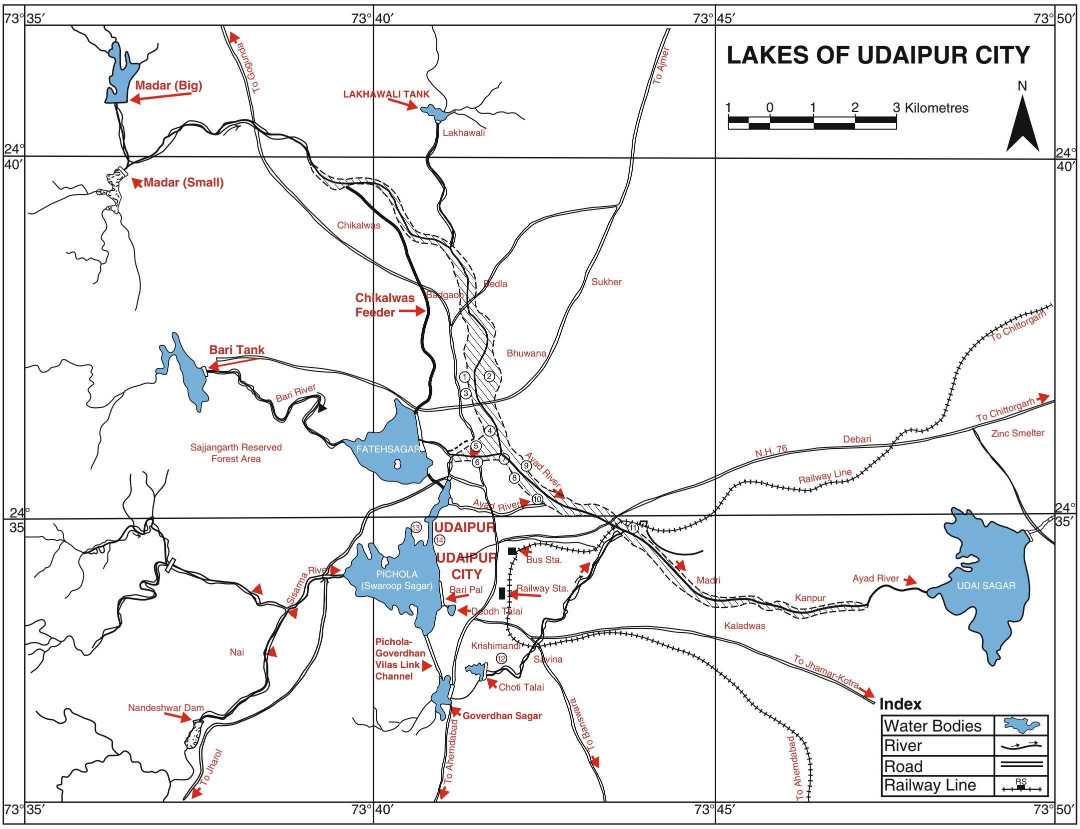

Fig. 2.2 River of Udaipur City

as Udai Sagar ka nala. Afterwards known as Berach it runs for another 70 km towards the northeast and finally merges into river Banas, near Bigod in the Bhilwara district, which is a tributary of Chambal river; Chambal again is a tributary of river Yamuna, and Yamuna is the principal tributary of the holy river Ganga. Near the town of Chittorgarh, it receives the water of Gambhiri river, then it turns northeast, and after flowing for about 190 km, it joins river Banas at the place acclaimed as Triveni Sangam near the village Bigod (Gupta 1991).

Lakes of Udaipur City

Pichhola Lake

Pichhola Lake is in Udaipur, was originally constructed by some Banjara, in the fourteenth century A.D., and later on was extended to Rang Sagar and Swaroop Sagar and finally was connected to Fateh Sagar by the successive rulers of the princely state of Mewar. Pichhola lies to the west of the majestic 'City Palace' providing them with unique and water frontage which enchants every tourist's heart and soul. It is roughly triangular in shape with its base along the palace ridge. It was renovated and enlarged in 1559 A.D. along with the establishment of Udaipur itself; it enjoys a water spread of 10.8 km^2 and a maximum depth of 9.15 m. The gross, live and dead capacities of the lake is 13.67 mcm, 9.00 mcm and 4.67 mcm, respectively, while the gauge height above and below sill level is 3.35 and 5.2 m. The lake has a net catchment area of 142 km^2, and it has an average yield of 493.5 mcft water. Presently 13.50 mld of water is drawn from this lake by the PHED to serve the thickly populated areas of the old city lying around this lake. The lake is extended towards the north and south forming smaller lakes, viz. Doodh Talai and Swaroop Sagar, as shown in map 2 which gives a detailed picture of the lakes of Udaipur (Sujas 2010).

Swaroop Sagar

It was constructed during 1845–1850 A.D. Its intermediate position has sluice gates and canal to feed water to Fateh Sagar Lake which is towards the north and linked with Pichhola through Rang Sagar Lake in the south.

Rang Sagar

It has an average depth of 7 m, but its width is about 245 m, whereas its westward extension is known as Kalaliya tank.

Fateh Sagar

It is situated in the northwestern part of the city and almost in the central west of the basin covering an area of 12.88 km^2. It has a pear-like shape, covering about 4 km^2 areas and gross, live and dead capacity of 12.0 mcm, 7.00 mcm, and 5.09 mcm, respectively. Nearly 20.71 km^2 of its catchment area yields annually 71.87 mcft of water, evidently lower than that of Pichhola. The daily drawl of water for domestic purposes has been recorded as 30 lakh litres in 2004 which was 0.00 in 2008, that is, no water was taken from Fateh Sagar for supply for domestic purpose which serves about 40 % of the population residing in the northern and western part of Udaipur City.

Bari

Bari ka talab or Lake Bari is lying 10 km away towards the west from Udaipur City. This lake was constructed by Maharaja Raj Singh in 1643 A.D. for recreation purpose. The lake is formed by damming the river Ubheswar coming from the west. The total length of the canal is measured as 3,300 m which is constructed for supplying water to the nearby areas, namely, Bari, Liyo ka Guda, Hawala Khurd and Dewali villages. The full gauge of the lake is 9.76 m. Almost no supply of water is rendered from this lake.

Lakhawali

It is located at a distance of 10 km from the centre of the basin in the north direction. It ranks fifth from the point of view of capacity, yield water level, catchment area and command area of the six lakes of the region. Its nearby terrain provides no scope for bed cultivation area. The lake is comprised of a good canal system spread over a length of 7.5 km of irrigation about 1,012.50 km^2 of land per year. The water of this lake is also used for domestic purposes.

Goverdhan Vilas

It is the smallest water reservoir of all the major lakes of the basin lying in the south. The length of the canals of this lake is also meagre extending over an area of only 3,750 m.

Udai Sagar

It is one of the largest lakes of the Udaipur basin constructed by Maharana Udai Singh in 1559 A.D. and named after him; this lake is situated in the far south-east of this basin. The lake was formed after damming river Ahar, particularly for the strategic and water source point of view.

Vallabh Nagar

Vallabh nagar is in Udaipur, on river Berach. The total catchment area is 1,188 km^2. Its gross, dead and live capacity is 31.14 mcm, 3.54 mcm and 27.60 mcm, respectively. Its full tank level is 492.71 mcm. Its water is used for irrigation as well as for drinking purpose (Sujas 2010).

Badgaon

Badgaon is in Udaipur, on river Berach. Its catchment area is 1,698.3 km^2. Its gross capacity is 31.50 mcm, with its dead and live capacity of 1.34 mcm and 30.16 mcm, respectively. Its water is used for irrigation as well as for drinking purpose.

Jaisamand

Also known as Dhebar, Jaisamand is located 51.48 km south-east of Udaipur. It was made by Maharaja Raj Singh in 4 years from 1687 to 1691. It is more than 14.48 km long, and its breadth is more than 9.65 km. The dam on this lake is made of marble and is in between two mountains. It is 1,000 ft long at a height of 95 ft. Behind this another water reservoir at the same height was constructed which according to Dr. O.J. Ojha remained empty for about 184 years. In the year 1875, being afraid of heavy rainfall, Maharana Sajjan Singh spent Rs. 2 lakh to fill the two third gap in between the two dams; the remaining work was completed afterwards (Raju et al. 2004). Jaisamand is the world-famous artificial lake. Its catchment area is 1,813 km^2 and gross capacity is 414.60 mcm followed by dead and live capacity of 118.46 mcm and 296.14 mcm, respectively. Its water is used for supplying drinking water to Udaipur and also for irrigation. All these water bodies stand endangered today because of their misuse.

Baovries of Udaipur City

There are 121 baovries in Udaipur out of which 83 have dried up (Goswami and Mathur 2000). Most of these baovries are situated in the Sajjan Niwas Garden area. Maximum load was recorded on Sarvaritu vilas Baovri and lowest was on the Chowk Wali Baovri. The other baovries of Udaipur are Sagasji Ki Baovri, Tarkari Wali Baovri, Garden Wali Baovri, Nalaka, Chhatriwali, Jalijiwali, Maji, Ayurvedic Hospital, Satyanarayan, Toranwali and Om Prakashji Ki Baovri, Customwali, Ramdas Colony, Dore Nagar, Goverdhan Vilas, Phoolji, Jethji, Maliwali, Bhanbagh, Kalanwali, Khilonawali, Delhi Gate and Maszidiji Baovri.

Underground Water Sources of Udaipur City

The Udaipur City average water level pre-monsoon was 11.44 mbgl and post-monsoon was 6.87 mbgl. All the years show a rise in post-monsoon water table which was less in 2007 in comparison to other years as shown in Fig. 2.3.

It becomes clear how rainfall affects the underground water availability. In the years when rainfall in two consecutive years had been above mean average, the underground water level pre-monsoon and post-monsoon observed a lesser gap which has been minimized in the year 2011. Although the post-monsoon water level has fallen down in comparison to 2010, water demand has been increasing every year, thus resulting in Udaipur City lying in an over-exploited zone because of overharvesting of underground water (Swati 2003).

Water Quality

The water quality of the lakes has a high sodium and bicarbonate content, which is attributed to

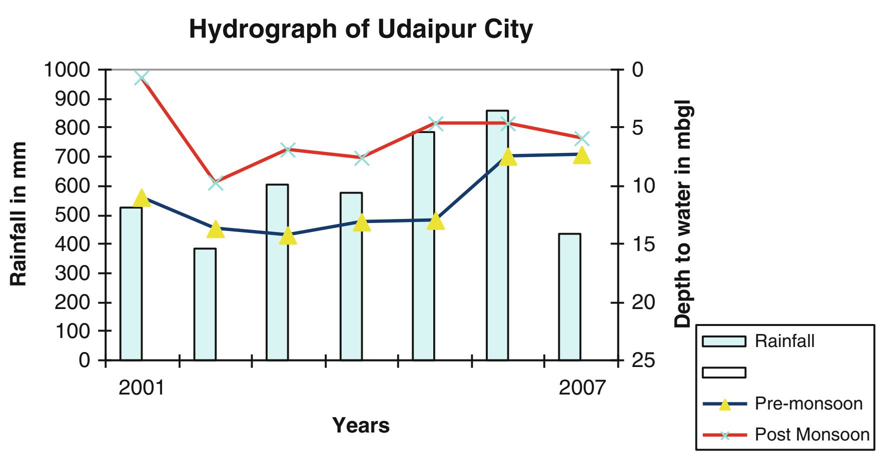

Fig. 2.3 Underground water sources of Udaipur City

continental weathering due to anthropogenic pressure, intense development activities in the basin area and untreated effluent from municipal and domestic sewage into the lake. The semiarid conditions of the area, saline and alkaline soil/groundwater conditions and weathering of the silicate rock exposed in the drainage basin are assessed as the reasons for the supply of major ions (Ramesh and Ramachandran 2005).

The assessment of the pollution parameters recorded at random intervals determined that water is polluted and needs remedial measures (Kumar et al. 2004). Water hyacinth growth has been found and the lake bottom is also covered with a thick mat of submerged vegetation, with the presence of floating microalgae which are detrimental to the public health.

pH value varies from a maximum of 8.4 on the surface to a minimum of 7.8 at the bottom. Maximum nitrogen concentration is 0.941 at 1 m below the surface and 0.523 at the bottom of the lake. The lake water is reported to be polymictic, and there is a lack of true thermocline. The lake water temperature varied from a minimum of 19 °C in January to 29.4 °C in June at the surface and correspondingly 16.8 °C and 28.5 °C at the bottom of the lake. Eutrophication has occurred in the lake due to algae bloom (dominant species are microcystis on the surface and macrophytes submerged). Urbanisation around the lakes has increased in nutrients on account of leaching from agricultural activities (Pamecha 2000).

The fauna recorded in the lake are 200 planktons, benthos and fishes. Macrophytes that merged in the lake are floating macrophytes, the submerged macrophytes and the phytoplanktons. The lake surroundings have sparse vegetation cover, but several species of plants in the periphery of the lakes. Lake Bari at one end touches Sajjangarh Wildlife Sanctuary. This lake acts as a mega water hole for the spillover animals of the surroundings. It was named Jiyan Sagar after Maharaja Raj Singh, its mother name Jana Devi by whom this lake was built, but because it is in close vicinity of village Bari, it is popularly known by this name. The lake has a surface area of 1.25 km^2 and has an embankment 180 m long and 18 m wide. The maximum depth of the lake is 150 m.

A total of 32 bird species belonging to 18 families were found; among these, 20 species were resident, 2 species were summer migrants and 10 species were counter migrant. An attempt has been made to analyse and compare the habitats of three lakes in order to understand as to why the number of bird species in all the lakes is almost similar, in spite of the fact that there is a lot more anthropogenic activity in lakes Fateh Sagar and Pichhola as compared to Lake Badi (Singh et al. 1990).

Sl. no.	Parameter	Status in Pichhola	Status in Lake Fateh Sagar	Status in Lake Bari
1.	Presence of tall trees in the vicinity of water bodies	Common	Common	Less common
2.	Presence of island	Many	Many	NIL
3.	Presence of seeds	Patchily present at few places	Patchily present at few places	Absent
4.	Width of water body	Quite more	Quite more	Narrow
5.	Depth of water at water line	Shallow zone is quite spread	Shallow zone is quite spread	Less shallow zone restricted towards the southern tip only
6.	Presence of crocodiles	None	None	Few
7.	Presence of railing	Present	Present	Absent
8.	Algae blooms	Present	Present	Interestingly absent

Conclusions

- The lake is polluted due to disposal of sewerage directly into surface drains of surface water bodies.
- Large-scale and uncontrolled mining of marble and other minerals leading to heavy deforestation of hill slopes.
- Catchment area degradation and soil erosion causing deposition of sediments and disturbance of the ecosystem of the area.
- Encroachments.
- Dumping of solid, liquid waste, destruction of submerged areas and over-exploitation of aquatic resources of Udaipur City.
- Poor governance.
- Lack of citizens' and stakeholders' participation in the management of the lakes.
- Due to deteriorated water quality, out of 42 species of fishes including mahseer and all major carp fishes, only 17 species of fishes have survived.
- In the catchment area of Fateh Sagar Lake, Pichhola effluents from synthetic fibre mills and soft drink plants, hotels, etc. are discharged. Apart from bathing and washing, vehicles are also washed in Lake Fateh Sagar and Pichhola. There is prolific growth of foul-smelling blue-green algae, which is neurotoxic and cannot be eradicated by normal filtration.
- No policy implementation for boring in the city.

Suggestions

- Anthropogenic activities should be controlled like motor boating, bathing, washing, etc.
- Public awareness to be made by various local means of communication like radio, TV, street play and banners.
- Syllabus in primary, secondary, senior secondary and at higher education should be framed keeping the education of the area among them.
- Garbage cans should be placed away from the lake areas.
- Solid water should not be disposed in the lakes.
- Sewerage water from hotels, industries and houses needs to undergo ETP before being disposed in lakes.
- Strict policy-making and its implementation is required as it will help in maintaining the biodiversity of the lakes of Udaipur City.

Thus aquatic resources at Udaipur City can be maintained if anthropogenic activities are checked by educating Udaipurites through various awareness programmes. It is not a day's task but needs a joint effort of all. Only aquatic resources in the form of various species of fauna and flora will add to the beauty of Lake City – the Kashmir of Rajasthan. Aquatic resources are a bliss; they should be conserve. Policy-making is not enough, but their proper implementation is the need of the hour.

References

Babel K, Gupta NL (1994) Urban water supply. Rawat Publication, Jaipur, 180 p

Bhattacharya AN (2000) Human geography of Mewar. Himanshu Publication, Udaipur/Delhi, p XIV

Goswami CG, Mathur MN (2000) Mewar and Udaipur. Himanshu Publication, Udaipur/New Delhi

Gupta RK (1991) Some aspects of hydrobiology of Daya dam. Tehsil Sarada, Udaipur (Rajasthan). M.Sc. thesis, Rajasthan Agriculture University, Bikaner, 235pp

Kumar V, Singh PK, Purohit RC (2004) Hydrology and water shed management. Himanshu Publication, New Delhi

Pamecha AK (2000) Water management and conservation, general overview and an industrial case study: water resource management, Vigyan Samiti, 84 p

Raju KS, Sarkar AK, Dash ML (2004) Integrated water resources – planning and management. Jain Brothers, New Delhi

Ramesh R, Ramachandran S (2005) Fresh water management 2005. editors Capital Publishing Company, New Delhi

Singh J, Acharya MS, Sharma A (1990) Water management (problems and prospects in command areas). Himanshu Publications, Udaipur

Sujas (2010) http://dipr.rajasthan.gov.in/publication.ASP

Swati B (2003) Water crisis in India. Panchaya 01(III): 84–92

Limnological Variations of Two Deccan Wetlands

3

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Abstract

A comparative study on physic-chemical and biological features with special reference to Rotifera and Cladocera of two Deccan wetlands *viz.*, Pocharam lake and Wyra lake, that are situated in Andhra Pradesh have been carried out during 2003–2004 and 2006–2007, on a seasonal basis. The physic-chemical factors revealed that the parameters like pH, turbidity, DO, carbonates and silicates are at higher side in Pocharam lake waters than the other and the factors like electric conductivity, bicarbonates, chloride, phosphates, sulphur, sodium and potassium of Wyra lake waters are at higher side. But total hardness and calcium values are more or less equal in both the lakes. The biotic factors revealed the presence of 24 species belonging to 9 genera of Rotifera and 11 species in 5 genera in Pocharam lake while in Wyra lake it was 20 species under 10 genera of Rotifers and 16 species belonging to 9 genera of cladocerans.

Keywords

Limnology • Rotifera • Cladocera • Pocharam lake • Wyra lake

Introduction

Large, medium and small water bodies called lakes/reservoirs/impoundments constitute the major freshwater resources of Andhra Pradesh, and these water bodies were formed by the construction of dams across small rivulets and streams for irrigation or as a source of drinking water of the region. Pocharam Lake that is situated in Medak-Nizamabad Districts and Wyra Lake in Khammam District of Andhra Pradesh in South India are presently the major sources of water in the regions. Pocharam Lake is situated at about 110 km from Hyderabad city in its northwest direction/17 km from Medak town, and Wyra Lake is about 250 km from Hyderabad city in its northern side/25 km from Khammam town.

Some of the notable contributions on limnology in the state include Zafar (1966),

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Table 3.1 Comparative case history and morphometry of two lakes

Sl. no.	Details	Pocharam Lake	Wyra Lake
1.	Construction year	1922	1929
2.	Location	18° 18′N and 77° 57′E	17° 15′N and 80° 25′E
3.	Catchment area	16.835 km^2	19.166 km^2
4.	Depth (depending on the season/ fluctuation in rain fall)	5–6 ft	5–6 ft
5.	Constructed on	Alair River	Godavari River
6.	Usage	Irrigation, domestic and forestry exploitation	Irrigation and domestic

Venkateswarlu (1969), Munawar (1970), Venu (1981), Ratna Rao (1984), Jaya Devi (1985), Chandrasekhar (1996, 2006), Chandrasekhar and Nageswara Rao (2006), Patil and Panda (2003), Malathi et al. (2003) Anitha et al. (2005) and Siddiiqi and Khan (2002). In an aquatic ecosystem, water quality influences its biotic components and it controls diversity, biomass and spatial distribution of the latter in time and space. The physico-chemical parameters exert their influence both individually and collectively, and their interaction produces abiotic environment which conditions the origin, development and finally succession of biotic communities. Further, biotic communities, in turn, continuously go on in a dynamic ecosystem.

The present study was undertaken to have a comparative account of physico-chemical and biological conditions of two Deccan wetlands, viz. Pocharam Lake and Wyra Lake, in Andhra Pradesh which differed significantly in their limnological aspects and trophy (nutrient status) with emphasis on the structure and composition of zooplankton particularly Rotifera and Cladocera.

Description of the Lakes The comparative morphometry of these two lakes is given based on the data gathered from different sources (Table 3.1).

Methods

The studies on Pocharam Lake had been carried out during three different seasons (November 2003, winter; March 2004, summer; and July 2004, monsoon) of 2003–2004 and on Wyra Lake 2006–2007 (November 2006, winter; March 2007, summer; and August 2007, monsoon). In order to cover the whole topography of the water bodies, seven surrounding villages located at the bank of Pocharam Lake and nine at Wyra were selected for the surveys. Physical parameters and titrimetric parameters were analysed in the field laboratories, and water samples were brought to head quarters by collecting in PVC bottles of one litre capacity and given to a private laboratory for the analysis of nutrients and light metals. Plankton samples were collected by diving the plankton net (No. 25) on the sublittoral regions of the lake waters and preserved in 4 % formaldehyde solution, and the identification of rotifer and cladoceran fauna was done with the aid of standard literature on these two groups.

Results and Discussion

Limnological investigations were restricted to the three major seasonal surveys, i.e. November (winter), March (summer) and July/August (monsoon) on both lakes. The ranges and mean station-wise/overall values of different physico-chemical parameters of seven stations of Pocharam Lake and nine of Wyra Lake were given in a table during the three major seasons (winter, summer and monsoon) of the study periods 2003–2004 and 2006–2007, respectively.

The pH values during the study periods varied between 7.24 and 9.16 with mean value of 8.0 on Pocharam Lake and 7.0–8.7 with mean value of 7.57 on Wyra Lake indicating the general alkaline tendency of waters. The higher pH values may be attributed to the carbonates/bicarbonates and higher photosynthetic activities. The lower pH value (7.24) was noticed at Rajpet in winter and the higher one (9.16) was during monsoon at Pochammaralu of Pocharam Lake, whereas in Wyra Lake the lower and higher values, i.e. 7.0 and 8.7, were found at Reddygudem in winter and summers. The electric conductivity was observed with a range of 230–810 micro-siemens/cm and 360–810 with mean values 349.5 and 542.2 in Pocharam and Wyra Lakes, respectively. The turbidity values of Pocharam Lake fluctuated between 15 and 300 NTU with a mean value of 67.3, whereas in Wyra Lake it was 5–184 with a mean value of 52.8. The lower value (15) was observed at Rajpet in winter and the higher one (300) was at Kottapalli of Pocharam Lake. Similarly in Wyra Lake, the lower turbidity value (5) was found at Brahmanapalli during winter, and the higher value (184) was at Singarayapalem in summer. Its higher values are known to affect the primary productivity by restricting the light penetration and photosynthesis. The dissolved oxygen (DO) profile revealed a variation between 2.6 and 8.2 with an average value of 5.2 in Pocharam Lake, and in Wyra Lake, it was 1.3–6.0 with a mean of 4.55. The lower value 2.6 mg/L of Pocharam Lake was observed at Burugapalle in monsoon and the higher one 8.2 was seen at Polkampet during winter and monsoon seasons. Likewise, the lower value (1.3) of Wyra Lake was noticed at Wyra spot during summer, and the higher value (6.0) was noticed at different localities of the water body in monsoon. Here the higher values of dissolved oxygen may be due to comparatively clear zones and increased photosynthetic activity by phytoplankton. The total absence of carbonates was noticed in monsoon in Wyra Lake. In the case of Pocharam Lake, the carbonates fluctuated between nil and 90 with an average of 54 mg/L, and in Wyra Lake it fluctuated between nil and 50 with a mean value of 41.1. The bicarbonate values of Pocharam Lake were seen from 35 to 100 mg/L with an average of 87.9, whereas in the case of Wyra Lake, it was found between 125 and 320 mg/L with a mean value of 215.2. The chloride content at different stations of Pocharam Lake varied from 15 to 43 mg/L with a mean value of 26.5, while at Wyra Lake it was 27–110 with an average value of 64.5. The maximum value (43) in Pocharam Lake was found during summer at Polkampet, and the minimal value (15) was noticed at Pocharam Lake in Pocharam (V) spot in winter. Similarly the minimal value (270) in Wyra Lake was noticed in summer at its Wyra locality, and the maximum value of 110 was observed in winter at Reddygudem. The peak in chloride values may be related to evapotranspiration and high evaporation due to the prevailing high temperature. The chloride content further involves the presence of organic matter of animal origin. Lower chloride values in the water body were probably due to its distant location and natural elevation that gives protection from inflows of domestic wasters and cattle feeding. The values of total hardness varied between 85 and 280 mg/L with a mean value of 158.6 in Pocharam Lake, whereas in Wyra Lake it was between 85 and 280 mg/L with a mean value of 148.9. The peak total hardness value (245 mg/L) of Wyra Lake was noticed at Singarayapalem during monsoon, while its minimal value (95) was at Narayanapuram in winter. The maximum quantity of total hardness value (245 mg/L) of Wyra Lake was noticed at Singarayapalem during monsoon, while its minimal value (85) was seen at Wadalparti in monsoon. The ranges of hardness values recorded were invariably lesser in the case of Wyra Lake, indicating the presence of other ions, and therefore all excess hardness can be termed as carbonate hardness, whereas it is reverse in the case of Pocharam Lake, and hence Wyra Lake waters may be classified as moderately hard to hard and indicate no physicochemical deterioration. The calcium hardness in the case of Pocharam Lake varied between 15 and 59 mg/L (mean 30.2), whereas in Wyra Lake it was between 21 and 42 (28.9). Higher concentration of calcium was observed at Pocharam (V) of Pocharam Lake in winter season, while it was at Reddygudem of Wyra Lake in monsoon.

In general, aquatic ecosystems receive excess nutrients through untreated domestic sewage and agriculture runoff. Phosphate acts as a limiting nutrient responsible for the process of eutrophication that ultimately leads to the degradation of an aquatic ecosystem. During the course of study on Pocharam Lake, the phosphate content between 0.01 and 0.09 mg/L (mean 0.36), while in Wyra Lake it was 0.03 to 0.28 mg/L with a mean of 0.86. The minimal value at Pocharam Lake

Table 3.2 Showing the overall ranges and mean values of the physico-chemical parameters of two lakes

		Pocharam Lake		Wyra Lake	
Sl. no.	Parameter	Range	Mean	Range	Mean
1.	pH	7.24–9.16	8.0	7.0–8.7	7.57
2.	EC (micro-siemens/cm)	230–810	349.5	360–810	542.2
3.	Turbidity (NTU)	15–300	67.3	5–184	52.8
4.	DO (mg/L)	2.6–8.2	5.2	1.3–6.0	4.55
5.	Carbonates (mg/L)	0–90	54	0–50	41.1
6.	Bicarbonates (mg/L)	35–180	87.9	125–320	215.2
7.	Chloride (mg/L)	15–43	26.5	27–110	64.5
8.	Total hardness (mg/L)	90–280	158.6	95–245	148.9
9.	Calcium (mg/L)	15–59	30.2	21–42	28.9
10.	Phosphates (mg/L)	0.01–0.09	0.36	0.03–0.28	0.86
11.	Nitrates (mg/L)	1–15	5.23	1.9–10.0	3.7
12.	Silicates (mg/L)	5–21	9.5	3.0–16.0	10.5
13.	Sulphates (mg/L)	6–43	16	16–97	39.1
14.	Sodium (mg/L)	8–46	26.9	30–92	61.3
15.	Potassium(mg/L)	1–5	1.95	2.0–5.0	3.1

was noticed at Pochammaralu and Burugapalle during winter, and its maximum was at Polkampet in monsoon. In the case of Wyra Lake, the minimal and maximum values were obtained at Wyra spot and Siddikhnagar during monsoon and winter, respectively. The higher phosphate content indicates the loading in of domestic sewage and agricultural runoff from surrounding colonies and agricultural fields, respectively.

The quantity of nitrate at Pocharam Lake fluctuated from 1 (several localities during winter) to 15 mg/L (Burugapalle in summer) with a mean value of 5.23, whereas its value at Wyra Lake ranged from 1.9 (Wyra spot in summer) to 10.0 mg/L with a mean value of 3.27, but the minimal and maximum values were obtained at Wyra spot and Siddikhnagar, respectively, during monsoon season. Silicate concentration in Pocharam Lake was found around 10 only. The silicate values during winter in Wyra Lake were comparatively low, and summer values are higher. High concentration of sulphates stimulates the action of sulphur-reducing bacteria, which produce hydrogen sulphide, a gas highly toxic to fish life. Sulphates at Wyra Lake water were observed from 16 to 97 mg/L with an average value of 39.1 wherein the minimal was noticed in summer at Lallapuram, while the maximum was in winter at Siddikhnagar. The sulphate concentration in Pocharam Lake waters fluctuated between 6 and 43 mg/L with a mean value of 16 wherein the lower value was found at Burugapalle in summer and the higher one was in monsoon at the same spot. Sodium, which can also be called as conservative metal, showed the variation in Pocharam Lake waters from S Pocharam in winter – 46 mg/L (Rajpet in winter) with a mean value of 26.9. But in Wyra Lake sodium concentration fluctuated between 30 (Wyra – winter) and 92 (Lallapuram – summer) with a mean value of 61.3. The quantity of potassium in Pocharam Lake waters was between 1 mg/L (several places in winter and summer) and 5 mg/L (Pochammaralu – winter) with a mean value of 1.95, whereas in Wyra Lake this concentration was between 2.0 (several places in winter and summer) and 5.0 (Lallapuram – summer), with an average value of 3.1 (Tables 3.2 and 3.3).

Biotic Profile

Detailed studies were carried out on the diverse rotifer and cladoceran faunal assemblage in Pocharam Lake and Wyra Lake during the study periods and given in Table 3.4 wherein the occurrences of the species of these two groups

Table 3.3 Showing the station-wise ranges and mean values of the physico-chemical parameters of two lakes

	pH		EC		Turb.		DO		Carb.		Bicarb.		Chloride		TH		Cal.		Phosphates		Nitrate		Silicates		Sulphate		Sodium		Potassium	
Pocharam Lake																														
Pocharam(V)	7.76–8.36	8.02	250–290	273.3	19–15.6	69.7	3.4–4.11	5	45–60	52.5	35–90	65	15–28	21	100–260	161.7	21.59	34.7	0.02–0.08	0.05	1–5	3.33	8–11	10	8–10	9	5–32	21.7	1.3	1.7
Pochammaralu	7.77–9.16	8.3	250–320	276.6	24–72	46.3	3.5–7.0	5.1	40–50	43.3	30–90		18–20	19.3	100–265	161.7	19–57	32.3	0.01–	0.04	2–4	3	8–12	10	9–12	10.3	9–29	18	1.5	2.7
Burugapalle	7.51–7.76	7.6	320–470	407	8–33	37.3	2.6–7.5	5.3	65	65	85–170	12.33	33–38	34.3	155–175	166.7	26–33	31	0.01–0.05	0.14	1–15	5	9–11	10	6–13	19.7	11–44	31	1.3	2
Rajpet	7.24–8.68	7.8	250–810	487	15–107	50	3.5–7.0	4.3	30–65	30–65	60–135	91.7	23–28	25.3	90–180	140	16–18	31.7	0.01–0.07	0.06	6–9	7.3	5–21	12	15–32	25	32–46	38	2.2	2
Wadalparti	7.57–9.09	8.3	230–330	266.7	31–126	73.3	3.8–7.5	5.4	35–70	35–70	40–55	55	20–28	24.3	85–140	121.7	15–42	24.3	0.05–0.08	0.07	3–9	6	5–11	8	9–18	12.0	11–28	20.3	1.2	1.7
Kottapalli	7.5–7.8	7.6	350–430	366.7	89–100	136.3	2.9–7.8	4.8	90	90	75–125	101.7	23–33	29.7	160–190	178.3	26–40	31.3	0.01–0.07	0.06	1–6	4	7–11	9	15–35	21.7	13–10	29	1.3	2
Polkampet	7.74–8.79	8.3	270–800	350	38–45	51.7	4.0–5.2	5.6	35–40	35–40	50–180	103.3	10–13	31.3	95–280	180	19–33	26	0.01–0.09	0.05	1–5	5	6–9	8	10–19	13	24–36	30	1.2	1.7
Wyra Lake																														
Siddikhnagar	7.2–7.6	7.3	580–510	660	16–120	127.3	3.9–5.5	4.8	0–50	50	135–320	238.3	58–93	71.3	135–150	141.6	21.37	29	0.05–0.28	0.176	20–100	6.26	5.7–28	42.7	43–97	64.3	73–90	79	3.0–7.0	4.3
Lallapuram	7.3–7.7	7.6	520–700	603.3	25–128	70.3	2.5–4.8	3.4	0–30	40	215–250	235	50–63	59.3	140–150	145	21.23	22	0.01–0.13	0.07	3.0–8.0	5.16	3.3–22	36.3	16–16	30	64–92	76	3.0–5	3.7
Wyra	7.1–7.9	7.5	420–590	506.6	6–6.1	27	1.3–6.0	4.3	0–15	45	125–235	190	27–88	59.3	150–175	165	22.32	26.3	0.03–0.12	0.08	1.9–1.32	2.74	5.2–14	28.2	19–43	32	30–79	57.3	2.0–4.0	3
Singarayapalem	7.1–7.9	7.6	490–620	513.3	15–18.1	75.7	1.0–6.0	4.1	0–10	40	190–235	218.3	55–73	64.3	125–245	186.6	25–29	27.1	0.01–0.1	0.07	2.0–3.15	2.72	5.0–16.0	31	25–42	34.3	38–68	56.6	2.0–3.0	2.7
Lallurugudem	–	–	–	–	–	–	–	–	0–15	45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mallavaram	7.4–7.7	7.5	440–560	333.3	12.61	38	5.0–6.0	5.5	0–15	45	140–260	200	48–98	73	105–155	130	21–37	29	0.05–0.13	0.9	3.0–4.0	3.5	50–10	15	30–44	37	30–68	49	3.0–4.0	3.5
Narayanapuram	7.3–7.6	7.4	360–510	290	15–53	34.5	5.1–5.8	5.4	0–15	45	130–265	197.5	38–95	66.5	95–145	120	27–39	33	0.01–0.09	0.65	2.0–5.0	3.5	4.0–12.0	16	13–38	25.5	40–65	52.5	2.0–3.0	2.5
Reddygudem	7.0–8.7	7.8	440–600	523.3	6.5.7	27.3	3.9–5.4	4.76	0.25	25	175–240	215	43–110	78.6	125–165	150	25–42	92.7	0.01–0.11	0.06	2.0–5.0	3	3.0–15.0	29	18–90	49.3	42–66	57.6	2.0–3.0	2.7
Brahmanapalli	7.3–8.2	7.8	440–580	513.3	5.12	11.7		4.7	0–35	35	180–250	216.6	38.65	71	125–150	136.6	28–37	33	0.01–0.11	0.066	2.0–3.0	2.3	6.0–14.0	32	23–45	35	40–64	55.3	2.0–3.0	2.3

I Ranges
II Mean values

Table 3.4 Showing the occurrence of zooplankton communities (Rotifera and Cladocera)

Sl. no.	Species	Pocharam Lake	Wyra Lake
Rotifera			
1.	*Brachionus angularis* Gosse	+	–
2.	*Brachionus caudatus* Barrios & Daday	+	–
3.	*Brachionus diversicornis* Daday	+	+
4.	*Brachionus forficula* Muller	+	+
5.	*Brachionus calyciflorus* f. *anuraeiformis* Brehm	+	–
6.	*Brachionus calyciflorus* f. *borgerti* Apstein	+	–
7.	*Brachionus calyciflorus* var. *dorcas* Gosse	+	–
8.	*Brachionus calyciflorus* var. *hymani* Dhanapathi	–	+
9.	*Brachionus falcatus* Zacharias	+	+
10.	*Brachionus plicatilis* Muller	+	–
11.	*Brachionus quadridentatus* Hermann	+	+
12.	*Brachionus patulus* (Muller)	–	+
13.	*Platyias quadricornis* Ehrenberg	+	+
14.	*Keratella tropica* Apstein	+	+
15.	*Mytilina ventralis* (Ehrenberg)	+	+
16.	*Macrochaetus serica* (Thorpe)	–	+
17.	*Lepadella ovalis* Muller	–	+
18.	*Lecane curvicornis* Murray	+	+
19.	*Lecane lauterborni* Hauer	+	–
20.	*Lecane leontina* (Turner)	+	–
21.	*Lecane luna* (Muller)	–	+
22.	*Lecane papuana* (Murray)	+	–
23.	*Lecane ungulata* (Gosse)	+	–
24.	*Lecane bulla* (Gosse)	+	+
25.	*Lecane clostocerca* (Schmarda)	–	+
26.	*Lecane tethis* (Harring & Myers)	–	+
27.	*Cephalodella* sp.	–	+
28.	*Scaridium longicaudum* (Muller)	–	+
29.	*Trichocerca pusilla* (Jennings)	+	–
30.	*Asplanchnopus bhimavaramensis* Dhanapathi	+	–
31.	*Filinia opoliensis* (Zach.)	+	–
32.	*Filinia terminalis* (Plate)	+	–
33.	*Testudinellidae* patina (Hermann)	–	+
34.	*Filinia mucronata* (Gosse)	+	+
Cladocera			
35.	*Diaphanosoma sarsi* Richard	–	+
36.	*Daphnia cornuta* (Jurine)	–	+
37.	*Scapheloberis kingi* Sars	–	+
38.	*Moina micrura* Kurz	+	–
39.	*Macrothrix spinosa* King	–	+
40.	*M. laticornis* (Jurine)	–	+
41.	*Echinisca triserialis* (Brady)	–	+
42.	*Ilyocryptus spinifer* Herrick	+	+
43.	*Chydorus sphaericus* (O.F. Muller)	–	+
44.	*C. parvus* (Daday)	+	–
45.	*C. barroisi* Richard	+	+
46.	*C. ventricosus* Daday	+	+

(continued)

Table 3.4 (continued)

Sl. no.	Species	Pocharam Lake	Wyra Lake
47.	*C. reticulates* Daday	+	−
48.	*Alona rectangula rectangula* Sars	+	+
49.	*A. rectangula richardi* (Stingelin)	+	+
50.	*A. davidi davidi* Richard	+	+
51.	*A. davidi punctata* (Daday)	−	+
52.	*A. costata* Sars	+	−
53.	*A. pulchella* King	−	+
54.	*Kurzia longirostris* Daday	+	−
55.	*Camptocercus rectirostris* Schoedler	−	+

were compared. The shallow littoral regions and also nearby limnetic zones play a host to a wide variety of the two zooplankton communities under study, viz. Rotifera and Cladocera. Rotifera (34 species) ranked one in order of abundance followed by cladocerans (21 species) in both lakes. There are 34 species belonging to 14 genera of Rotifera and 21 species belonging to 11 genera in both lakes. In Pocharam Lake 24 species belonging to 9 genera of rotifers and 11 species belonging to 5 genera of cladocerans were observed, whereas in Wyra Lake 20 species belonging to 10 genera of rotifers and 16 species belonging to 9 genera of cladocerans were noticed. There are also 10 species belonging to 6 genera to rotifers and 6 species belonging to 3 genera of cladocerans that are commonly available in both lakes.

Among the Cladocera, chydorids, which are well known to occur in littoral vegetated zone of freshwaters in general, have dominated qualitatively in both lakes. The species like *Moina micrura, Chydorus parvus, C. reticulates, Alona costata and Kurzia longirostris* are available in Pocharam Lake only. Of the 24 species of rotifers available in Pocharam Lake, *Brachionus angularis, B. caudatus, B. calyciflorus* f. *anuraeiformis, B. calyciflorus borgerti, B. calyciflorus* var. *dorcas, B. plicatilis, Lecane (L) lauterborni, L. (L) luna, L. (L) papuana, L. (L) ungulata, Trichocerca pusilla, Asplanchnopus bhimavaramensis, Filinia opoliensis* and *F. terminalis* are available in Pocharam Lake only.

The species like *Brachionus calyciflorus* var. *hymani, B. patulus, Macrochaetus serica, Lepadella ovalis, Lecane (L) luna, L. (M) clostocerca, L. (M) tethis, Cephalodella* sp. and *Testudinellidae patina* are available in Wyra Lake only. Similarly, the cladocerans like *Diaphanosoma sarsi, Ceriodaphnia cornuta, Scapheloberis kingi, Macrothrix spinosa, Echinisca triserialis, Chydorus sphaericus, Alona davidi punctata* (Daday), *Alona pulchella* King and *Camptocercus rectirostris* are available in Wyra Lake only.

In Wyra Lake the rotifers showed high diversity represented by families, viz. Brachionidae, Mytilinidae, Trichocercidae, Colurellidae, Lecanidae, Notommatidae and Testudinellidae, out of which Brachionidae and Lecanidae equally dominated with eight species each and the rest are representatives only. Among the cladocerans in Wyra Lake, chydorids have dominated with nine species, and the rest are representatives only.

Rotifers formed the most dominant plankters of Pocharam Lake and showed higher diversity and are represented by families, viz. Brachionidae (nine species), Mytilinidae, Trichocercidae, Asplanchnidae and Testudinellidae (one species each), Lecanidae (six species) and Filinidae (two species). Cladocerans in Pocharam Lake were represented by the families Chydoridae (nine species), Moinidae and Macrothricidae (one species each).

Among the Rotifers in Pocharam Lake, brachionids dominated the rest of the taxa, represented by three genera, viz. *Brachionus, Keratella and Platyias.* Out of the three brachionid genera, *Brachionus* was constituted by eight species with three varieties/forms; the genera *Keratella* and

Platyias were represented each with one species. The other important group, Lecanidae, was represented by six species of the genus *Lecane*. In general, most of the tropical alkaline waters are dominated by the genus *Brachionus* as it has got adopted with its large number of species, subspecies and polymorphs to the alkaline conditions of the waters. The second dominant group, Cladocera, has been represented with 11 species belonging to the Chydoridae family with three genera, viz. *Chydorus* and *Alona* each with four and *Kurzia* with one species. The other two families, Moinidae and Macrothricidae, got one species each.

Brachionus diversicornis, B. falcatus, B. quadridentatus, Platyias quadricornis, Lecane (Lecane) curvicornis, L. (Monostyla) bulla and *Testudinellidae mucronata* among rotifers and *Ilyocryptus spinifer, Chydorus barroisi, C. ventricosus, Alona rectangula rectangula*, *A. rectangula richardi* and *A. davidi davidi* are available in both lakes.

As is quite obvious from the above results, these two impoundments differed significantly in their limnological attributes, and these two can be categorized as oligotrophic lakes. In general, these two lake waters showed seasonality in most of the physico-chemical factors which mainly depend on the monsoon, i.e. insufficient rains or heavy rains in the preceding periods. The physico-chemical parameters of both lakes are also indicating that these two are clean waters, but abnormal values of the nutrients indicate that these are slightly polluted, and the reason can be attributed to agricultural runoff or anthropogenic activities. Both lakes were characterized by highly alkaline, soft to hard, moderate turbidity, and the chloride content of these two water bodies indicates their potability.

The parameters like pH, turbidity, dissolved oxygen (DO), carbonates and silicates are at higher side in Pocharam Lake than the other, whereas factors like electric conductivity, bicarbonates, chloride, phosphates, sulphates, sodium and potassium of Wyra Lake were at side but total hardness and calcium are more or less equal both the water bodies. The reasons for the variations in the levels of ranges of physico-chemical parameters of both lakes can be attributed to the differences in the quantum of rain fall, domestic sewage that is letting into the water bodies, agricultural runoff, anthropogenic activities at the lake basins, etc. during the study periods.

Summary

Studies on the comparative study on physico-chemical and biological characteristics with special reference to Rotifera and Cladocera of two Deccan wetlands, viz. Pocharam Lake and Wyra Lake, that are situated in Andhra Pradesh have been carried out during 2003–2004 and 2006–2007. These studies were conducted on seasonal basis, i.e. during the winter, summer and monsoon periods. The abiotic factors revealed that the parameters like pH, turbidity, DO, carbonates and silicates are at higher side in Pocharam Lake waters than the other and factors like electric conductivity, bicarbonates, chloride, phosphates, sulphur, sodium and potassium of Wyra Lake waters are at higher side. But total hardness and calcium values are more or less equal in both lakes. The biotic factors revealed the presence of 24 species belonging to 9 genera of Rotifera and 11 species in 5 genera in Pocharam Lake, while in Wyra Lake it was 20 species under 10 genera of Rotifers and 16 species belonging to 9 genera of cladocerans.

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References

Anitha G, Chandrasekhar SVA, Kodarkar MS (2005) Hydrography in relation to benthic macroinvertebrates in Mir Alam lake. Records of the Zoological Survey of India, Hyderabad, Occ. paper 235

Chandrasekhar SVA (1996) Ecological studies on Saroornagar lake, Hyderabad. PhD thesis, Osmania University, Hyderabad

Chandrasekhar SVA (2006) Zooplankton: Pocharam lake, Andhra Pradesh. Rec Zool Surv India (submitted for publication)

Chandrasekhar SVA, CA Nageswara Rao (2006) Introduction and limnology: Pocharam lake, Andhra Pradesh. Rec Zool Surv India (submitted for publication)

Jaya Devi M (1985) Ecological studies of Limnoplankton of three fresh water bodies of Hyderabad. PhD thesis, Osmania University, Hyderabad

Malathi D, Chandrasekhar SVA, Kodarkar MS (2003) Ecological studies on Hussain Sagar lake, Hyderabad with special reference of Zooplankton communities. Records of Zoological Survey of India, Kolkata (in press)

Munawar M (1970) Limnological studies on freshwater ponds of Hyderabad I. The biotope. Hydrobiologia 25(1):127–162

Patil SG, Panda P (2003) Limnological studies of a freshwater fish tank, Bibi Nagar tank Part-I. Abiotic factors. Rec Zool Surv India 96(1–4):173–178

Ratna Rao (1984) Studies on limnological aspects of lake Kondakarla (Visakhapatnam) with special reference to plankton and periphyton. PhD thesis, Andhra University, Visakhapatnam

Siddiiqi SZ, Khan RA (2002) Comparative limnology of few-man-made lakes in and around Hyderabad, India. Records of Zoological Survey of India, Occ. paper no. 203

Venkateshwarlu V (1969) An ecological study of algae of Musi, Hyderabad with special reference to water Pollution II factors including distribution of algae. Hydrobiologia 33(3–4):352–363

Venu P (1981) A Limnological aspects of lake Kondakarla. PhD thesis, Andhra University, Visakhapatnam

Zafar AR (1966) Limnology of Hussain Sagar lake of Hyderabad. Phykos 5(1&2):115–126

4 Spatial Distribution of Benthic Macroinvertebrate Fauna in Mountain Streams of Uttarakhand, India

Prakash Nautiyal, Asheesh Shivam Mishra, and Vijay Prakash Semwal

Abstract

The large-scale (regional) distribution pattern for the benthic macroinvertebrate fauna has been investigated for the first time in the west Himalayan streams. The macroinvertebrate fauna in the river basins of Uttarakhand region consists of Trichoptera, Ephemeroptera, Diptera, Coleoptera and Plecoptera. The faunal composition varied from the western (Yamuna) to eastern part (the Ramganga) of the Himalaya as the share of Trichoptera and Ephemeroptera is relatively low in the Yamuna river basin but dominates from Bhagirathi to Ramganga basin. The marginal increase of Diptera, Coleoptera and Mollusca in the Yamuna basin accounted for the decline of Trichoptera and Ephemeroptera in this basin. Leptoceridae and Glossosomatidae are the dominant taxa in the river Alaknanda and Mandakini, respectively, while Glossosomatidae and Philopotamidae are simultaneously dominant in the Bhagirathi, all trichopterans. Heptageniidae is dominant in the Ramganga and Yamuna, while Heptageniidae and Glossosomatidae are simultaneously dominant in the Pindar. The taxonomic composition is similar in the basins; Bhagirathi (Mandakini and Alaknanda), Yamuna and Ramganga, Pindar. The characteristic taxa varied among the forest type. No taxa are characteristic to Deodar forest. The characteristic taxa varied from oak in the west to pine forest type in the east. The scrapers (Blephariceridae, Limnephilidae, Planorbidae, Lymnaeidae), predators (Dixidae, Perlidae) and gatherers (Ephemerellidae, Baetidae, Hydropsychidae) characterised the pine forest. Similarly, the shredders (Leptoceridae) and filterers (Simuliidae) characterised the oak

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forest, while the scrappers (Elmidae, Dryopidae) and predators (Rhyacophilidae, Agrionidae) the pine–oak forest. Trichoptera is abundant in the forest as well as forest–agriculture land use. They functioned as shredders, collectors and gatherers in the former, whereas collectors, gatherers, filterers in the forest–agriculture land use. Scrapers (mainly Ephemeroptera) occurred in very low percentage in the forest–agriculture land use. Slope is observed to be an important environmental variable influencing taxonomic composition and distribution of caddisfly with case (Limnephilidae, Leptoceridae, Philopotamidae) along with mayfly (Leptophlebiidae, Baetidae) and stonefly (Perlodidae). As slope is a manifestation of altitude, it indirectly indicates the role of altitude and hence the forest.

Keywords
Forest type • Himalaya • Ordination techniques • Slope • Trichoptera

Introduction

Odum (1996) classified organisms in water according to their life form or life habit based on their mode of life into the following:

1. Periphyton or Aufwuchs, the organisms (both plant and animals) attached or clinging to streams and leaves of rooted plants or other surface projecting above the bottom.
2. Plankton, the free-floating microscopic organisms of plant or animal origin, which remain at the mercy of the current and associated with water–water interface.
3. Benthos, the floral or faunal components that dwell on the bottom or in the bottom sediments of the stream and are associated with solid–water interface.
4. Neuston, the organisms associated with air–water interface and resting or swimming on the surface of water.
5. Nekton, the fauna associated with water–water interface capable of performing active locomotion as they have powerful locomotory organs (e.g. fishes).

The rivers are characterised by their unidirectional flow and thoroughly mixed waters (Patrick 1948). Cooper et al. (1998) state that streams are characterised by a unidirectional flow, and solutes, detritus, sediments and organisms are constantly delivered from upstream to downstream areas. Odum (1996) is of the view that current velocity is the major limiting factor in the lotic environment. Thus streams generally exhibit two major communities, rapids and pools; within these broad categories the type of bottom whether sand, pebbles, clay and bedrock determines the nature of the communities and the population density of community dominants. The biota of a river channel resembles that of the rapids, except the population distribution is highly "clumped" owing to the frequent absence of firm substrates.

The feeding relationships and other interactions form a complex whole often referred to as the biological community. Community is usually applied to a group of populations that occur together, but there ends any similarity among definitions. Ecologists also define communities on the basis of interactions among associated populations. This is a functional rather than descriptive use of the term. Community itself is a wide term with various meanings, but essentially it is used to denote a collection of species, living together, and usually linked to a particular habitat. Kendeigh (1980) considered community or biocenose as an aggregate of organisms, which form a distinct ecological unit. Association is sometimes used for group of populations that occur in the same area without regard to their interactions; community however denotes an association of interacting population (Ricklefs 1990). Begon et al. (1995) considered community as an assemblage of species population which occurs together in space and time. Odum (1996) defined community as any assemblage area of populations living in a prescribed area or physical habitat; it is an organised unit to the extent that it has characteristics additional to its individual and population components and functions as a unit through coupled metabolic transformation. Communities not only have a definite functional unity with characteristic trophic structures and patterns of energy flow but they also have compositional unity in that there is certain probability that certain species will occur together. However species are to a large extent replaceable in time and space so that functionally similar communities may have different species composition.

Distribution is the geographical extent of population or other ecological units. Primarily the presence or absence of suitable habitat condition determines its range. Individuals in a population may be distributed according to three broad patterns – random, uniform and clumped. Random distribution is relatively rare in nature, occurring where the environment is very uniform and there is no tendency to aggregate. Uniform distribution may occur where competition between individuals is severe or where there is positive antagonism, which promotes even spacing. Clumping or aggregation results from social tendencies of individuals to form groups, the clumped distributions of resources, and the tendency of progeny to remain in the vicinity of their parents (Ricklefs 1990). Odum (1996) stated that determination of the type of distribution, of the degree of clumping (if any) and of the size and permanence of groups is necessary if a real understanding of the nature of a population is to be obtained and especially if density is to be correctly measured. Thus, sampling methods and statistical analyses which would be quite sound for random or uniform distribution might be entirely inadequate or misleading when applied to strongly clumped distribution.

Considerable interest has been generated on distribution of communities in a variety of water bodies. A fundamental task of community ecology is to identify factors that determine the relative abundance and distribution of species so that factors that structure one community may be useful in predicting another, given similar environmental components (Seifert 1984). The distributional patterns of organisms are controlled by dispersal mechanisms, historical factors (connecting pathways, dispersal barriers) and tolerance to environmental factors (Carter et al. 1980). Wilbur and Travis (1984) group the description of species patterns into two study types: species association within replicated physical environments along environmental gradients (Whittaker 1967) or along derived multifactorial gradients (Gauch 1989).

Research efforts have focused on macro distributional patterns of benthic invertebrate communities within drainage basin (Hawkes 1975) and in larger biogeographical studies within and among drainage basins (Wright et al. 1984; Corkum and Curries 1987; Moss et al. 1987). In developing the River Continuum Concept, Vannote et al. (1980) used drainage basin as a framework within which a continuously integrated series of physical gradients along a river are associated with changes in functional feeding mechanisms of invertebrates. However, difficulties occurred and modifications are necessary when applying this scheme to the lotic systems located in different biomes (Wiggins and Mackay 1978; Minshall et al. 1985) and to rivers in other parts of the world (Winterbourn et al. 1981). A patchy (contagious) distribution of insects is a common feature of aquatic habitats (Minshall and Minshall 1977) and probably is frequently a result of the patchiness of the substrate. Little effort has been made to document this for either plant or mineral substrates, but the works by Jonasson (1948), Ulfstrand (1967), Resh (1976, 1979) and Lamberti and Resh (1979) are notable exceptions and generally support this causal hypothesis. Such studies have been initiated recently in the Himalayan streams, which are of global importance to biodiversity (Ormerod et al. 1994; Suren 1994; Rothfritz et al. 1997; Cantonati et al. 2001; Nautiyal et al. 2004). Biodiversity in the Himalayan mountains is globally significant due to pronounced endemism, habitat heterogeneity and biogeographic location (Myers 1990; Myers et al. 2000).

In the mountain streams of India, spatial scales have been examined with respect to small patches within a single stream (Badola and Singh 1981; Nautiyal 1984, 1986; Negi and Singh 1990; Gusain 1994; Kishor et al. 1998; Kishor et al. 2004) or longitudinally (Singh and Nautiyal 1990; Singh et al. 1994; Gusain 1994; Nautiyal et al. 1996, 1997a; Julka et al. 1999). The patterns of distribution at larger scales are not known in the Himalaya. Therefore, this study focused on distribution patterns of benthic macroinvertebrate community at the basin scale and longitudinally for some streams in the Uttarakhand. Mountains present an entirely different landscape as they provide biome gradations analogous to latitude differences. It remains to be seen if the structuring force is retained in the biomes analogous to forest type vis-a-vis subbasins or the effect of altitude overrides it. The influence of land use has also been assessed.

Study Area

Location The study area extended from Yamuna to Ramganga basin in the state of Uttarakhand (Fig. 4.1). The Lesser Himalayan stream basins selected for study included Yamuna, Bhagirathi (including Bhilangana), Alaknanda, Mandakini, Pindar and Ramganga (Saryu–Gomti). The latitude decreases from 30° N in the Yamuna basin to 29° N to the Ramganga basin. Streams in different land use and forest types are selected (Table 4.1), especially intensively cultivated areas both in the hills and foothills and forested areas [pure oak and pine forests, mixed forests]. The benthic macroinvertebrate community is sampled at seasonal intervals from over 10 subbasin and 77 mountain streams of different orders (3rd–5th).

Geology The geology of the Himalaya is vast and varied. The Himalayas' main axis is formed c. 25–70 Ma ago as the earth's crust folded against the northward-moving Indian subcontinent (Columbia Encyclopedia, 6th edition 2001.htm). The Greater Himalaya (*Himadri*) lies above the main central thrust; the Lesser Himalaya (*Himanchal*) is separated from the *Himadri* by the 'main central thrust' in the north and by the 'main boundary thrust' in the south, consisting of high mountains cut into deep ravines and precipitous defiles; and the Sub-Himalayan tract (*Sivalik*) – the foothill belt of the region – consists of the latest geological formation of loose boulders and soil. The Greater Himalaya is composed of central crystallines, generally granite and gneisses, quite hard and resistant to weathering. The Lesser Himalaya is mostly composed of crystalline and metamorphic rocks – gneisses – and schists, with unfossiliferous sedimentary Purana and Mesozoic deposits (Valdiya 1962).

Climate In the Himalaya the topographical variations do not straightaway correlate with the latitudinal or continental trends. Also the precipitation changes from rain to snow from the Outer to Greater Himalaya. Therefore, many rivers have glaciers at their source, which renders their water cold. Spatial average rainfalls are 1,472 mm for Terai/Bhabar, 1,782 mm for the Sivalik ranges, 1,591 mm for the Lesser Himalayas and 1,635 mm for the Greater Himalayan region. The mean aerial rainfall in the region is 1,608 mm (Basistha et al. 2008).

Vegetation The Himalayan rivers flow through a cross section of biomes. The vegetation of Garhwal is usually divided into three main zones (i) submontane zone (Sivalik 1,500 m), (ii) montane zone (1,500–3,300 m) and (iii) alpine zone (3,100–7,300 m) (Rawat et al. 2001). There is a considerable change in the vegetation from alpine to submontane zone. The alpine is

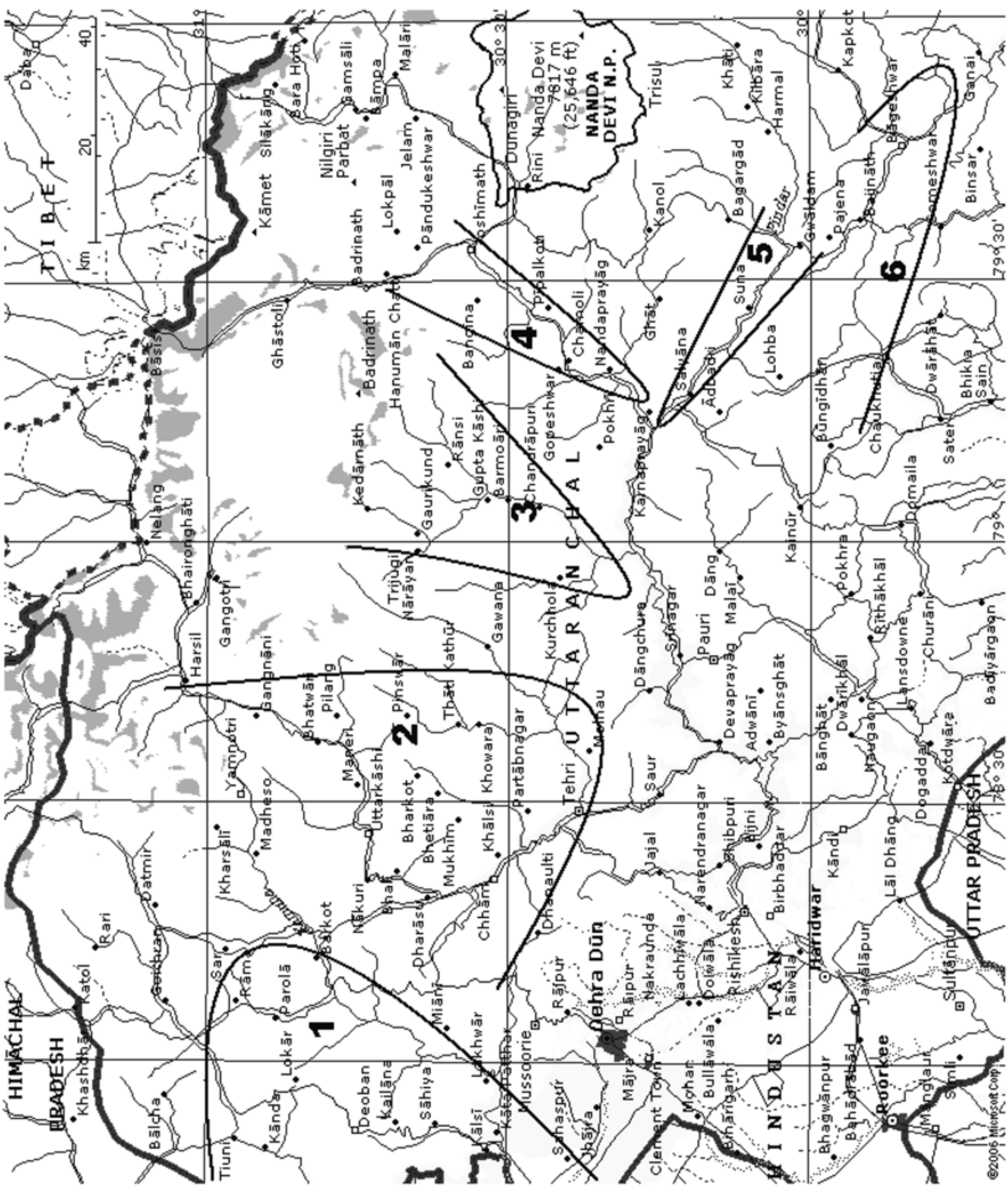

Fig. 4.1 Map of the Uttarakhand region showing major basins selected for sampling the streams for collecting the benthic macroinvertebrate community. Encircled region indicates the location of sampled basin/streams

Table 4.1 Geographical location, stream order and land-use patterns of the streams in the subbasins of the Ganga and Yamuna river systems in the Kumaon and Garhwal regions of Uttarakhand

Basins/streams	Altitude (m)	Latitude (N)	Stream order	Number of stream sampled in different land uses in the subbasins F	F–A	A
Yamuna/R, S, T, N	800–2,000	30° N	II–V	7	–	–
Ganga	450–3,000	29° N	II–IV	4	2	1
Bhagirathi/H, K, D, B	450–2,620	30° N	II–VI		9	–
Bhilangana/Bh, N	817–1,000	30° N	II–V		2	–
Alaknanda/BG, AG, Ba, Ta, M	450–1,900	30° N	II–VI	2	7	–
Nandakini	880–1,000	30° N	II–V	2	2	–
Mandakini/Da, Ka, Si, Ku, L, SG	620–2,440	30° N	II–V	7	11	–
Pindar/A, PN, PS	750–1,000	30° N	II–V		7	–
Ramganga/R1, R2	>1,000	29°–30° N	II–V	5	2	–
Saryu	>1,000	29°–30° N	II–IV	4	3	–

Acronyms: *A* agriculture, *F* forest, *R* Rupin, *S* Supin, *T* Tons *N* Naitwar (Rupin, Supin are parent rivers forming Tons), *H* Harsil Gad, *K* Kaldi Gad, *D* Dharasu Gad, *B* Bhagirathi (Dharasu), *Bh* Bhilangana, *N* Nailchami, *BG* Birahi Ganga, *AG* Amrit Ganga, *Ba* Balasuti, *Ta* Tapovan, *M* Mana, *Da* Damar, *Ka* Kaidung, *Si* Sitapur, *Ku* Kunja, *L* Laster, *SG* Saraswati Ganga, *A* Atta Gad, *PN* Pindar Narayanbagdh, *PS* Pindar (Simli), *R1* Chaukhutia, *R2* Dwarahat

characterised by *Rhododendron campanulatum* D. Don and *Juniperus squamata* Buch.-Ham., while the high montane by *Quercus semicarpifolia* Sm., *Betula utilis* D. Don and *Rhododendron arboretum* Sm.; montane by *Quercus incana, Cedrus deodara* Loud. and *Pinus wallichiana* Jacks; and submontane by *Quercus incana* and *Myrica nagi* D. Don (Sundriyal 1995). The upper catchment of the Ganga river system below the snowline is forested, and the middle catchment/lower catchment is devoid of dense forests due to a wide variety of anthropogenic activities in the Alaknanda basin.

Land Use Forest is the major land use in the Himalaya. Scattered small settlements surrounded by agricultural fields, primarily for subsistence[1] except for pockets of apple, apricot, citrus, peach and walnut orchard, constitute the other major form of land use. The crops depend on rain in the terraced fields along the high mountain slopes and on irrigation in the valleys. The region lacks major industries. A 30-year-old dam exists at Maneri on the Bhagirathi, and a 8-year-old dam at Tehri after confluence with the Bhilangana. A dam has recently (year 2007) come up on the Alaknanda at Vishnuprayag. Human settlements of larger magnitude (district headquarters) exist around 1,000 m elevation. As the mountain climate and terrain becomes increasingly hospitable below this elevation, subsistence agriculture and a number of small settlements also enhance. One major human settlement exists along the Alaknanda River and two along the Bhagirathi. Industrial and municipal discharges join the river, human settlements become larger and agriculture becomes commercial as habitation increased in the foothills. The industries include distilleries, glass factories, heavy engineering and pharmacy. Run-of-the-river projects are proposed/under construction on the Alaknanda, Bhagirathi and the Ganga downstream of Devprayag. The Ganga has been extensively

[1] Paddy, millets, maize and pulses (leguminous) are the major traditional *kharif* (April–October) crops while wheat, barley, mustard, lentils and peas are *rabi* crops (October–March) [Semwal R. L., Maikhuri R. K. and Rao K. S. 2001. In: Eds Kandari, O. P. and Gusain O. P., Garhwal Himalaya: Nature, Culture and Society. p. 259–276].

regulated in the foothill stretch between Rishikesh and Hardwar.

Physical and Chemical Characteristics of Rivers

The following characteristics are recorded:

Map variables: Latitude (N°), altitude (metre; above sea level), slope (metre), vegetation, land use, distance to source (metre).

Site variables: Stream width (m), mean current velocity (ms^{-1}), mean depth (m), substrate, solar radiation, water temperature, pH, dissolved oxygen, and aquatic vegetation. The air and water temperature are recorded with the help of a mercury thermometer and compared with the help of a digital temperature probe. Flow is measured with the help of digital EMCON current metre. pH is measured with the help of digital pocket pH metre and DO is measured with the help of Aquamerck kit and verified by titrimetric Winkler's method.

Sampling: Benthic Macroinvertebrate Fauna

Benthic macroinvertebrates are sampled in 5 quadrates of 1 ft^2 each. The substratum in the form of small boulders, cobbles and pebbles is lifted carefully from the marked area and washed in a bucket full of water by dipping it a number of times to dislodge the attached fauna. The fauna that remained attached to the substrate surface is removed with the help of brush. The bucket water is filtered through a 0.5 mm sieve to retain benthic macroinvertebrates (Singh and Nautiyal 1990; Habdija et al. 1997). The samples are preserved in 5 % formalin for further analysis. Various benthic taxa are identified to family level with the help of different keys (Burks 1953; Pennak 1953; Edmundson et al. 1976; Macan 1979). Family-level studies have been successfully used to describe biogeographical patterns across large areas (Corkum 1989). Relative abundance of various taxa at above-stated sites during each month is computed as percentage of total benthic macroinvertebrate count from five samples to determine the macro- and microdistribution patterns in the various subbasins of the western Himalaya. The count data is subjected to cluster analysis (statistic aver. 5.0) and multivariate analysis using software (ter Braak and Smilauer 2002).

Benthic Invertebrate Fauna and Communities in Different River Basins

The benthic macroinvertebrate assemblages are represented by 31 taxa (families) from 6 insect and 1 gastropod order. The majority of insect taxa belonged to the order Trichoptera (8 families) and Ephemeroptera (6 families), followed by Coleoptera (5 families), Diptera (4) and Plecoptera (2), while the gastropod are represented by 2 families (order Basommatophora). Ephemeroptera, Trichoptera, Diptera and Plecoptera are the major components of the benthic macroinvertebrate community in the mountain streams (Hynes 1970; Winterbourn and Ryan 1994), as also observed earlier in the rivers of Himalaya, Alaknanda (its tributary Khanda Gad), Bhagirathi and Ganga (Nautiyal 1986; Singh and Nautiyal 1990; Kumar 1991; Singh et al. 1994; Nautiyal et al. 1997a, 2004) and the Central Highlands, Ken, Paisuni and Tons (Nautiyal et al. 2007).

Among the invertebrate orders the relative abundance of Trichoptera is relatively higher in all the basins. Highest abundance is recorded for Pindar (45 %), followed by Alaknanda (41 %), Mandakini (39 %), Bhagirathi (39 %), Ramganga (32 %) and Yamuna (31 %; Fig. 4.2). Notably, instead of a similar share of Trichoptera in the benthic community or gradient of increase or decrease from east to west or vice versa, their share (relative abundance) is considerably higher in the basins located between the Ramganga and Yamuna. Among the basins Trichoptera is the abundant taxon in all streams/rivers of the Pindar, Alaknanda, Bhagirathi (except Dharasu), Mandakini (except Damar) and Ramganga basins. However, in the Yamuna basin, Trichoptera is abundant in the Yamuna and Tons tributary at Naitwar and Ephemeroptera in the Rupin and Tons, while Ephemeroptera and Trichoptera

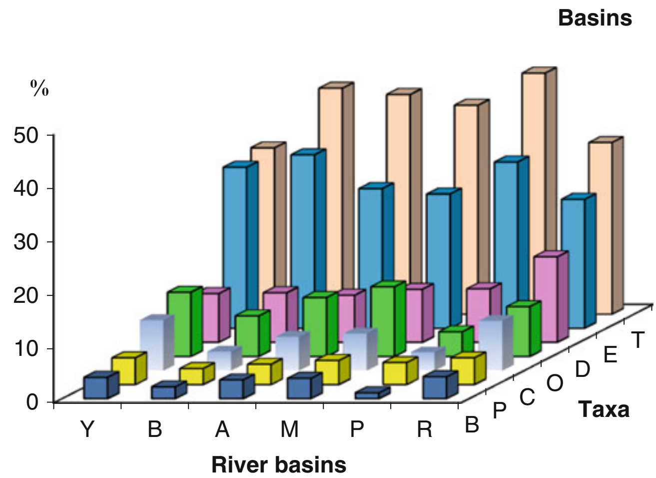

Fig. 4.2 Taxonomic composition of benthic macroinvertebrate community (order level) among the different basins of the Himalayan region (acronyms: River basins; *A* Alaknanda, *B* Bhagirathi, M Mandakini, *P* Pindar, R Ramganga, *Y* Yamuna, Taxa; *B* Basommatophora, *C* Coleoptera, *D* Diptera, *E* Ephemeroptera, *O* Others, *P* Plecoptera, *T* Trichoptera)

are equally abundant in the Supin. Decrease in the relative abundance of Trichoptera corresponded to increase of Ephemeroptera at all the locations (Fig. 4.3). Besides, the abundance of Ephemeroptera marginally exceeds that of Trichoptera. In contrast, the abundance of Trichoptera is considerably higher than Ephemeroptera.

Trichoptera is dominating in the pine and pine-dominating forest types in most of the streams of all the river basins except Rupin and Supin (in the Yamuna basin), Dharasu Gad (Bhagirathi basin) and Damar Gad (Mandakini basin) where Ephemeroptera is dominant. Functionally, all Trichoptera recorded during the study are shredders and collectors which process the coarse particulate organic matter (CPOM) so important to the detritus chain. On the other hand most of the Ephemeroptera observed are basically scrapers, and only few feed on the FPOM component of the detritus. Diptera is abundant after Ephemeroptera and Trichoptera in the Yamuna, Bhagirathi, Pindar and Ramganga basins. The relative abundance of Trichoptera is higher with respect to Ephemeroptera in all river basins examined during the study (Table 4.2).

This is quite contrary to the observation that the relative abundance of Ephemeroptera exceeds Trichoptera in glacier-fed Himalayan rivers, the Bhilangana (Man Mohan and Bisht 1991), the Ganga near the foothills at Hardwar (Nautiyal et al. 1997b) and the Bhagirathi (Nautiyal et al. 2007), while Diptera is abundant in the Alaknanda (Nautiyal et al. 2004). The spring-fed Himalayan streams are also dominated by Ephemeroptera, Khanda Gad (Kumar 1991), Alikhad stream (Joshi 1994) and the Gaula (Sunder 1997), while Trichoptera is the abundant taxon in the headwater zone of Vindhyan (Central Highlands) river Paisuni (Shivam 2006). Contrarily, Ward (1994) observed that Ephemeroptera precede Trichoptera in the alpine glacier-fed streams. Thus, headwaters are not necessarily dominated by Trichoptera, nor do they appear to be related to lower temperatures in the alpine zone. The higher relative abundance of Trichoptera in this study could be attributed to the fact that most of the locations studied earlier are located below 800 m above sea level compared with an elevation range of 800–2,000 m asl which is also quite below the alpine zone. As forest is usually the major land use in these elevations, the abundance of Trichoptera seems reasonable as they feed on the coarse to fine particulate organic matter generated from the forest detritus, thus functioning as shredder, collector and gatherer in the detritus food chain.

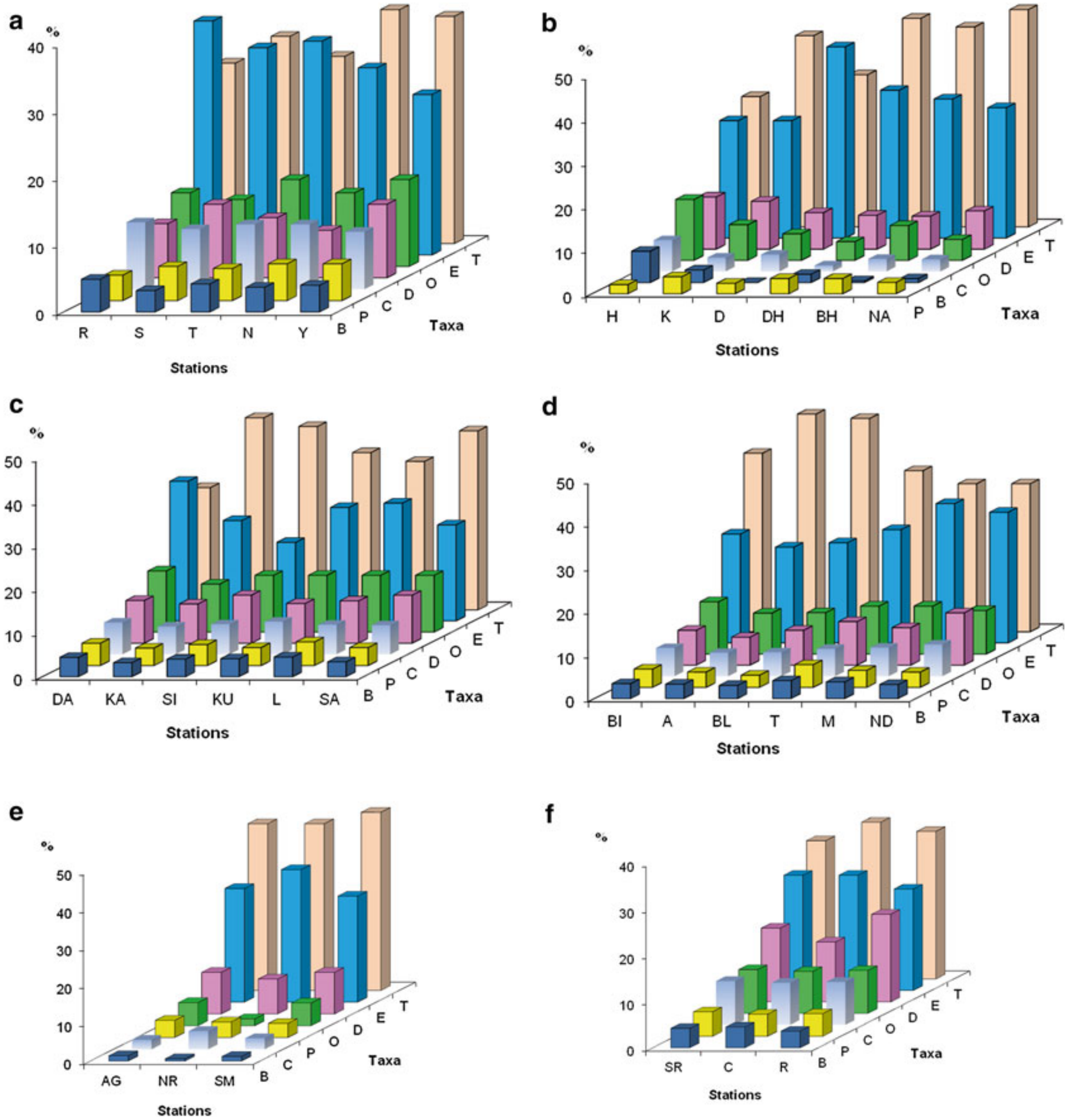

Fig. 4.3 Taxonomic composition of benthic macroinvertebrate community (order level) within different basins of the Himalayan region. (**a**) Yamuna basin. (**b**) Bhagirathi basin. (**c**) Mandakini basin. (**d**) Alaknanda basin. (**e**) Pindar basin. (**f**) Ramganga basin

Benthic Invertebrate Fauna and Communities in Different Forest Types

In the Yamuna basin, the oak and deodar forest streams are characterised by Ephemeroptera, while pine–oak and oak–deodar–fir are characterised by Trichoptera, both being forest land use. The relative abundance of Ephemeroptera and Trichoptera is almost similar in this basin (Table 4.2). In the Bhagirathi basin, Trichoptera is dominant in the deodar–oak, pine–utees and even pine forest streams of this and Bhilangana basin. Ephemeroptera is also abundant in the pine forest (Dharasu Gad). In the Mandakini basin all forest types are dominated by the Trichoptera except

Table 4.2 Percentage composition of benthic macroinvertebrate fauna with respect to land use and forest type in major river basins in Uttarakhand

Basins	Basins	Forest	S-O	L-U	E	T	D	P	C	B	O
Yamuna	Rupin	O	II–V	F+A	35	27	8.1	3.8	10	4.9	11
	Supin	O		F+A	31	31	11	5.1	9	3.2	10
	Tons	D		F+A	32	28	9	4.8	9.7	4.2	13
	Naitwar	ODF		F+A	28	35	7.1	5.5	9.7	3.7	11
	Yamuna	PO		F+A	24	34	11	5.5	8.6	4	13
Average					30	31	9.1	5	9.4	4	12
Ganga/Bhagirathi	Harsil Gad	DO	II–VI	F+A	27	30	12	2.1	7.2	7.2	14
	Kaldi Gad	PU		F+U+A	27	44	11	3.9	3.2	2.9	8.2
	Dharasu Gad	P		F	44	35	8.4	2.4	3.9	0	6.1
	Bhagirathi (Dharasu)	P		F	34	48	7.8	3.5	1.4	1.9	4.3
Average					33	39	9.9	3	3.9	3	8.2
Bhilangana	Bhilangana	P	II–VI	F+A	32	46	7.6	3.5	2.9	0.4	8
	Nailchami	P		F+A	30	50	8.8	2.6	2.8	0.9	4.8
Average					31	48	8.2	3	2.9	0.6	6.4
Alaknanda	Birahi Ganga	P	II–VI	F+A	25	41	8	4.2	6.5	3.4	12
	Amrit Ganga	P		F	22	50	6.4	3.5	5.4	3.3	9.4
	Balasuti	O		F	23	49	8	2.8	5.5	3	9.5
	Tapovan	M		F	26	37	10	5.2	6.3	4.1	11
	Mana	M		F	32	34	8.6	3.9	6.6	3.8	11
	Nandakini	PO		F+U+A	30	34	12	3.5	7.3	3.2	10
Average					26	41	8.8	3.8	6.3	3.5	11
Mandakini	Damar	PO	II–V	F+A	32	28	9.8	5.1	7.3	4.4	14
	Kaidung	O		F	23	44	9	4	6.4	3.2	11
	Sitapur	O		F	18	42	11	4.8	6.9	4	13
	Kunja	–		A	26	36	9.1	4.1	7.5	4.1	13
	Laster	PO		F+A	27	34	9.7	5.4	6.8	4.5	13
	Saraswati Ganga	OP		F	22	41	11	4.1	6.7	3.4	13
Average					25	39	9.9	4.5	6.9	3.8	13
Pindar	Atta Gad	P	II–V	F+A	30	44	11	4.5	2.5	1.4	6.1
	Pindar NR	P		F+A	35	44	9.2	4.1	4.8	0.6	1.8
	Pindar (Simli)	P		F+A	28	47	11	3.7	2.9	1.2	6
Average					31	45	10	4.1	3.4	1.1	4.6
Ramganga	R1 Saryu	P	II–V	F+A	25	30	16	5.3	9.5	4.2	9.5
	R2 Chaukhutia	P		F+A	25	34	13	4.8	9.1	4.5	9.1
	R3 Dwarahat	P		F+A	22	32	19	4.9	9.3	3.6	9.3
Average					24	32	16	5	9.3	4.1	9.3

O oak; *D* deodar, *ODF* oak–deodar–fir, *PO* pine–oak, *U* utees, *M* alpine meadow, *S-O* stream order, *L-U* land use, *E* Ephemeroptera, *T* Trichoptera, *D* Diptera, *P* Plecoptera, *C* Coleoptera, *B* Basommatophora (Mollusca), *O* others

pine–oak (Damar stream) where Ephemeroptera is abundant. The Alaknanda basin with pine, oak, alpine meadow and pine–oak forest type is dominated by the Trichoptera. Pine forest is characterised by the abundance of Trichoptera in the Pindar and Ramganga basin also (Table 4.2). At family level, the dominant taxa included Heptageniidae and Baetidae in the Yamuna, Baetidae and Ephemerellidae in the Bhagirathi, Leptoceridae and Limnephilidae in the Alaknanda, Glossosomatidae and Baetidae in the Mandakini, Glossosomatidae and Heptageniidae in the Pindar and Simuliidae and Heptageniidae in the Ramganga (Table 4.3, Plate 4.1).

This change is due to reduction in food particle size from CPOM (coarse particulate organic matter) to FPOM (fine particulate organic matter) as the stream flows down from the origin. The oak forest is characterised by the shredders (Lepidoptera) and filterers (Simuliidae), which feed on CPOM and FPOM. Pine forest type is characterised by the scrapers (Blephariceridae, Limnephilidae), predators and gatherers (Ephemerellidae, Baetidae, Hydropsychidae) and filterers (Planorbidae, Lymnaeidae) which feed on periphyton, CPOM and FPOM, respectively. The pine–oak forest type is characterised by the scrapper (Elmidae, Dryopidae) and predator (Rhyacophilidae, Agrionidae), which feed on periphyton and CPOM, respectively. The forest types are known to govern the characteristic taxa in the streams draining them (Corkum 1992; Sivaramakrishanan et al. 1995).

By virtue of low nutrient concentration near the origin and headwater zone, the algal (primarily diatom) density (Nautiyal et al. 1997b) and hence their biomass and the primary production are low. The streams are thus largely heterotrophic in this zone and tend to become autotrophic towards the middle and lower zones near the foothills (Welcomme 1985; Cotta Ramusino et al. 1995). Headwater streams are heavily influenced by riparian vegetation, which is responsible for large-scale inputs of allochthonous nutrients while at the same time hindering autotrophic production by shading (Welcomme 1985). Owing to allochthonous nutrients in the headwaters, the detritus-feeding Trichoptera which function as shredders, gatherers and collectors are predominant.

The abundance of both Trichoptera and Ephemeroptera increased gradually from the eastern (the Ramganga) to the western river basins (the Bhagirathi), but declined further in the Yamuna basin where Diptera increased marginally. This pattern in the change of taxonomic composition may be explained by the prevailing forest types in the respective basins from east to west, i.e. pine (Ramganga and Pindar), pine–oak–meadow (Alaknanda and Mandakini), pine–oak–deodar (Bhagirathi) and oak–deodar–fir (Yamuna). In all these forest types only the families functioning as shredders, collectors, gatherers and filterers in the case of Trichoptera and collectors, gatherers, filterers and scrapers in the case of Ephemeroptera are abundant. The lattermost (scraper) is least abundant in the system indicating low autochthonous inputs and thus low levels of autotrophy. In all the basins Trichoptera and Ephemeroptera are followed by Diptera. Diptera increased in the Yamuna basin due to forest–agriculture land use, which may provide more FPOM necessary for the development of filterers.

Classification of the Basins Based on Invertebrate Faunal Composition

The cluster analysis revealed two broad groups among the river basins with respect to taxonomic composition observed in them. The first group comprised Mandakini and Bhagirathi, while the second cluster included three subgroups the Pindar, Yamuna–Ramganga and Alaknanda. The subclusters explained the grouping of similar streams. The Bhilangana (B5–B6), though a tributary of the Bhagirathi, clumped with Pindar. The Alaknanda is the third group (Fig. 4.4). The cluster also grouped together sites with similar forest and land use.

The cluster analysis revealed close similarity in the taxonomic composition (family level) of the Mandakini–Bhagirathi basin. There is weak similarity among the Ramganga and Yamuna basins, while the Pindar and Alaknanda basins are opposite extremes in this loose grouping. This suggests that similarity among the adjacent basins is not a rule and even distant basins can be similar. The similarity between the adjacent Mandakini and Bhagirathi basin due to identical climatic conditions supports the hypothesis that the localities in close proximity should be similar. The similarity among the distantly located basins, Ramganga (eastern extreme of Uttarakhand) and Yamuna (western extreme of Uttarakhand), and their similarity to the

Table 4.3 Percentage composition of benthic macroinvertebrate fauna in different Himalayan river basins

		Yamuna	Bhagirathi	Alaknanda	Mandakini	Pindar	Ramganga
Ephemeroptera	Heptageniidae	**6.97**	8.62	5.69	5.44	**9.49**	**7.14**
	Baetidae	**6.41**	**10.51**	5.82	**6.13**	8.49	5.17
	Ephemerellidae	5.34	**8.97**	4.69	4.20	4.75	3.59
	Leptophlebiidae	3.13	8.16	3.32	3.78	2.39	2.87
	Caenidae	3.87	7.32	3.79	3.46	2.74	2.95
	Siphlonuridae	2.61	6.52	2.50	3.21	2.39	2.95
Trichoptera	Hydropsychidae	5.02	5.78	4.56	4.49	6.70	6.87
	Philopotamidae	4.74	5.05	5.20	5.50	7.79	3.89
	Psychomyiidae	3.64	3.54	2.49	4.54	3.48	3.32
	Rhyacophilidae	1.37	3.40	1.45	1.80	0.00	1.55
	Glossosomatidae	4.48	3.36	6.47	**6.49**	**9.84**	2.95
	Leptoceridae	4.54	3.12	**9.33**	4.70	7.62	3.17
	Limnephilidae	4.19	2.56	**8.71**	4.83	7.27	4.91
	Brachycentridae	3.52	2.52	3.49	2.79	2.92	2.30
Diptera	Blephariceridae	2.44	2.42	2.09	2.45	1.18	2.38
	Chironomidae	2.68	2.10	2.84	2.43	5.79	2.53
	Simuliidae	2.44	2.00	1.98	2.81	2.70	**8.72**
	Dixidae	1.99	1.75	1.72	2.11	0.91	2.00
Plecoptera	Perlidae	2.59	1.40	1.96	2.54	2.26	2.57
	Perlodidae	2.54	1.37	1.80	2.29	1.87	2.53
Coleoptera	Sialidae	2.20	1.30	1.72	2.27	0.96	2.19
	Corydalidae	1.80	1.23	1.67	2.27	0.35	2.00
	Psephenidae	4.38	1.02	2.49	2.59	3.48	4.15
	Dryopidae	2.37	0.98	1.71	2.11	0.26	2.38
	Elmidae	2.47	0.91	2.06	2.29	1.13	2.72
Odonata	Gomphidae	2.20	0.88	1.77	2.04	0.35	2.15
	Agrionidae	2.03	0.88	1.77	2.07	0.44	2.04
Neuroptera		2.20	0.88	1.97	2.27	0.87	2.30
Hemiptera	Hemiptera	1.80	0.81	1.59	1.98	0.44	1.62
Basommatophora	Planorbidae	2.06	0.67	1.72	2.02	0.52	2.00
	Lymnaeidae	1.96	0.00	1.66	2.11	0.61	2.08

The dominant taxon is shown in *bold*

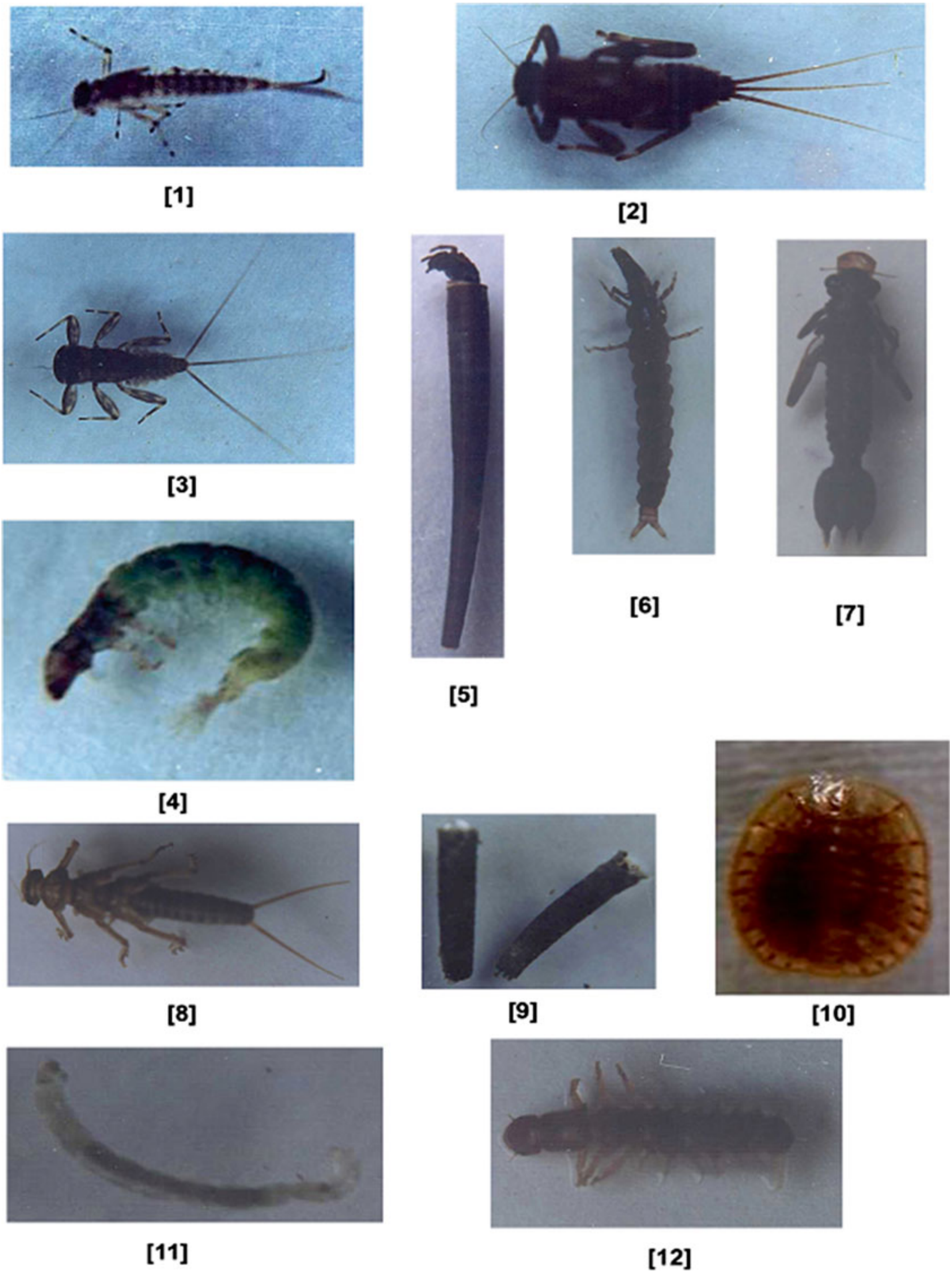

Plate 4.1 *1* Baetidae, *2* Caenidae, *3* Heptageniidae, *4* Hydropsychidae, *5* Leptoceridae, *6* Psychomyiidae, *7* Agrionidae, *8* Perlidae, *9* Limnephilidae, *10* Psephenidae, *11* Chironomidae, *12* Neuroptera

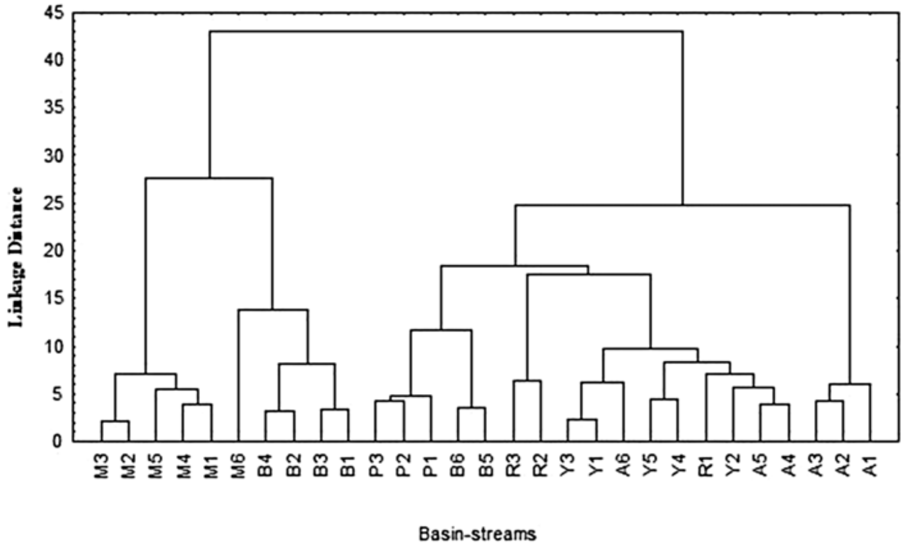

Fig. 4.4 Cluster analysis classified the Himalayan river basins in two broad groups with respect to taxonomic composition (acronyms: *A* Alaknanda, *B* Bhagirathi, *B* Bhilangana, *M* Mandakini, *P* Pindar, *R* Ramganga *Y* Yamuna)

Alaknanda basin distantly located from these basins, supports the alternate hypothesis (Corkum 1990) that even adjacent basins (Alaknanda and Pindar) can be dissimilar despite identical climatic and physiographic conditions and distant localities can be similar, as discussed below on the basis of Principal Component Analysis for the sites.

Both distantly located basins showed forest–agriculture-type land use resulting in similar food chain, which support the similarity between these basins. It seems that the similarity is influenced by factors, which become powerful at local scale, such as altitude as the river flows towards decreasing elevation. In conjunction with soil type, it would influence the vegetation. Since the streams are heterotrophic in headwaters, the type of vegetation together with the climatic conditions (by virtue of altitude) and slope of the stream, substrate type and discharge will be the structuring forces. Cluster analysis revealed similarity of taxonomic composition in Mandakini and Bhagirathi on one hand, while Ramganga (Pindar) and Alaknanda (Yamuna) on the other.

Characteristic Taxa in Relation to Forest Type and River Basins

No taxa are characteristic to the Tons – Rupin and Supin (Yamuna basin). In the Ramganga basin, Blephariceridae is distinctly characteristic to forest (pine)–agriculture land use. In the Pindar (Atta Gad and Pindar River) and the Bhagirathi basins (Bhilangana River, Dharasu Gad, Nailchami Gad), Limnephilidae is characteristic to forest (pine)–agriculture land use. However, in the Bhagirathi River (Bhagirathi basin), Glossosomatidae is characteristic to the forest (pine) land use.

In the Alaknanda basin, Brachycentridae is characteristic to the forest (oak) land use in the Balasuti Gad and forest (pine)–agriculture land use in Birahi Ganga. Dixidae and Perlidae are characteristic to forest (pine) land use in the Amrit Ganga (Alaknanda basin); Coleoptera and Perlodidae are characteristic to the forest (pine–oak) land use at Mana and forest (meadow) land use at Tapovan, while forest (deodar–oak–fir)–agriculture land use at Naitwar in the Yamuna basin. In the Nandakini River of this basin, Psychomyiidae and Elmidae

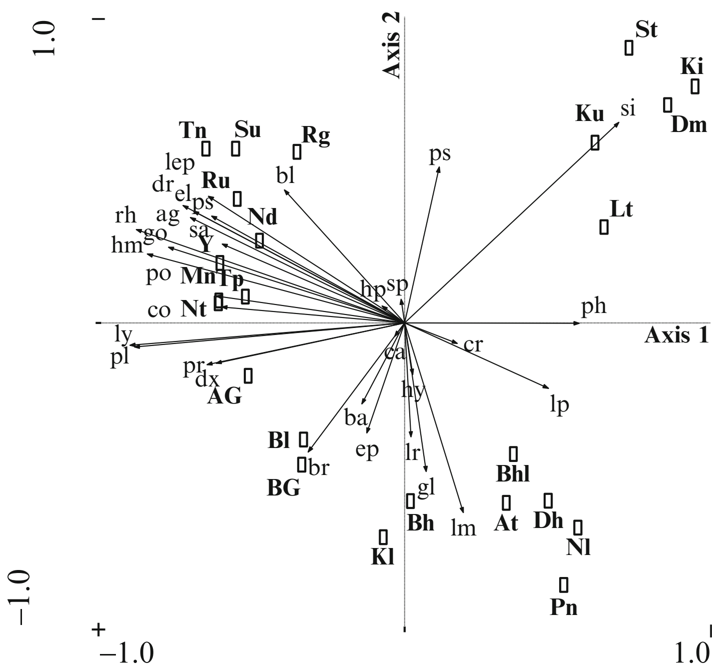

Fig. 4.5 PCA indicates characteristic taxa in the various streams of the different basins of the Himalayan region (acronyms: *At* Atta Gad, *Ag* Amrit Ganga, *Bh* Bhagirathi (Dharasu), *Bi* Birahi Ganga, *Bhl* Bhilangana, *Bl* Balasuti, *Dd* Dharasu Gad, *Dm* Damar, *Kl* Kaldi Gad, *Ki* Kaidung, *Ku* Kunja, *Lt* Laster, *Mn* Mana, *Nd* Nandakini, *Nl* Nailchami, *Nt* Naitwar, *Pn* Pindar, *Rg* Ramganga, *Ru* Rupin, *Su* Supin, *St* Sitapur, *Tp* Tapovan, *Tn* Tons, *Y* Yamuna; *ag* Agrionidae, *ba* Baetidae, *bl* Blephariceridae, *br* Brachycentridae, *ca* Caenidae, *co* Corydalidae, *cr* Chironomidae, *dx* Dixidae, *dr* Dryopidae, *el* Elmidae, *ep* Ephemerellidae, *gl* Glossosomatidae, *go* Gomphidae, *hp* Heptageniidae, *hem* Hemiptera, *hy* Hydropsychidae, *lp* Leptophlebiidae, *lep* Lepidoptera, *lp* Leptoceridae, *lm* Limnephilidae, *ly* Lymnaeidae, *ph* Philopotamidae, *po* Perlodidae, *pr* Perlidae, *ps* Psephenidae, *pl* Planorbidae, *psy* Psychomyiidae, *rh* Rhyacophilidae, *sp* Siphlonuridae, *si* Simuliidae, *sa* Sialidae)

are characteristic to the forest (oak)–agriculture land use and forest (pine–oak)–agriculture land use, respectively. In the Mandakini basin, Simuliidae is characteristic to the forest (oak)–agriculture land use in the Kunja Gad, while none to the Damar Gad in the forest (pine–oak)–agriculture land use and forest (oak) land use in the Kaidung and the Sitapur Gad (Figs. 4.5, 4.6, and 4.7).

Among the basins, Leptoceridae, Perlodidae, Hydropsychidae, Psychomyiidae and Heptageniidae are characteristic taxa to the Ramganga, Alaknanda and Yamuna basins. Siphlonuridae, Blephariceridae, Caenidae and Psephenidae are characteristic to the Pindar basin. Simuliidae, Leptophlebiidae, Chironomidae, Philopotamidae and Limnephilidae are characteristic taxa of the Mandakini and Bhagirathi basins (Fig. 4.8).

The PCA classified the groups of the taxa among sites/streams/basins, forest and land-use type. The forest type changes with decreasing elevation, deodar, oak, pine–oak and pine with mixed forest type in certain localities. The characteristic taxa are feebly correlated to change in the forest as well as land-use type because the area under agriculture is always far too less than the area under forest. Therefore, the taxa characteristic to the forest are on most occasions characteristic to the forest–agriculture land use also. Similarity among the basins is attributable to the fact that a large number of locations have pine forest type. The biome dependency hypothesis (Ross 1963; Corkum 1989) predicts that similar assemblages of macroinvertebrate are most likely to occur at sites along the rivers, if the

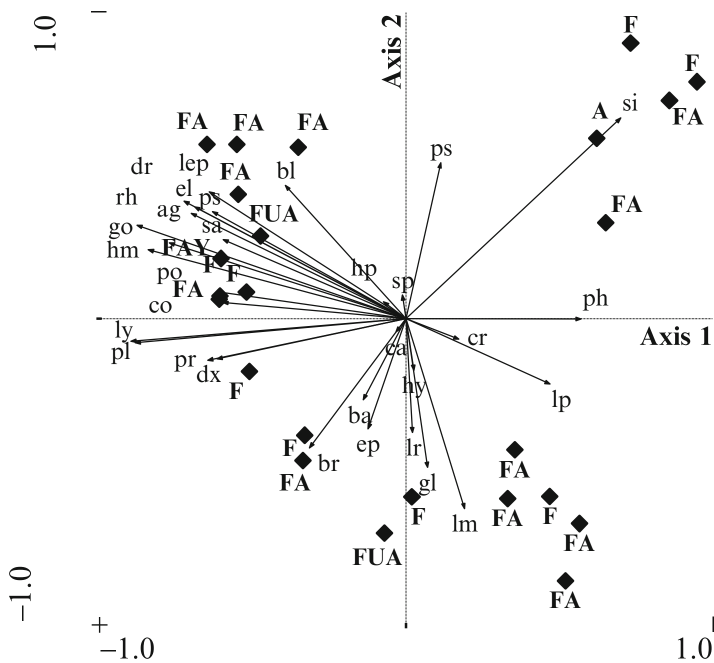

Fig. 4.6 PCA identified the characteristic taxa in various landuse in the different basins of Himalayan region (acronyms: *F* Forest, *FA* Forest + agriculture, *A* Agriculture, *FUA* Forest + urban + agriculture). The rest of the acronyms are similar to Fig. 4.5

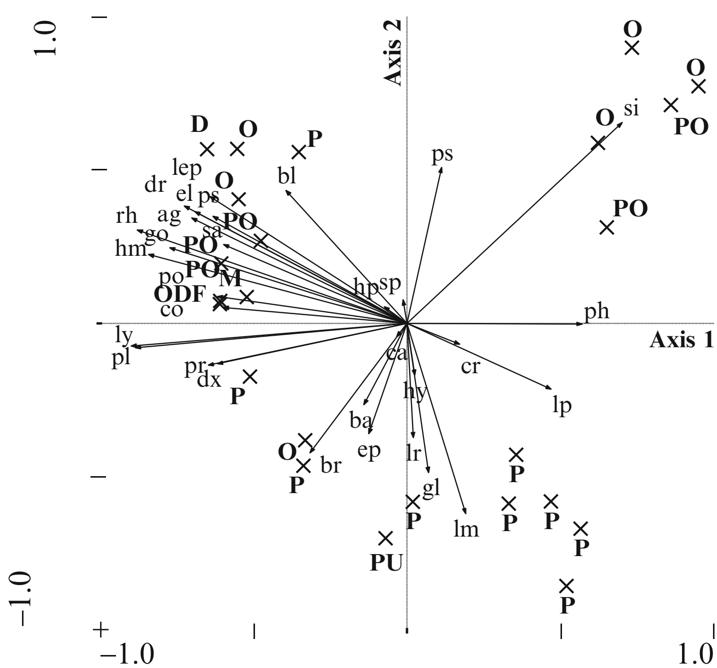

Fig. 4.7 PCA identified the characteristic taxa in various forest types of the different basins of Himalayan region (acronyms: *D* deodar, *O* oak, *P* pine, *ODF* oak + deodar + fir, *PO* pine + oak; *U* utees, *M* alpine meadow). The rest of the acronyms are similar to Fig. 4.5

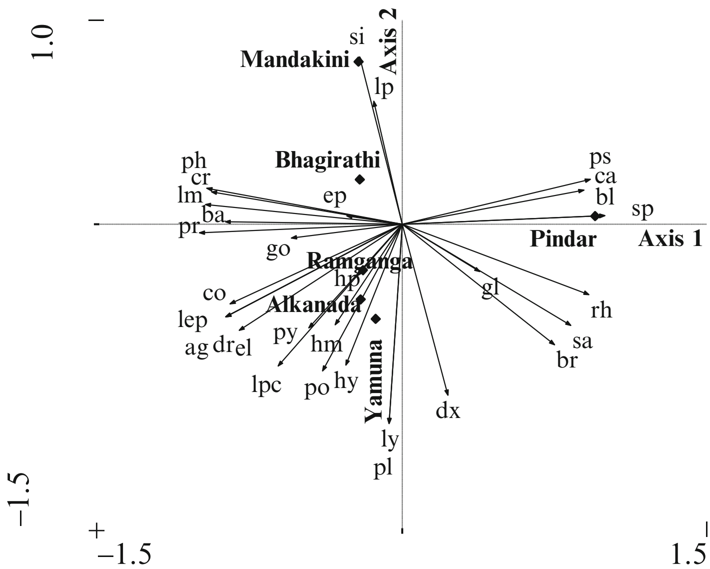

Fig. 4.8 PCA identified the characteristic taxa in each basin of Himalayan region. The rest of the acronyms are similar to Fig. 4.5

drainage basin occupies the same biome. However, pine forest exists in the other basins too (Pindar, Mandakini and Bhagirathi), but the characteristic taxa are different, probably due to differences in the water characteristics, thus emphasising the role of proximate factors.

Role of Environmental Variables

Based on the above discussion, it is apparent that the stations/streams/basins are similar in taxonomic composition despite the latitudinal, forest-type and land-use-type variations within the mountain biome. Among the array of variables, slope, forest type, stream order and land use, slope ($p \leq 0.042$, F 2.2) and forest type ($p \leq 0.524$, F 0.77) emerge as the main environmental factors that cause 66.67 % and 33.33 % variation in the taxonomic composition, respectively. On removing stream order from the analysis, similar results are obtained. But on removing both (stream order and slope) from the analysis, land use ($p \leq 0.652$, F 0.7) emerged as the main environmental factor causing 100 % variation in the taxonomic composition. These environmental variables are hence important to distribution of the benthic macroinvertebrate community in the river basins of Uttarakhand. The taxa Philopotamidae, Limnephilidae, Leptoceridae, Baetidae, Perlodidae and Leptophlebiidae are associated with the slope, while Ephemerellidae and Coleoptera are associated with the forest type (Fig. 4.9). The taxa associated with the slope are mainly families of Trichoptera. Ephemerellidae is related to the pine forest, while Coleoptera to oak–deodar–fir forest.

Slope is observed to be an important environmental variable influencing taxonomic composition and distribution of caddisfly with case (Limnephilidae, Leptoceridae, Philopotamidae) along with mayfly (Leptophlebiidae, Baetidae) and stonefly (Perlodidae). As slope is a manifestation of altitude, it indirectly indicates the role of altitude and hence the forest. Land use is an important factor as it indicates stress due to human activity. The macroinvertebrate fauna differed significantly among the rivers within biome due to different land use (Corkum 1991; Rundle et al. 1993; Ormerod et al. 1994). The assemblages of benthic macroinvertebrate taxa are affected by current velocity, water conductivity and substrate size (Miserendino 2001), pH and hardness (Ormerod and Edwards 1987).

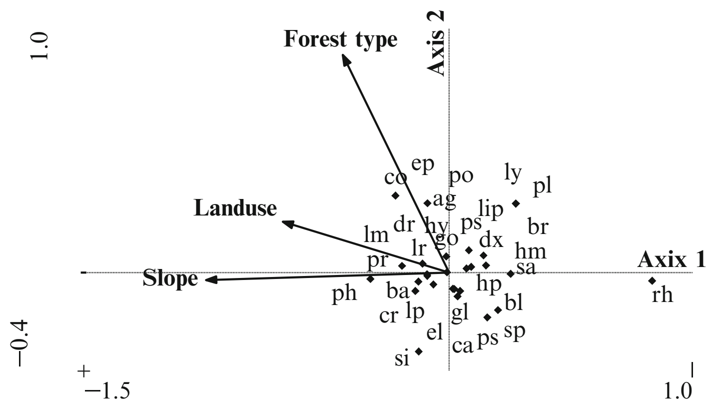

Fig. 4.9 Ordination diagram based on Canonical Correspondence Analysis (CCA) of the macroinvertebrate community with respect to environmental variables among various Himalayan river basins. The acronyms are similar to Fig. 4.5

Among the streams the characteristic taxa varied with change in the land use (forest, forest–agriculture, forest–urban–agriculture and agriculture). In the forest land use, i.e. at higher elevation, where the streams are heterotrophic, conditions inhospitable and forest laws restrict human habitation, predators are observed to be the characteristic taxa. The forest–agriculture-type land use is characterised by shredders, collectors, gatherers, filterers and predators.

Conclusions

The macroinvertebrate fauna in the river basins of Uttarakhand region consists of Trichoptera, Ephemeroptera, Diptera, Coleoptera and Plecoptera. The relative abundance of Trichoptera is higher both among and within the basins. Trichoptera is the abundant taxon in the share of Trichoptera, and Ephemeroptera is relatively low in the Yamuna river basins but dominate from Bhagirathi to Ramganga basin. At family level Leptoceridae and Glossosomatidae and Glossosomatidae and Philopotamidae are the abundant taxa in the river Alaknanda and Mandakini, respectively. Heptageniidae is dominant in the Ramganga and Yamuna, while Heptageniidae and Glossosomatidae are simultaneously dominant in the Pindar. The assemblages of abundant taxa varied among the basins. Heptageniidae and Baetidae among Ephemeroptera are abundant in most of the basins, while the abundance of Trichoptera and Diptera families is restricted to some basins. The faunal composition depicts that Bhagirathi and Mandakini basins are distinct from Yamuna, Ramganga and Pindar basins. However, most of the streams of Alaknanda basins grouped and show similarity with Bhagirathi and Mandakini.

The characteristic taxa varied from oak in the west to pine forest type in the east. The scrapers (Blephariceridae, Limnephilidae, Planorbidae, Lymnaeidae), predators (Dixidae, Perlidae) and gatherers (Ephemerellidae, Baetidae, Hydropsychidae) characterised the pine forest. Similarly, shredders and filterers (Simuliidae) characterised the oak forest, while scrappers (Elmidae, Dryopidae) and predators (Rhyacophilidae, Agrionidae) the pine–oak forest. Slope and forest type emerged as the main environmental factors that cause 66.67 % and 33.33 % variation in the taxonomic composition, respectively. Slope caused variation in taxonomic composition and distribution of caddisfly with case (Limnephilidae, Leptoceridae, Philopotamidae) along with mayfly (Leptophlebiidae, Baetidae) and stonefly (Perlodidae). As slope is a manifestation of altitude, it indirectly indicates the role of altitude and hence the forest.

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References

Badola SP, Singh HR (1981) Hydrobiology of the river Alaknanda of the Garhwal Himalaya. Ind J Ecol 8(2):269–276

Basistha A, Arya DS, Goel NK (2008) Spatial distribution of rainfall in Indian Himalayas – a case study of Uttarakhand region. Water Res Manage 22:1325–1346

Begon M, Harper JL, Townsend CR (1995) Ecology: individuals population and community, 2nd edn. Blackwell Science, Boston, 945 p

Burks BD (1953) The mayflies or Ephemeroptera of Illinois. Bull III Nat Hist Surv 26:1–215

Cantonati M, Corradini G, Jüttner I, Cox EJ (2001) Diatom assemblages in high mountain streams of the Alps & the Himalaya. Nova Hedwig Beih 123:37–61

Carter JCH, Dadswell MJ, Roff JC, Sprules WG (1980) Distribution and zoogeography of planktonic crustaceans and dipterans in glaciated eastern. North Am Can J Zool 58:1355–1387

Cooper SD, Diehl S, Kratz K, Sarnelle O (1998) Implications of scale for patterns and processes in stream ecology. Aust J Ecol 23(1):27–40

Corkum LD (1989) Patterns of benthic invertebrates assemblages in rivers of northwestern North America. Freshw Biol 21:191–205

Corkum LD (1990) Interbiome distributional patterns of lotic macroinvertebrates assemblages. Can J Fish Aquat Sci 47:2146–2157

Corkum LD (1991) Spatial patterns of macroinvertebrate distribution along rivers in eastern deciduous forest and grassland biomes. J North Am Benthol Soc 7(3):167–179

Corkum LD (1992) Relationship between density of macroinvertebrate and detritus in the rivers. Arch Fur Hydrobiol 239:149–166

Corkum LD, Curries DC (1987) Distributional patterns of immature Simuliidae(Diptera) in North America. Freshw Biol 17:201–221

Cotta Ramusino M, Villa S, Calamari D (1995) River continuum concept and correspondence analysis to study Alpine stream macroinvertebrate assemblage. Memorie dll'lstituto Italiano di Idrobiologia 53:101–114

Edmundson GF, Jenson SL, Bermer L (1976) The mayflies of North and Central America. University Minnesota Press, Minneapolis, 330 p

Gauch HG (1989) Multivariate analysis in community ecology. Cambridge University Press, Cambridge, 295 p

Gusain MP (1994) Himalayan Mahseer-ecological perspectives migration routes, River Alaknanda. In: Nautiyal P (ed) Mahseer-the game fish. Jagdamba Prakashan Dehradun for RACHNA, Srinagar (Garhwal), pp B123–B135

Habdija I, Radanovic I, Habdija BP (1997) Longitudinal distribution of predatory benthic macroinvertebrates in Karstic river. Arch Hydrobilogie 4:527–546

Hawkes CP (1975) River zonation and classification. In: Whitton BA (ed) River ecology. Blackwell Scientific Publication, Oxford

Hynes HBN (1970) The ecology of running waters. Liverpool University Press, Liverpool, 555 p

Jonasson PM (1948) Ecology and production of the profundal benthos in relation to phytoplankton in Lake Esrom. Oikos Supple 14:1–148

Joshi CB (1994) Habitat and breeding grounds: Alikhad (Sutlej river system) Juvenile habitat and breeding grounds. In: Nautiyal P (ed) Mahseer-the game fish. Jagdamba Prakashan Dehradun for RACHNA, Srinagar (Garhwal), pp B98–B120

Julka JM, Vasisht HS, Bala B (1999) Distribution of aquatic insects in a small stream in north-west Himalaya India. J Bombay Nat Hist Soc 96(1):55–62

Kendeigh SC (1980) Ecology (with special reference to animal and man), 2nd edn. Prentice Hall of India Private Limited, New Delhi, 474 p

Kishor B, Bhatt JP, Rawat VS, Nautiyal P (1998) Stream regulation: variations in the density of benthic macroinvertebrate fauna of Ganga in lateral canals at Hardwar. J Hill Res 11(1):62–67

Kishor B, Nautiyal R, Nautiyal P, Singh HR (2004) Stream regulation: variations in the density, composition and diversity of benthic macroinvertebrate occurring in the up and downstream sections of the impoundment zone of the river Ganga in the foothill. Trop Ecol 45(2):251–261

Kumar N (1991) Ecological studies on the macrozoobenthic communities of some Hill streams of the Alaknanda river system. D. Phil. thesis H N B Garhwal University, Srinagar (Garhwal), 216 p

Lamberti GA, Resh VH (1979) Substrate relationships, spatial distribution patterns, and sampling variability in a stream caddisfly population. Environ Entomol 8:561–567

Macan TT (1979) A key to nymphs of the British species of ephemeroptera with notes on their ecology, 3rd edn. Freshwater Biology association Scientific Publication no. 20, Ambleside

Minshall GW, Minshall JN (1977) Microdistribution of benthic invertebrates in a Rocky Mountain (U.S.A.) stream. Hydrobiologia 55:231–249

Minshall GW, Cummins KW, Petersen RC, Cushing CE, Burns DA, Sedell JR, Vannote RL (1985) Developments in stream ecosystem theory. Can J Fish Aquat Sci 42:1045–1055

Miserendino ML (2001) Macroinvertebrate assemblages in Andean Patagonian rivers and streams: environmental relationships. Hydrobiologia 444:147–148

Mohan M, Bisht RS (1991) Taxo-ecology of aquatic entomofauna in freshwater ecosystem with special reference to river Bhagirathi and Bhilangana in Garhwal Himalaya. In: Bhatt SD, Pande RK (eds) Ecology of the mountain waters. Ashish Publishing House, New Delhi, pp 251–265

Moss D, Furse MT, Wright JF, Armitage PD (1987) The prediction of the macroinvertebrate fauna of unpolluted running water sites in Great Britain using environmental data. Freshw Biol 17:41–52

Myers N (1990) The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10:243–256

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Nautiyal P (1984) Studies on the riverine ecology of the torrential waters in Indian uplands of Garhwal region. 2 Seasonal fluctuations in diatom density. Proc Ind Acad Sci (Anim Sci) 93:671–674

Nautiyal P (1986) Studies on the riverine ecology of torrential waters in the Indian uplands of the Garhwal region III. Floristic and faunistic survey. Trop Ecol 27:157–165

Nautiyal R, Nautiyal P, Singh HR (1996) Impact of sewage on the diatom communities of the river Alaknanda (Srinagar Garhwal). Int J Ecol Environ Sci 22:289–296

Nautiyal P, Bhatt JP, Kishor B, Rawat VS, Nautiyal R, Singh HR (1997a) Assessment of fish food resource in relation to the migratory habits of *Tor putitora* (Ham) found in the impounded sections of the river Ganga between Rishikesh and Hardwar. Proc Nat Acad Sci Allahabad. 67(B)3–4:204–212

Nautiyal P, Bhatt JP, Kishor B, Rawat VS, Nautiyal R, Badoni K, Singh HR (1997b) Altitudinal variations in phytobenthos density and its components in the coldwater mountain river Alaknanda-Ganga. Phykos 36(1&2):81–88

Nautiyal P, Shivam A, Rawat G, Singh KR, Verma J, Dwivedi AC (2004) Longitudinal variation in the structure of benthic communities in the upland Vindhyan and Himalayan: River Continuum concept approach. Nat J Life Sci 1(1):85–88

Nautiyal P, Shivam A, Verma J, Semwal VP (2007) Bhgirathi River- an endangered ecosystem. In Proceeding of national symposium on limnology, Department of Aquaculture College of Fisheries, Udaipur, Rajasthan, pp 164–166

Negi M, Singh HR (1990) Substratum as determining factor for bottom fauna in the river Alaknanda. Proc Nat Acad Sci India B 56(5&6):417–423

Odum EP (1996) Fundamentals of ecology, 3rd edn. Saunders College Publishing, Philadelphia, p 574

Ormerod SJ, Edwards RW (1987) The ordination and classification of macroinvertebrate assemblages in the catchments of the river Wye in relation to environmental factors. Freshw Biol 17:533–546

Ormerod SJ, Rundle SD, Wilkinson SM, Daly GP, Dal KM, Juttner I (1994) Altitudinal trends in the diatoms, bryophytes macroinvertebrates and fish of the Nepalese river system. Freshw Biol 32:309–322

Patrick R (1948) Factors effecting the distribution of diatoms. Bot Rev 14:473–524

Rawat DS, Bhandari BS, Gaur RD (2001) Vegetation wealth. In: Kandari OP, Gusain OP (eds) Garhwal Himalaya; nature, culture & society. Transmedia, Media House, Srinagar (Garhwal), pp 69–92

Resh VH (1976) Life histories of coexisting species of *Ceraclea* caddisflies (Trichoptera: Leptoceridae): the operation of independent functional units in a stream ecosystem. Can Entomol 108:1303–1318

Resh VH (1979) Sampling variability and life history features: basic considerations in the design of aquatic insects studies. J Fish Res Board Can 36:290–311

Ricklefs RE (1990) Ecology, 3rd edn. W.H. Freeman & Company, New York, 896 p

Ross HH (1963) Stream communities and terrestrial biomes. Arch Fur Hydrobiol 59:235–245

Rothfritz H, Juttner I, Suren AM, Ormerod SJ (1997) Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity & water quality. Arch Hydrobiol 138:465–482

Rundle SD, Jenkins A, Ormerod SJ (1993) Macroinvertebrate communities in the stream of Himalaya, Nepal. Freshw Biol 30:169–180

Seifert RP (1984) Does competition structure communities? Field studies on Neotropical *Heliconia* insects communities. In: Strong DR Jr, Simberloff D, Abele LG, Thistle AB (eds) Ecological communities: conceptual issues and the evidence. Princeton University Press, Princeton, pp 54–63

Shivam A (2006) Longitudinal distribution of benthic macroinvertebrate community in the fluvial system of Vindhyan hills. D. Phil. thesis, University of Allahabad, Allahabad, p 134

Singh HR, Nautiyal P (1990) Altitudinal changes and the impact of municipal sewage on the community structure of macrobenthic insects in the torrential reaches of the river Ganges in the Garhwal Himalaya (India). Acta Hydrobiol 32(314):407–421

Singh HR, Nautiyal P, Dobriyal AK, Pokhriyal RC, Negi M, Badoni V, Nautiyal R, Agarwal NK, Gautam A (1994) Water quality of river Ganga (Garhwal Himalaya). Acta Hydrobiol 36(1):3–15

Sivaramakrishanan KG, Venkataraman K, Sridhar S, Marimuthu S (1995) Spatial patterns of benthic macroinvertebrate distributions along river Kaveri and its tributaries (India). Int J Ecol Environ Sci 21:141–161

Sunder S (1997) Biotic communities of a Kumaon Himalaya river-The Gaula- 1. macrobenthic invertebrates. Proc Nat Acad Sci India 67(B)II:157–167

Sundriyal RC (1995) Grassland forage production and management in Himalaya. A review. J Hill Res 8:135–150

Suren AM (1994) Macroinvertebrate communities of streams in western Nepal: effects of altitude and land use. Freshw Biol 32:323–336

ter Braak CJF, Smilauer P (2002) CANOCO reference manual and CanoDraw for windows user's guide: software for Canonical Assemblage Ordination (version 4.5). Microcomputer Power, Ithaca

Ulfstrand S (1967) Microdistribution of benthic species (Ephemeroptera, Plecoptera, Trichoptera, Diptera: Simuliidae) in Lapland streams. Oikos 18:293–310

Valdiya KS (1962) Geology of a part of Uttar Pradesh Himalaya. PhD thesis Lucknow University, Lucknow

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE (1980) The river continuum concept. Can J Fish Aquat Sci 37:130–137

Ward JV (1994) Ecology of alpine streams. Freshw Biol 32:277–294

Welcomme RL (1985) Food and agriculture organization of the Unites Nations, Rome (Fisheries technical paper, 262) 330 p

Whittaker RH (1967) Gradient analysis of vegetation. Biol Rev 42:207–264

Wiggins GB, Mackay RJ (1978) Some relationship between systematic and trophic ecology in Nearctic aquatic insects with special reference to Trichoptera. Ecology 59:1211–1220

Wilbur HM, Travis J (1984) An experimental approach to understand pattern in natural communities. In: Strong DR, Simberloff D, Abele LG, Thistle AB (eds) Ecological communities conceptual issues and the evidence. Princeton University Press, Princeton, pp 113–122

Winterbourn MJ, Ryan PA (1994) Mountain streams in Westland New Zealand: Benthic ecology and management issues. Freshw Biol 32:359–373

Winterbourn MJ, Rounick JS, Cowie B (1981) Are New Zealand streams ecosystems really different. N Z J Mar Freshw Res 16:271–281

Wright JF, Furse MT, Armiatge PD (1984) Use of macroinvertebrates in chalk streams, Berkshire, England. Hydrobiologia 248:11–30

5

Diversity and Distribution of Polychaetes (Annelida: Polychaeta) Along Maharashtra Coast, India

S.K. Pati, D. Swain, K.C. Sahu, and R.M. Sharma

Abstract

Polychaetes are an important component in marine benthic communities having high ecological and economical significance. The scientific information on this group in Indian waters is scanty particularly with reference to costal region of Maharashtra. There are many polychaete records published from different localities of Maharashtra, but comprehensive report is still lacking. Hence, a systematic list of all the valid polychaete species along with their distribution is provided in this paper. A total of 180 species and seven subspecies of polychaetes in 113 genera in 21 subfamilies under 41 families and six orders have been recorded so far from Maharashtra coast. Suggestions are given for further biosystematic studies on the group in the state and the country as a whole.

Keywords

Annelida • Polychaeta • Diversity • Distribution • Maharashtra Coast

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Introduction

Polychaetes are generally benthic organisms occurring in a wide range of marine habitat including estuaries, lagoons, backwaters, coastal and inshore waters, etc. They belong to the phylum Annelida and mainly characterised by segmented soft body with parapodia and bristles. Many of the polychaetes are sedentary and some groups are also common in fouling (Gobin 2010). Due to their enigmatic presence in burrows of sandy and muddy bottoms and small size, they can easily be overlooked by

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many researchers. However, there are about 14,000 known species of class Polychaeta in the world (Rouse and Pleijel 2006) and 338 marine annelids including oligochaetes in India (Wafar et al. 2011). Larva and adults of some polychaetes are important component in the marine food chain and are reported to be excellent food for many economically important fishes and other animals (Musale and Desai 2011). Thus, they can be useful in determination of marine fishing grounds (Lloret et al. 2007) besides utilisation as fishing baits (Scaps 2002). Since these worms are abundant and have short lifespan besides direct contact with sediments/ water columns, they can be best regarded as bioindicators (Dean 2008; Sukumaran and Sarala Devi 2009; Sivadas et al. 2010).

Due to high economic and ecological importance of polychaetes, many studies have been carried out in different parts of world from temperate to tropical seas (Siciński 2000; Rozbaczylo and Simonetti 2000; Solís-Weiss et al. 2004; La Porta et al. 2011). Some of the important contributions to world polychaete taxonomy are that of Day (1967), Fauchald (1977, 1992), Sendall (1985), Colbath (1989), Hutchings et al. (1991) and Glasby (1999), though there are many debates and improvements in their classification and phylogeny (Fauchald and Rouse 1997, 1998; Rouse 2000; Bakken and Wilson 2005; Struck et al. 2006). In India, important systematic contributions on polychaetes are from Fauvel (1932, 1953), Devi et al. (1996), Sunil Kumar (2001, 2003) and Ajmal Khan and Murugesan (2005). A perusal of literature on polychaetes from Maharashtra Coast (Fauvel 1932, 1953; James et al. 1969; Lakshmana Rao 1969; Parulekar 1971, 1981; Hartman 1974; Padmakumar 1984; Ansari et al. 1986; Misra and Chakraborty 1991; Harkantra and Parulekar 1994; Mathew and Govindan 1995; Varshney and Govindan 1995; Sunil Kumar 1999, 2001; Ingole et al. 2002, 2008; Wehe and Fiege 2002; Sivadas et al. 2005; Ajmal Khan and Murugesan 2005; Jayaraj et al. 2008; Sukumaran and Sarala Devi 2009; Gaonkar et al. 2010a, b; Swami and Udhayakumar 2010; Sukumaran et al. 2011; Yokoyama and Sukumaran 2012) revealed that the data on marine polychaetes are in scattered form. Hence, we have compiled all the records of polychaete fauna of Maharashtra coast and presented as a systematic list along with their distribution.

Importance of Polychaetes

Polychaetes are both ecologically and economically important as they are useful component in the food web of marine ecosystem. They are vital food for many important fishes besides they are helpful in monitoring of marine pollution as bio-indicators. As foulers, they add extra weight to various ships/boats, fixed structures, etc. and may lead to many economic consequences.

Methods

The present study area Maharashtra (Figs. 5.1 and 5.2) (15°43′13.10″ to 20°08′13.30″N and 72°44′16.54″ to 73°41′05.11″E) is having 6 coastal districts (Thane, Mumbai Suburban, Mumbai, Raigad, Ratnagiri and Sindhudurg) stretching over 653 km long coastline. Its shoreline is indented by many west flowing river mouths, creeks, bays, headlands, promontories and cliffs. There are about 18 prominent creeks/ estuaries, many of which having mangrove vegetation. Major portion (about 80 %) of the Maharashtra coast is either muddy or rocky. Polychaeta records were compiled from published literature available for the state. The classification followed here is adopted mostly from Rouse (2000), modified after Fauchald and Rouse (1997) and updated from Read and Fauchald (2012).

Results and Discussion

A total of 180 species and seven subspecies of polychaetes in 113 genera in 21 subfamilies under 41 families and six orders are recorded in the present study. Some of the representatives of polychaetes are presented in Fig. 5.3. A systematic list of polychaetes along with their distribution in Maharashtra coast is given below.

Fig. 5.1 Map of coastal Maharashtra indicating localities having polychaete records

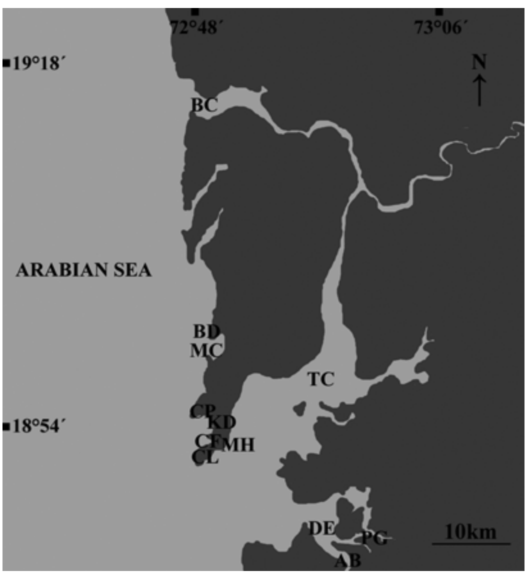

Fig. 5.2 Map of Mumbai Coast showing localities having polychaete records (*BC* Bassein Creek, *BD* Bandra, *MC* Mahim Creek, *TC* Thane Creek, *CP* Chowpatty, *KD* Kalbadevi, *CP* Cuffe Parade, *MH* Mumbai Harbour, *CL* Colaba, *DE* Dharamtar Estuary, *AB* Amba River, *PG* Patalganga)

Systematic List

Phylum Annelida Lamarck, 1809

Class Polychaeta Grube, 1850

Family Arenicolidae Johnston, 1835

1. *Arenicola bombayensis* Kewalarami, Wagh and Ramade, 1960:	Mumbai

Family Maldanidae Malmgren, 1867

Subfamily Maldaninae Arwidsson, 1906

2. *Maldane sarsi* Malmgren, 1865:	Mumbai Harbour

Subfamily Nicomachinae Arwidsson, 1906

3. *Petaloproctus terricolus* Quatrefages, 1866:	Mumbai Harbour

Subfamily Euclymeninae Arwidsson, 1906

4. *Axiothella obockensis* (Gravier, 1905):	Rajapur Bay

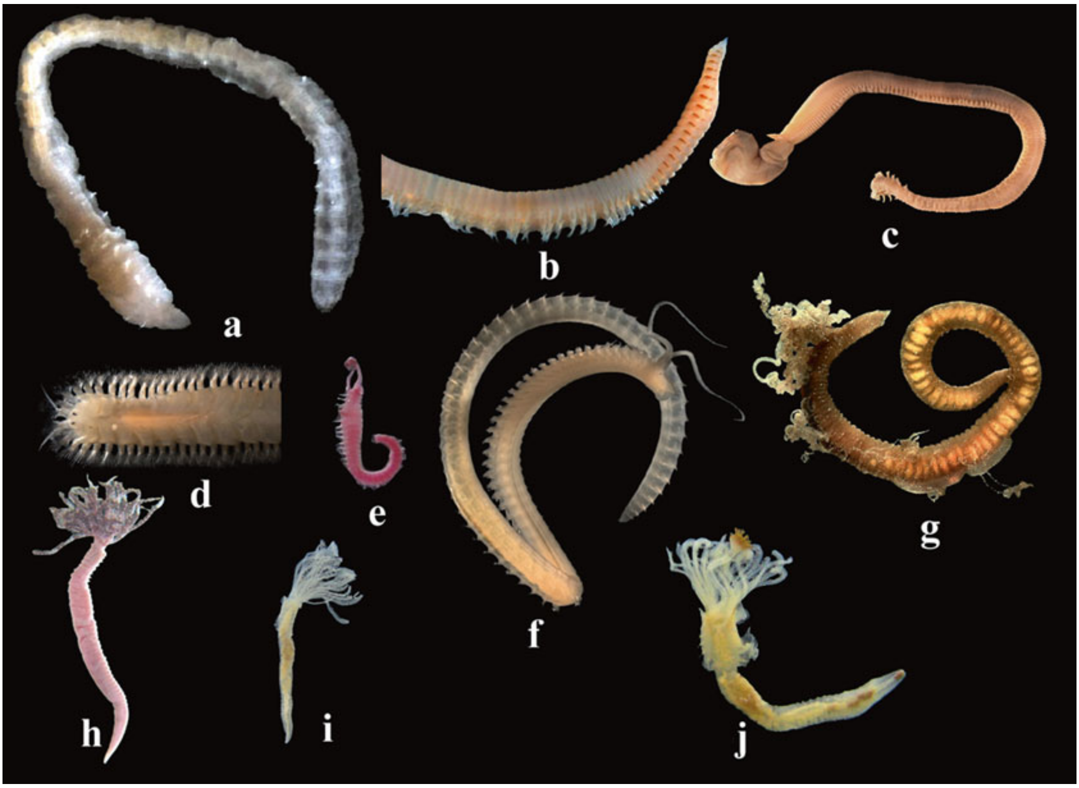

Fig. 5.3 Some polychaetes of Maharashtra coast (**a**–**j**) (**a**) *Capitella capitata* (Fabricius, 1780); (**b**) *Scoloplos* (*Scoloplos*) *armiger* (Müller, 1776); (**c**) *Glycera alba* (O.F. Müller, 1776); (**d**) *Sthenelais boa* (Johnston, 1833); (**e**) *Polydora ciliata* (Johnston, 1838); (**f**) *Scolelepis* (*Scolelepis*) *squamata* (O.F. Muller, 1806); (**g**) *Cirratulus cirratus* (O. F. Müller, 1776); (**h**) *Dasychone cingulata* Grube, 1870; (**i**) *Serpula vermicularis* Linnaeus, 1767; (**j**) *Hydroides diramphus* Mörch, 1863. (Specimens not to scale) (Photo **a**–**d**, **f**, **g**. Courtesy: Wikipedia)

5.	*Euclymene annandalei* Southern, 1921:	Mumbai Harbour
6.	*Maldanella grossa* (Baird, 1873):	Thane Creek, Bassein Creek
7.	*Praxillella affinis pacifica* Berkeley, 1929:	Mumbai Harbour

Family Capitellidae Grube, 1862

8.	*Branchiocapitella singularis* Fauvel, 1932:	Mumbai Harbour
9.	*Capitella capitata* (Fabricius, 1780):	Mumbai Harbour
10.	*Heteromastides bifidus* Augener, 1914:	Mumbai Harbour
11.	*Heteromastus filiformis* (Claparède, 1864):	Mumbai Harbour
12.	*Heteromastus similis* Southern, 1921:	Mumbai Harbour
13.	*Mediomastus capensis* Day, 1961:	Mumbai Harbour
14.	*Notomastus aberans* Day, 1957:	Mumbai Harbour
15.	*Notomastus fauveli* Day, 1955:	Mumbai Harbour
16.	*Notomastus latericeus* Sars, 1851:	Mumbai Harbour
17.	*Parheteromastus tenuis* Monro, 1937:	Bassein Creek, Mahim Creek, Mumbai Harbour, Thane Creek, Ratnagiri
18.	*Pulliella armata* Fauvel, 1929:	Bassein Creek, Mumbai Harbour, Thane Creek, Mumbai Coast

19.	*Scyphoproctus djiboutiensis* Gravier, 1906:	Mumbai Harbour

Family Opheliidae Malmgren, 1867

20.	*Armandia lanceolata* Willey, 1905:	Malvan

Subfamily Ophelininae Hartmann-Schröder, 1974

21.	*Ophelina acuminata* Örsted, 1843:	Mumbai Harbour

Family Orbiniidae Hartman, 1942

22.	*Haploscoloplos kerguelensis* (McIntosh, 1885):	Mumbai Harbour
23.	*Orbinia angrapequensis* (Augener, 1918):	Mumbai Harbour
24.	*Scoloplella capensis* Day, 1963:	Mumbai Harbour
25.	*Scoloplos* (*Scoloplos*) *armiger* (Müller, 1776):	Ratnagiri
26.	*Scoloplos* (*Scoloplos*) *marsupialis* (Southern, 1921):	Kalbadevi

Family Cossuridae Day, 1963

27.	*Cossura coasta* Kitamori, 1960:	Bassein creek, Mahim Creek, Mumbai Harbour, Thane Creek, Ratnagiri
28.	*Cossura longocirrata* Webster and Benedict, 1887:	Mumbai Harbour

Order Phyllodocida Dales, 1962
Family Chrysopetalidae Ehlers, 1864

29.	*Bhawania cryptocephala* Gravier, 1901:	Malvan

Family Glyceridae Grube, 1850

30.	*Glycera alba* (O.F. Müller, 1776):	Gholvad, Bassein creek, Mahim Creek, Mumbai Harbour, Thane Creek, Mumbai, Alibag, Ratnagiri, Rajapur Bay, Vijaydurg, Malvan
31.	*Glycera convoluta* Keferstein, 1862:	Mumbai
32.	*Glycera incerta* Hansen, 1882:	Mumbai Harbour
33.	*Glycera longipinnis* Grube, 1878:	Bassein creek, Mumbai Harbour, Thane Creek, Ratnagiri
34.	*Glycera unicornis* Savigny in Lamarck, 1818:	Mahim Creek

Family Goniadidae Kinberg, 1866

35.	*Glycinde multidens* Müller in Grube, 1858:	Ratnagiri
36.	*Glycinde oligodon* Southern, 1921:	Malvan
37.	*Goniada emerita* Audouin and Milne-Edwards, 1833:	Mumbai Harbour
38.	*Goniadella gracilis* (Verrill, 1873):	Ratnagiri
39.	*Goniadopsis longicirrata* (Arwindsson, 1899):	Mumbai

Family Pisionidae Southern, 1914

40.	*Pisionidens indica* (Aiyar and Alikunhi, 1940):	Kalbadevi

Family Phyllodocidae Örsted, 1843
Subfamily Phyllodocinae Oersted, 1843

41.	*Phyllodoce madeirensis* Langerhans, 1880:	Mumbai, Alibag

Subfamily Eteoninae Bergstroem, 1914

42.	*Eteone syphodonta* (Delle Chiaje, 1822):	Mumbai Harbour
43.	*Eteone ornata* Grube, 1878:	Ratnagiri

Family Nephtyidae Grube, 1850

44.	*Aglaophamus dibranchis* (Grube, 1877):	Mumbai Harbour, Ratnagiri
45.	*Inermonephtys inermis* (Ehlers, 1887):	Mahim Creek, Mumbai Harbour
46.	*Nephtys lyrochaeta* Fauvel, 1902:	Ratnagiri
47.	*Nephtys oligobranchia* Southern, 1921:	Bassein Creek, Colaba, Mumbai Harbour, Thane Creek, Dabhol

48.	*Nephtys polybranchia* Southern, 1921:	Dahanu, Danda Creek, Savta Creek, Mahim Creek
49.	*Micronephthys sphaerocirrata* (Wesenberg-Lund, 1949):	Mumbai Harbour

Family Nereididae Blainville, 1818

50.	*Dendronereis aestuarina* Southern, 1921:	Mumbai Harbour, Ratnagiri, Malvan
51.	*Dendronereis arborifera* Peters, 1854:	Mumbai, Rajapur Bay
52.	*Perinereis cavifrons* (Ehlers, 1920):	Bassein Creek, Mumbai Harbour, Thane Creek
53.	*Perinereis cultrifera* (Grube, 1840):	Arnala, Mahim Creek, Mumbai, Malvan
54.	*Perinereis helleri* (Grube, 1878):	Arnala, Mumbai Harbour, Mumbai
55.	*Perinereis nigropunctata* (Horst, 1889):	Gholvad, Dahanu, Tarapur, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
56.	*Perinereis nuntia* (Savigny in Lamarck, 1818):	Bandra
57.	*Perinereis nuntia bombayensis* Bhatt in Parulekar, 1972:	Mumbai, Alibag
58.	*Perinereis nuntia brevicirris* (Grube, 1867):	Gholvad, Dahanu, Tarapur, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
59.	*Perinereis nuntia typica* (Grube, 1857):	Dahanu, Tarapur, Arnala, Bandra, Mumbai Harbour, Mumbai, Alibag, Ratnagiri, Vijaydurg, Malvan, Vengurla
60.	*Perinereis nuntia vallata* (Grube, 1857):	Mumbai, Ratnagiri, Malvan
61.	*Perinereis vancaurica* (Ehlers, 1868):	Gholvad, Tarapur, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
62.	*Perinereis vancaurica indica* Bhatt in Parulekar, 1972:	Gholvad, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi

Subfamily Gymnonereidinae Banse, 1977

63.	*Dendronereides heteropoda* Southern, 1921:	Tarapur, Mumbai
64.	*Micronereides capensis* Day, 1963:	Mumbai Harbour
65.	*Tambalagamia orientalis* Hartman, 1974:	Mumbai

Subfamily Namanereidinae Hartman, 1959

66.	*Namalycastis indica* (Southern, 1921):	Mumbai

Subfamily Nereidinae Blainville, 1818

67.	*Ceratonereis mirabilis* Kinberg, 1865:	Gholvad, Arnala, Mumbai, Ratnagiri, Malvan
68.	*Ceratonereis (Composetia) burmensis* (Monro, 1937):	Off Bombay
69.	*Ceratonereis (Composetia) costae* (Grube, 1840):	Mumbai, Malvan
70.	*Neanthes chilkaensis* (Southern, 1921):	Dabhol, Vijaydurg, Devgad, Malvan, Vengurla
71.	*Neanthes chingrighattensis* (Fauvel, 1932):	Malvan
72.	*Neanthes cricognatha* Ehlers, 1904:	Mumbai Harbour
73.	*Neanthes unifasciata* (Willey, 1905):	Mumbai Harbour, Thane creek
74.	*Nereis aibuhitensis* (Grube, 1878):	Gholvad, Dahanu, Tarapur, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
75.	*Nereis falcaria* (Willey, 1905):	Mumbai Harbour
76.	*Nereis talehsapensis* Fauvel, 1932:	Mumbai, Ratnagiri, Vijaydurg, Devgad

Family Hesionidae Grube, 1850

77.	*Leocratides ehlersi* (Horst, 1924):	Gholvad, Mumbai, Ratnagiri, Malvan
78.	*Podarke angustifrons* (Grube, 1878):	Malvan

Subfamily Hesioninae Grube, 1850

79. *Hesione pantherina* Risso, 1826:	Dahanu, Malvan
80. *Leocrates claparedii* (Costa in Claparède, 1868):	Mumbai, Ratnagiri, Malvan

Family Pilargidae de Saint-Joseph, 1899

81. *Hermundura annandalei* (Fauvel, 1932):	Mumbai

Subfamily Pilarginae de Saint-Joseph, 1899

82. *Sigambra constricta* (Southern, 1921):	Bassein Creek, Mahim Creek, Mumbai Harbour, Thane Creek, Malvan
83. *Sigambra parva* (Day, 1963):	Ratnagiri

Family Syllidae Grube, 1850

84. *Irmula spissipes* Ehlers, 1913:	Mumbai Harbour

Subfamily Exogoninae Langerhans, 1879

85. *Sphaerosyllis sublaevis* Ehlers, 1913:	Mumbai Harbour

Subfamily Syllinae Rioja, 1925

86. *Haplosyllis spongicola* (Grube, 1855):	Dahanu Creek, Danda Creek, Savta Creek, Mumbai Harbour, Dabhol, Ratnagiri, Malvan
87. *Syllis armillaris* (O.F. Müller, 1776):	Gholvad, Dahanu, Tarapur, Arnala, Mahim Creek, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
88. *Syllis cornuta* Rathke, 1843:	Malvan
89. *Syllis gracilis* Grube, 1840:	Dahanu, Arnala, Mahim Creek, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
90. *Syllis hyalina* Grube, 1863:	Mumbai Harbour
91. *Syllis variegata* Grube, 1860:	Gholvad, Dahanu, Tarapur, Arnala, Mahim Creek, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla

Family Acoetidae Kinberg, 1856

92. *Acoetes melanonota* (Grube, 1876):	Mumbai, Malvan
93. *Panthalis oerstedi* Kinberg, 1856:	Mumbai, Malvan

Family Aphroditidae Malmgren, 1867

94. *Aphrodita alta* Kinberg, 1856:	Mumbai Harbour

Family Polynoidae Malmgren, 1867
Subfamily Lepidonotinae Willey, 1902

95. *Lepidonotus carinulatus* (Grube, 1870):	Alibag, Malvan
96. *Lepidonotus tenuisetosus* (Gravier, 1902):	Tarapur, Arnala, Mumbai, Mumbai Harbour, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi

Subfamily Polynoinae Kinberg, 1856

97. *Gaudichaudius cimex* (Quatrefages, 1866):	Mumbai, Ratnagiri, Malvan
98. *Paralepidonotus ampulliferus* (Grube, 1878):	Dahanu, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi

Family Sigalionidae Malmgren, 1867

99. *Sthenelais boa* (Johnston, 1833):	Gholvad, Mumbai Harbour, Mumbai, Dharamtar Estuary, Alibag, Ratnagiri, Malvan
100. *Sthenolepis japonica* (McIntosh, 1885):	Mumbai, Malvan, Vengurla

Order Amphinomida Fauchald, 1977
Family Amphinomidae Savigny in Lamarck, 1818

101.	*Chloeia rosea* Potts, 1909:	Malvan
102.	*Eurythoe complanata* (Pallas, 1766):	Gholvad, Dahanu, Tarapur, Arnala, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
103.	*Eurythoe parvecarunculata* Horst, 1912:	Mumbai

Family Euphrosinidae Williams, 1851

104.	*Euphrosine capensis* Kinberg, 1857:	Mumbai Harbour

Order Eunicida Fauchald, 1977
Family Onuphidae Kinberg, 1865
Subfamily Onuphinae Kinberg, 1865

105.	*Diopatra claparedii* Grube, 1878:	Malvan
106.	*Diopatra cuprea* (Bosc, 1802):	Mumbai Harbour
107.	*Diopatra cuprea cuprea* (Bosc, 1802):	Mahim Creek, Ratnagiri
108.	*Diopatra neapolitana* Delle Chiaje, 1841:	Gholvad, Dahanu, Tarapur, Arnala, Bassein Creek, Mahim Creek, Mumbai Harbour, Thane Creek, Mumbai, Alibag, Ratnagiri, Vijaydurg, Devgad, Malvan, Vengurla, Redi
109.	*Onuphis eremita* Audouin and Milne-Edwards, 1833:	Mumbai Harbour, Kalbadevi, Malvan
110.	*Onuphis geophiliformis* (Moore, 1903):	Ratnagiri
111.	*Onuphis holobranchiata* Marenzeller, 1879:	Mumbai Harbour

Family Eunicidae Berthold, 1827

112.	*Eunice antennata* (Savigny in Lamarck, 1818):	Mahim Creek, Mumbai, Malvan
113.	*Eunice guttata* Baird, 1869:	Mumbai
114.	*Eunice laticeps* Ehlers, 1868:	Gholvad, Malvan
115.	*Eunice savignyi* Grube, 1878:	Mumbai, Dabhol
116.	*Marphysa mossambica* (Peters, 1855):	Mumbai
117.	*Marphysa sanguinea* (Montagu, 1815):	Malvan

Family Dorvilleidae Chamberlin, 1919

118.	*Protodorvillea biarticulata* Day, 1963:	Mahim Creek

Family Oenonidae Kinberg, 1865

119.	*Arabella* (*Arabella*) *iricolor* (Montagu, 1804):	Arnala, Mumbai Harbour, Mumbai, Alibag, Ratnagiri, Malvan, Vengurla

Family Lumbrineridae Schmarda, 1861

120.	*Lumbrineris bifilaris* Ehlers, 1901:	Mumbai Harbour
121.	*Lumbrineris brevicirra* (Schmarda, 1861):	Ratnagiri
122.	*Lumbrineris hartmani* Day, 1953:	Mumbai Harbour
123.	*Lumbrineris heteropoda* Marenzeller, 1879:	Gholvad, Dahanu, Tarapur, Arnala, Mumbai (Chowpatty), Mumbai, Alibag, Ratnagiri, Devgad, Malvan, Vengurla
124.	*Lumbrineris japonica* (Marenzeller, 1879):	Bassein creek, Mahim Creek, Mumbai Harbour, Thane Creek, Rajapur Bay
125.	*Lumbrineris pseudobifilaris* Fauvel, 1932:	Mumbai Harbour
126.	*Lumbrineris polydesma* Southern, 1921:	Mumbai
127.	*Lumbrineris simplex* Southern, 1921:	Mumbai, Mumbai Harbour
128.	*Ninoe lagosiana* Augener, 1918:	Ratnagiri
129.	*Ninoe notocirrata* (Fauvel, 1932):	Mumbai Harbour

Order Spionida sensu Rouse and Fauchald, 1997
Family Spionidae Grube, 1850

130.	*Boccardia polybranchia* (Haswell, 1885):	Ratnagiri
131.	*Dipolydora coeca* (Oersted, 1843):	Arnala, Mumbai, Alibag, Ratnagiri, Devgad, Malvan, Vengurla
132.	*Dipolydora giardi* (Mesnil, 1896):	Mumbai Harbour
133.	*Malacoceros indicus* (Fauvel, 1928):	Mumbai Harbour
134.	*Minuspio cirrifera* (Wirén, 1883):	Mumbai Harbour, Malvan
135.	*Paraprionospio cristata* Zhou, Yokoyama and Li, 2008:	Thane Creek, Mahim Bay, Mumbai Bay (Mumbai Port Area), Mumbai (Confluence of Amba and Patalganga Estuaries), Off Alibag
136.	*Paraprionospio pinnata* (Ehlers, 1901):	Bassein Creek, Mahim Creek, Mumbai Harbour-Thane Creek System, Mumbai Harbour, Rajapur Bay, Ratnagiri
137.	*Polydora capensis* Day, 1955:	Mumbai Harbour
138.	*Polydora ciliata* (Johnston, 1838):	Mahim Creek
139.	*Prionospio aucklandica* Augener, 1923:	Ratnagiri
140.	*Prionospio cirrifera* Wirén, 1883:	Mahim Creek
141.	*Prionospio polybranchiata* Fauvel, 1929:	Bassein Creek, Mumbai Harbour, Thane Creek, Dabhol
142.	*Scolelepis* (*Scolelepis*) *squamata* (O.F. Muller, 1806):	Mumbai Harbour, Kalbadevi, Malvan
143.	*Spiophanes bombyx* (Claparède, 1870):	Mumbai Harbour
144.	*Streblospio benedicti* Webster, 1879:	Dabhol

Family Magelonidae Cunningham and Ramage, 1888

145.	*Magelona cincta* Ehlers, 1908:	Ratnagiri
146.	*Magelona rosea* Moore, 1907:	Dabhol

Family Poecilochaetidae Hannerz, 1956

147.	*Poecilochaetus serpens* Allen, 1904:	Ratnagiri

Family Chaetopteridae Audouin and Milne-Edwards, 1833

148.	*Chaetopterus variopedatus* Cuvier, 1827:	Mumbai Harbour, Mumbai
149.	*Phyllochaetopterus socialis* Claparède, 1869:	Mumbai, Malvan

Order Terebellida sensu Rouse and Fauchald, 1997
Family Cirratulidae Carus, 1863

150.	*Cirratulus cirratus* (O. F. Müller, 1776):	Mahim Creek, Mumbai Harbour
151.	*Cirratulus concinnus* Ehlers, 1908:	Mumbai Harbour
152.	*Cirriformia afer* (Ehlers, 1908):	Mumbai Harbour, North West Coast
153.	*Cirriformia chrysoderma* (Claparède, 1869):	Mumbai Harbour
154.	*Cirriformia filigera* (Delle Chiaje, 1828):	Mumbai Harbour
155.	*Cirriformia limnoricola* Kirkegaard and Santhakumaran, 1967:	Arnala, Mumbai harbour, Mumbai, Ratnagiri, Malvan, Vangurla
156.	*Cirriformia tentaculata* (Montagu, 1808):	Ratnagiri
157.	*Tharyx filibranchia* Day, 1961:	Mumbai Harbour

Family Ampharetidae Malmgren, 1866

158.	*Isolda pulchella* Müller in Grube, 1858:	Ratnagiri

Subfamily Ampharetinae Malmgren, 1865

159.	*Ampharete capensis* (Day, 1961):	Mumbai Harbour

Family Terebellidae Malmgren, 1867
Subfamily Terebellinae Malmgren, 1867

160.	*Pista herpini* Fauvel, 1928:	Mumbai Harbour

161.	*Pista indica* Fauvel, 1940:	Mumbai Harbour, Thane Creek, Mumbai Coast
162.	*Pista pachybranchiata* Fauvel, 1932:	Mumbai Harbour

Family Trichobranchidae Malmgren, 1866
Subfamily Trichobranchinae Malmgren, 1866

163.	*Terebellides stroemii* Sars, 1835:	Ratnagiri, Malvan

Family Sternaspidae Carus, 1863

164.	*Sternaspis scutata* Ranzani, 1817:	Mahim Creek, Mumbai Harbour, Ratnagiri

Order Sabellida Fauchald, 1977
Family Sabellariidae Johnston, 1865

165.	*Neosabellaria cementarium* (Moore, 1906):	Mumbai Harbour, Thane creek

Family Sabellidae Latreille, 1825

166.	*Vermiliopsis glandigerus* Gravier, 1906:	Mumbai, Malvan

Subfamily Sabellinae Chamberlin, 1919

167.	*Dasychone cingulata* Grube, 1870:	Malvan
168.	*Dasychone serratibranchis* Grube, 1932:	Mumbai, Ratnagiri, Malvan
169.	*Potamilla leptochaeta* Southern, 1921:	Arnala, Mumbai
170.	*Sabella spallanzanii* (Gmelin, 1791):	Dahanu, Arnala, Mumbai (Chowpatty, Cuffe Parade), Alibag, Ratnagiri, Devgad, Malvan
171.	*Sabellastarte longa* (Kinberg, 1866):	Ratnagiri

Family Fabriciidae Rioja, 1923

172.	*Fabricia bansei* Day, 1961:	Ratnagiri

Family Serpulidae Rafinesque, 1815

173.	*Serpula vermicularis* Linnaeus, 1767:	Mumbai Harbour
174.	*Hydroides albiceps* (Grube, 1870):	Mumbai Harbour
175.	*Hydroides diramphus* Mörch, 1863:	Mumbai Harbour
176.	*Hydroides heterocerus* (Grube, 1868):	Mumbai Harbour
177.	*Hydroides norvegicus* Gunnerus, 1768:	Mumbai Harbour
178.	*Hydroides operculatus* (Treadwell, 1929):	Mumbai Harbour, Thane-Mumbai Bay
179.	*Ficopomatus uschakovi* (Pillai, 1960):	Mumbai Harbour
180.	*Spirobranchus kraussii* (Baird, 1865):	Mumbai Harbour
181.	*Protula tubularia* (Montagu, 1803):	Mumbai Harbour
182.	*Salmacina dysteri* (Huxley, 1855):	Mumbai Harbour

Subfamily Spirorbinae Chamberlin, 1919

183.	*Spirorbis foraminosus* Bush, 1905:	Mumbai, Vengurla

Family Oweniidae Rioja, 1917

184.	*Galathowenia oculata* (Zachs, 1923):	Mumbai Harbour
185.	*Owenia fusiformis* Delle Chiaje, 1844:	Mumbai Harbour

Remarks

Parulekar (1971) reported 46 species and five subspecies of marine polychaetes from Maharashtra. Present compilation of all the polychaete records revealed an increase in the species richness to considerable number (from 46 to 180 species). Almost half the numbers of Indian species of polychaetes occur in the state. Though there have been many faunal studies since that of Parulekar, more studies are still required in the unexplored habitats/areas.

Conclusion

Though the marine polychaete diversity along Maharashtra coast appears to be quite rich, the future studies on dynamic and diversified marine habitats of the unexplored areas of the coast will throw more light on these animals' habit, habitat preference and species diversity.

Recommendations

As far as systematic studies are concerned, the polychaetes are one of the poorly studied marine groups in India as compared to world scenario (around 14,000 species); the number of these worms is significantly less (nearly 320 species). Hence, the priority has to be given to study the systematics/taxonomy of these animals in India by exploring more areas and habitats followed by biological studies on the groups having ecological significance and economical importance. The conservation issues pertaining to these groups can be addressed once biosystematic studies are well established. This is only possible if the sustained efforts of researchers are supported by liberal funding from Government as well as nongovernment bodies.

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References

Ajmal Khan S, Murugesan P (2005) Polychaete diversity in Indian estuaries. Ind J Mar Sci 34(1):114–119

Ansari ZA, Ingole BS, Parulekar AH (1986) Effect of high organic enrichment of benthic polychaete population in an estuary. Mar Pollut Bull 17:361–365

Bakken T, Wilson RS (2005) Phylogeny of nereidids (Polychaeta, Nereididae) with paragnaths. Zool Scr 34(5):507–547

Colbath KG (1989) Revision of the family Lysaretidae, and recognition of the family Oenonidae Kinberg, 1865 (Eunicida: Polychaeta). Proc Biol Soc Wash 102(1):116–123

Day JH (1967) A monograph on the Polychaeta of Southern Africa. Trustees of the British Museum (Natural History): London: Pt 1, Erranta, pp 1–458; Pt 2, Sedentaria, pp 459–878

Dean HK (2008) The use of polychaetes (Annelida) as indicator species of marine pollution: a review. Rev Biol Trop 56(Suppl 4):11–38

Devi KS, Sheba P, Balasubramanian T, Venugopal P, Sankaranarayanan VN (1996) Benthic fauna of southwest and southeast coasts of India. The fourth Indian fisheries forum proceedings, Kochi, Kerala, pp 9–12

Fauchald K (1977) The polychaete worms. Definitions and keys to the orders, families and genera. Nat Hist Mus Los Angeles Cty Sci Ser 28:1–188

Fauchald K (1992) A review of the genus *Eunice* (Polychaeta: Eunicidae) based upon type material. Smithson Contrib Zool 523:1–422

Fauchald K, Rouse GW (1997) Polychaete systematics: past and present. Zool Scr 26:71–138

Fauchald K, Rouse GW (1998) Recent views on the status, delineation and classification of the Annelida. Am Zool 38:953–964

Fauvel P (1932) Annelida, Polychaeta of the Indian Museum. Mem Ind Mus XII(1):1–262

Fauvel P (1953) The fauna of India including Pakistan, Ceylon, Burma and Malaya: Annelida, Polychaeta. The Indian Press Ltd., Allahabad, 507 p

Gaonkar CA, Sawant SS, Anil AC, Krishnamurthy V, Harkantra SN (2010a) Changes in the occurrence of hard substratum fauna: a case study from Mumbai harbour, India. Ind J Mar Sci 39(1):74–84

Gaonkar CA, Sawant SS, Anil AC, Krishnamurthy V, Harkantra SN (2010b) Mumbai harbour, India: gateway for introduction of marine organisms. Environ Monit Assess 163:583–589

Glasby CJ (1999) The Namaneridinae (Polychaeta: Nereididae). Part 1, Taxonomy and Phylogeny. Rec Aust Mus Suppl 25:1–129

Gobin JF (2010) Free-living marine polychaetes (Annelida) inhabiting hard-bottom substrates in Trinidad and Tobago, West Indies. Rev Biol Trop 58(1):147–157

Harkantra SN, Parulekar AH (1994) Soft sediment dwelling macro-invertebrates of Rajapur Bay, central west coast of India. Ind J Mar Sci 23(1):31–34

Hartman O (1974) Polychaetous annelids of the Indian Ocean including an account of species collected by members of the International Indian Ocean expeditions, 1963–1964, and a catalogue and bibliography of the species from India. Part II. J Mar Biol Assoc India 16(2):609–644

Hutchings PA, Reid A, Wilson RS (1991) *Perinereis* (Polychaeta, Nereididae) from Australia, with redescriptions of six additional species. Rec Aust Mus 43(3):241–274

Ingole BS, Rodrigues N, Ansari ZA (2002) Macrobenthic communities of the coastal waters of Dabhol, west coast of India. Ind J Mar Sci 31:93–99

Ingole B, Sivadas S, Nanajkar M, Sautya S, Nag A (2008) A comparative study of macrobenthic community from harbours along the central west coast of India. Environ Monit Assess 154(1–4):135–146

James PSBR, Thomas PA, Gopinadha Pillai CS, Kumaraswamy Achari GP, Thomas MM, James DB (1969) Catalogue of types and of sponges, corals, polychaetes, crabs and echinoderms in the reference collections of the Central Marine Fisheries Research Institute. Bull Cent Mar Res Inst 7:1–66

Jayaraj KA, Josia J, Dinesh Kumar PK (2008) Infaunal macrobenthic community of soft bottom sediment in a tropical shelf. J Coast Res 24(3):708–718

La Porta B, Tomassetti P, Lomiri S, Marzialetti S, Vani D, Penna M, Lanera P, Nicoletti L (2011) Ecology and spatial distribution of selected polychaete species from the Italian continental shelf. Ital J Zool 78(Suppl 1):290–303

Lakshmana Rao MV (1969) Fouling serpulids from Indian harbours. J Timber Dev Assoc India 15(2):1–20

Lloret J, Demestre M, Sánchez-Pardo J (2007) Lipid reserves of red mullet (*Mullus barbatus*) during pre-spawning in the northwestern Mediterranean. Scientia Mar 71(2):269–277

Mathew A, Govindan K (1995) Macrobenthos in the near-shore coastal system of Bombay. Proc Nat Acad Sci India (B: Biol Sci), 65(IV):411–430

Misra A, Chakraborty RK (1991) Annelida: Polychaeta. Fauna of Lakshadweep, State fauna series. Zool Surv India 2:137–165

Musale AS, Desai DV (2011) Distribution and abundance of macrobenthic polychaetes along the South Indian coast. Environ Monit Assess 178(1–4):423–436

Padmakumar KG (1984) Ecology of a mangrove swamp near Juhu Beach, Bombay with reference to sewage pollution. Unpublished PhD thesis submitted to the University of Bombay

Parulekar AH (1971) Polychaetes from Maharashtra and Goa. J Bombay Nat Hist Soc 68(3):726–749

Parulekar AH (1981) Marine fauna of Malvan, central west coast of India. Mahasagar Bull Nat Inst Oceanogr 14(1):33–44

Read G, Fauchald K (2012) World polychaeta database. Available online at http://www.marinespecies.org/polychaeta/. Accessed 13 July 2012

Rouse GW (2000) Classification of the Annelida and Polychaeta. In: Beesley, PL, Ross GJB, Glasby CJ (eds) Polychaetes and allies: the Southern synthesis, vol 4, Fauna of Australia, A Polychaeta, Myzostomida, Pogonophora, Echiura, Sipuncula. CSIRO Publishing, Melbourne, xii + 465 pp, pp 51–53

Rouse GW, Pleijel F (2006) Annelid phylogeny and systematics. In: Rouse GW, Pleijel F (eds) Reproductive biology and phylogeny of Annelida. Science Publishers Inc., Enfield, pp 3–21

Rozbaczylo N, Simonetti JA (2000) Diversity and distribution of Chilean benthic marine polychaetes: state of the art. Bull Mar Sci 67(1):359–372

Scaps P (2002) A review of the biology, ecology and potential use of the common ragworm Hediste *diversicolor* (O.F. Müller) (Annelida: Polychaeta). Hydrobiologia 470(1–3):203–218

Sendall K (1985) Review and revision of the genus *Sternaspis* (Polychaeta: Sternaspidae) using cladistics on morphological characters. MSc thesis, University of Victoria, p 146

Siciński J (2000) Polychaeta (Annelida) of Admiralty Bay: species richness, diversity, and abundance. Polish Polar Res 21(3–4):153–169

Sivadas S, Sautye S, Nanajkar M, Ingole B (2005) Potential impact of sand mining on macrobenthic community at Kalbadevi Beach, Ratnagiri, West coast of India. In: Loveson VJ, Chandrasekar NVJ, Sinha A (eds) National seminar on development planning of coastal placer minerals (PLACER- 2005). Allied Publishers, New Delhi, pp 264–270

Sivadas S, Ingole B, Nanajkar M (2010) Benthic polychaetes as good indicators of anthropogenic impact. Ind J Mar Sci 39(2):201–211

Solís-Weiss V, Bertrand Y, Helléouet MN, Pleijel F (2004) Types of polychaetous annelids at the Muséum national d'Histoire naturelle, Paris. Zoosystema 26(3):377–384

Struck TH, Purschke G, Halanych KM (2006) Phylogeny of Eunicida (Annelida) and exploring data congruence using a Partition Addition Bootstrap Alteration (PABA) approach. Syst Biol 55(1):1–20

Sukumaran S, Sarala Devi K (2009) Polychaete diversity and its relevance in the rapid environmental assessment of Mumbai Port. Curr Sci 97(10):1439–1444

Sukumaran S, Bhokepode K, Telavane M, Kubal P, Gajbhiye SN (2011) Benthic Polychaetes in the Ratnagiri Bay, India: Influence of anthropogenic factors. J Environ Biol 32:719–724

Sunil Kumar R (1999) New record of five annelids (Class: Polychaeta) from the mangrove habitat of the south west coast of India. J Mar Biol Assoc India 41(1&2):116–118

Sunil Kumar R (2001) A checklist of soil-dwelling polychaetous annelids from some Indian mangrove habitats. Zoos Print J 16(3):439–441

Sunil Kumar R (2003) A checklist of polychaete species some mangroves of Asia. Zoos Print J 18(2):1017–1020

Swami BS, Udhayakumar M (2010) Seasonal influence on settlement, distribution and diversity of fouling organisms at Mumbai harbour. Ind J Mar Sci 39(1):57–67

Varshney PK, Govindan K (1995) Macrobenthos off Mahim (Bombay), west coast of India in relation to coastal pollution and aquaculture. J Ind Fish Assoc 25:47–56

Wafar M, Venkataraman K, Ingole B, Ajmal Khan S, LokaBharathi P (2011) State of knowledge of coastal and marine biodiversity of Indian Ocean countries. PLoS ONE 6(1) e14613:1–12

Wehe T, Fiege D (2002) Annotated checklist of the polychaete species of the seas surrounding the Arabian Peninsula: Red Sea, Gulf of Aden, Arabian Sea, Gulf of Oman, Arabian Gulf. Fauna of Arabia 19:7–238

Yokoyama H, Sukumaran S (2012) First records of three *Paraprionospio* Species (Polychaeta: Spionidae) from Indian waters. Cah Biol Mar 53:279–287

Structure and Dynamics of Rotifer Community in a Lotic Ecosystem

6

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Abstract

The Vishwamitri is one of the major rivers of central Gujarat and on its banks evolved the picturesque city of Vadodara. Like any other lotic ecosystem of the modern era, the Vishwamitri too is used as a dumping ground for domestic and industrial wastes. Nevertheless, the river inhabits a sizable population of microfauna and the notable among them is rotifer. The current study was aimed at understanding the factors influencing the structure and dynamics of rotifer community in the river Vishwamitri. Seasonal sampling was done during 2002–2004 from five selected sampling stations that were representing upstream, midstream, and downstream of Vishwamitri. These stations, therefore, varied in their pollution loads. The taxonomic analysis of rotifers revealed the presence of 59 species, belonging to 24 genera and 17 families. The Lecanidae family had the maximum representation with 18 species followed by Brachionidae with 15 species. However, species belonging to *Brachionus* genus are found as the predominant group, among rotifers, in Vishwamitri. Further, a definite periodicity in the rotifer community was noticed on a temporal scale at all the stations. The species diversity was observed to be highest during the post-monsoon, whereas the least diversity was observed during winter. Analysis for water chemistry followed by suitable statistical analysis revealed that the rotifer community responded differently to various physicochemical cues. Dissolved oxygen, normally a major rate-limiting parameter for aquatic life, was found to have no statistically significant influence in regulating rotifer diversity. The study further revealed that elevated levels of suspended solids and total reactive phosphate have a negative influence on the rotifer diversity.

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Pearson's correlation between rotifer diversity and temperature as well as pH revealed that rotifers thrive well in warm alkaline part of the river. In addition nitrate nitrogen and chlorophyll-a levels had a significant positive influence on rotifer community composition. To sum it up in the current study, we observed that water chemistry does influence rotifer community in Vishwamitri River and the prominent among the chemical parameters that influence the rotifer community are pH and chlorophyll-a. The right blend of these abiotic factors together with the presence of aquatic macrophytes makes the upstream sampling stations of Vishwamitri richer in terms of rotifer diversity as compared to their more polluted downstream stations.

Keywords
Rotifer • Distribution • Diversity • Gujarat

Introduction

Extensive environmental variation is one of the most basic facts of life for any organism living in the tropical water bodies. Among the most notable contributors to this environmental variation are the temperature and chemistry of water. Chemical analysis measures an essential part of the environment, and when closely related with biological study, it greatly enhances its value. Hynes (1978) stated that when the chemist and the biologist both work on the assessment of pollution, they can discover much more than either can alone. Physicochemical analysis of the water is an important aspect from the point of view of aquatic biology. Tebutt (1992) observed that the physicochemical characteristics of water have a direct bearing on the faunal composition of ponds. Lougheed et al. (1998) stated that variability in abiotic factors contributes to seasonal and spatial variability in water quality characteristics and the amount of available habitat and aquatic invertebrates. Yoshinaga et al. (2001) also stated that animal populations live in a diversity of environments, and therefore their population dynamics are regulated by a complex mixture of environmental factors. Zooplankton species succession and spatial distribution is a function of their tolerance to various abiotic and biotic environmental parameters (Marneffe et al. 1998). Most of these factors follow a seasonal pattern of change within an annual cycle. Seasonal variation is clearly driven by climate (Green 2001). Rotifers, due to their high turnover rates, are particularly sensitive to changes in water quality (Sladecek 1983).

Changes in community structure can be explained numerically with diversity index (Kaushik and Saksena 1995). These indices are useful in assessing water quality. Diversity indices are used to characterize species abundance and their relationships in the communities. These mathematical expressions describe the components of community structure, namely, richness (number of species), evenness (uniformity in the distribution of individuals among species), and abundance (total number of organisms), that reveal the response of a community to the quality of its environment (Ludwig and Reynolds 1988). In addition to the changes in the physicochemical composition, interspecific and intraspecific composition, pollution level and the presence or absence of predators are some factors influencing rotifer species composition and structure (Kaushik and Saksena 1995). This chapter discusses the influence of various physicochemical parameters on the rotifer community structure in the various seasons in river Vishwamitri.

Study Area

Location and Topography (Fig. 6.1)

Desai and Clarke (1923) in "The Gazette of Baroda" state that the River Vishwamitri takes its origin from the hills of Pavagadh, which is about 43 km away from the Northeast of Vadodara City. Of its total length of about 90 km, it flows for 58 km through Vadodara district. The entire stretch of the river was traced through a reconnaissance survey to select the suitable sampling stations. Considering the short length of the river, five sampling stations were selected in a manner such that two stations were in the clean zone of the river, two in the septic zone, and one in the recovery zone. Later, however, it was realized that no true recovery zone exists for this river. The five sampling stations and their location obtained with the help of a Geographical Positioning System (*Garmin, GPS 12XL*) are as follows:

Station I: Baska Position: N – 22° 22.088′; E – 73° 27.079′; Altitude – 104 m.

This is the first upstream station near the foothills of Pavagadh. Here the water exists for most part of the year except in the month of May when the river dries up completely. By the end of June, the monsoon water begins to flow through the riverbed again. The river remains in the flowing condition for about 4 months. By the end of November, the water stops flowing, and slowly and steadily stagnation sets in and the water level begins to reduce till only small pools exist in the river bed till the end of April.

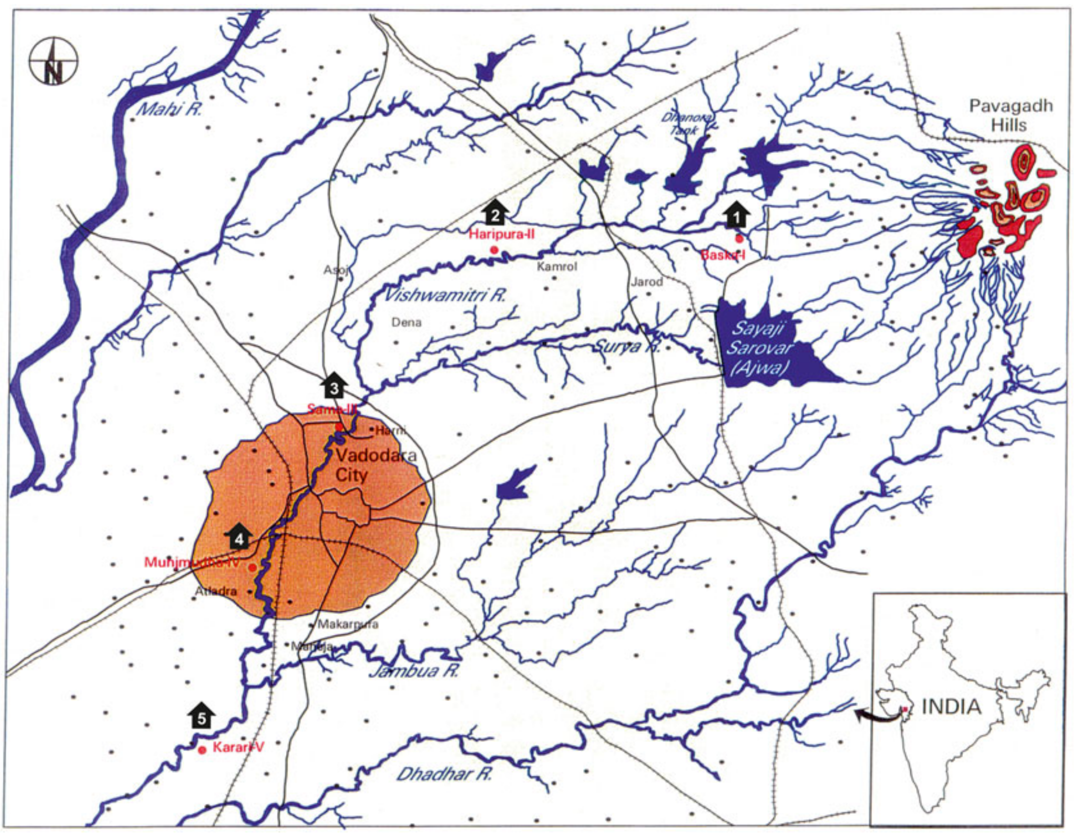

Fig. 6.1 Location map of the study area and the sampling stations (1–5)

Station II: Haripura Position: N – 22° 27.026′; E – 73° 19.361′; Altitude – 62 m.

This is the second station in the upstream part of the river. Water exists in here for a very short duration of time. With the onset of the monsoon by mid June, the water begins to flow through the river. This condition remains till the end of October. Later the farmers along the bank begin to use this water for cultivation, and all the water is pumped out of the river, thus causing the river to dry up by the month of January.

Station III: Sama Position: N – 22° 20.260′; E – 73° 12.301′; Altitude – 46 m.

This station lies within the Vadodara city limits. Water exists at this site throughout the year on account of the sewage water that is released from the city into the river. For most of the year, the water remains flowing except during summer when the water level recedes. This site supports a fairly good population of aquatic vegetation.

Station IV: Munjmahuda Position: N – 22° 17.093′; E – 73° 10.314′; Altitude – 43 m.

This sites lies at the point where the river begins to exit from the city limits. The water is in a flowing condition throughout the year. River at this point receives high amount of sewage that is evident from the black color and strong distasteful odor the water exudes. The aquatic vegetation is nonexistent at this station.

Station V: Karari Position: N – 22° 10.755′; E – 73° 08.730′; Altitude – 40 m.

This is the last sampling station and is located outside the city limit, after the river passes through the industrial sector of the city. The water is in a flowing condition throughout the year. This would otherwise have been the recovery zone; however, right up to the very end of the river, wastes are dumped and the river gets no time for recovery.

Methods

Water samples were collected and analyzed for the physicochemical parameters as per the treatise, "Standard Methods for the Examination of Water and Wastewater," prepared and published jointly by the American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). Sampling was done on five consecutive days in each month during the years 2002–2004. Sample of each day was separately analyzed in the same day, and then the data were pooled to represent the monthly data. Five samples were collected from each site in clean and contamination-free polyethylene containers of two liters volume. They were maintained at 4 °C during transportation to the laboratory in order to reduce the growth of microorganisms. The water samples were collected from the middle of the stream at mid-depth. Stratified random sampling was not possible as the stations were having 1 m or less deep water during major part of the year. The containers were then labeled indicating the sample number, time, and weather conditions.

1. Temperature: Temperature is basically important for its effect on the chemistry and biological reactions of the organisms in water. A rise in temperature of the water leads to the speeding up of the chemical reactions in water and reduces the solubility of gases (Sawyer et al. 1994). In the present study, the ambient as well as the water temperatures were measured at the site using calibrated good grade mercury-filled Celsius thermometer.
2. pH: This is a measure of the intensity of acidity or alkalinity. pH of water gets drastically changed with time due to exposure to air, biological activities, and temperature changes. In natural waters, pH also changes diurnally and seasonally due to variation in photosynthetic activity (Sawyer et al. 1994). Therefore, pH was measured electrometrically using a handheld pH meter.
3. Dissolved oxygen (DO): Dissolved oxygen is one of the most important parameters in water assessment. It reflects the physical and biological processes prevailing in the waters. Its presence is essential to maintain the higher forms of biological life in the water. Organisms have specific requirements of oxygen (APHA et al. 1998). Winkler's modified method as described in APHA, AWWA (1998) was employed for determining the dissolved oxygen.

4. Total suspended solids (TSS): Water samples were analyzed gravimetrically for TSS (APHA et al. 1998).
5. Chlorophyll-a: The green pigment chlorophyll-a has been reported to be a reliable indicator of phytoplankton biomass (Trivedi and Goel 1986). Chlorophyll was, therefore, extracted in 90 % aqueous acetone and spectrophotometrically analyzed for its concentration as described in APHA, AWWA (1998).
6. Nitrate nitrogen: In the present study, total oxidized nitrogen was estimated using the cadmium reduction method (APHA et al. 1998).
7. Phosphorus: Phosphorous occurs in natural waters and in wastewater almost solely as phosphates. In the current study, the total reactive phosphorus of the water was estimated using the stannous chloride method (APHA et al. 1998).
8. Biological oxygen demand (BOD): The BOD test is widely used to determine the pollution strength of domestic and industrial wastes and is one of the most important in stream pollution control activities. During the present study, the BOD was estimated employing the 5-day BOD test (APHA et al. 1998).

Biological Sampling

Separate samples were collected by filtering a volume of 10 L subsurface water through a plankton net made up of bolting silk cloth No. 20 (the inside width of the meshes was 74 μm). Extreme care was taken to keep water undisturbed at the time of sampling and also to avoid spilling of water from the net. The samples were immediately preserved by adding a few drops of 5 % formalin. The samples were then concentrated to 10 ml by centrifugation. For final analysis, 0.5 ml of sample was taken on Sedgwick-Rafter chambers and rotifers were enumerated and analyzed under a Leica DMRB research microscope.

Results

The rotifer fauna of River Vishwamitri is represented by a total of 59 species belonging to 24 genera and 17 families.

Species Numbers

Station III has the highest number of rotifer species. This station has 40 species (Table 6.1) out of a total of 59, thus harboring about 67.8 % of the total rotifer species. This was followed by station I which has 37 rotifer species (Table 6.2), representing 62.7 % of the rotifer fauna. Next was station II that had a total of 33 species (Table 6.3), thus having about 56 % of the total rotifer species. Station IV and station V had the least number of rotifer species, a total of 12 (Table 6.4) and 10 species (Table 6.5), respectively, thus harboring just about 20.3 % and 16.9 % of the total rotifer fauna of the river.

Exclusive Species

Rotifer species that occurred at a single station have been termed as "exclusive species" in the present study. Twenty rotifer species out of a total of 59 species have been found to occur exclusively at just one particular station. Thus, 33.9 % of the species can be termed as exclusive species or species occurring exclusively at a single station. From the data (Table 6.1), it is evident that station III supports the maximum number of such exclusive species. This station harbors a total of 12 such exclusive species accounting for 63 % of the total exclusive species. This is followed by station I having a total of five exclusive species (Table 6.2), thus accounting for 21 %; station II is next, harboring three exclusive species (Table 6.3) and accounting for 15.8 % of these exclusive species. Sites IV and V do not support any of the exclusive species.

Distribution Pattern of Species

As stated earlier, 20 species out of a total of 59 species are exclusive. Six species of rotifers in River Vishwamitri are common and found at all five stations. Thus, 10.2 % of the species are commonly found at all the stations. Four species are such that they occur at four stations, i.e., 6.8 % of the species can be found in at least four stations. Seven species are such that they

Table 6.1 Composition of rotifer species at station III

Family (11)[b]	Genera (16)	Species (40)
Asplanchnidae	*Asplanchna*	*A. sieboldi*[a]
Brachionidae	*Anuraeopsis*	*A. fissa*
	Brachionus	*B. angularis*
		B. calyciflorus
		B. caudatus
		B. diversicornis[a]
		B. falcatus[a]
		B. forficula
		B. quadridentatus
		B. rubens[a]
	Keratella	*K. procurva*
		K. tropica
	Platyias	*P. quadricornis*[a]
Colurellidae	*Colurella*	*C. unicata*
	Lepadella	*L. acuminate*
		L. ovalis
		L. patella
Dicranophoridae	*Dicranophorous*	*D. australiensis*
	Encentrum	*Sp.1*[a]
Euchlanidae	*Euchlanis*	*E. meneta*
		E. dilatata[a]
Filiniidae	*Filinia*	*F. longiseta*
		F. opoliensis
Lecanidae	*Lecane*	*L. arcula*
		L. bulla
		L. closterocerca
		L. curvicornis
		L. elachi[a]
		L. hamata
		L. inermis
		L. inopinata[a]
		L. luna
		L. nana[a]
		L. papuana
		L. stenroosi[a]
		L. ungulate
Notommatidae	*Cephalodella*	*C. misgurunus*
Synchaetidae	*Polyarthra*	*Sp.1*
Testudinellidae	*Testudinella*	*T. patina*
Trichotriidae	*Trichotria*	*T. tetractis*[a]

[a]Indicates exclusive species
[b]Total number in parenthesis

occur at only three stations, i.e., 11 % species occur at three stations. Twenty-three species occur at only two stations, thus showing that 38.98 % of the species can be found at only two stations.

Table 6.2 Composition of rotifer species at station I

Family (12)[b]	Genera (17)	Species (37)
Brachionidae	*Anueropsis*	*A. coelata*
		A. fissa
	Brachionus	*B. angularis*
		B. bidentata
		B. calyciflorus
		B. quadridentatus
	Keratella	*K. procurva*
		K. tropica
	Plationus	*P. patulus*
Colurellidae	*Colurella*	*C. unicata*
		C. obtuse
	Lepadella	*L. ovalis*
		L. patella
		L. rhomboides[a]
Dicranophoridae	*Dicranophorous*	*D. australiensis*
Euchlanidae	*Euchlanis*	*E. meneta*
		E. oropha[a]
Flosculariidae	*Lacinularia*	*Sp.1*
Hexarthridae	*Hexarthra*	*H. mira*
Lecanidae	*Lecane*	*L. bulla*
		L. closterocerca
		L. crepida[a]
		L. crenata[a]
		L. curvicornis
		L. hamata
		L. inermis
		L. leontina
		L. luna
		L. pyriformis[a]
		L. quadridentata
		L. ungulate
Mytilinidae	*Mytilina*	*M. ventralis*
Notommatidae	*Cephalodella*	*C. misgurnus*
	Scaridium	*S. longicaudum*
Synchaetidae	*Polyarthra*	*Sp.1*
Testudinellidae	*Testudinella*	*T. patina*
Trichocercidae	Trichocerca	*T. braziliensis*

[a]Indicates exclusive species
[b]Total number in parenthesis

Similarities Between Regions

This involved calculating the numbers of species shared by each pair of stations. The general pattern was as expected, in that each site shares the greatest number of species with the closest other region and fewest species with the most remote region (Tables 6.6 and 6.7). For example, station I shares

Table 6.3 Composition of rotifer species at station II

Family (14)[b]	Genera (19)	Species (33)
Asplanchnidae	*Asplanchna*	*A. brightwelli*[a]
Atrochidae	*Cupelopagis*	*C. vorax*[a]
Brachionidae	*Anuraeopsis*	*A. coelata*
		A. fissa
	Brachionus	*B. angularis*
		B. bidentatus
		B. calyciflorus
		B. caudatus
		B. forficula
		B. quadridentatus
	Keratella	*K. procurva*
		K. tropica
	Plationus	*P. patulus*
Colurellidae	*Colurella*	*C. obtuse*
	Lepadella	*L. patella*
Dicranophoridae	*Dicranophorous*	*D. australiensis*
Euchlanidae	*Euchlanis*	*E. meneta*
Filiniidae	*Filinia*	*F. longiseta*
		F. opoliensis
Flosculariidae	*Lacinularia*	*Sp.1*
Hexarthridae	*Hexarthra*	*H. mira*
Lecanidae	*Lecane*	*L. arcula*
		L. bulla
		L. inermis
		L. leontina
		L. luna
		L. papuana
		L. quadridentata
Mytilinidae	*Mytilina*	*M. ventralis*
Notommatidae	*Cephalodella*	*C. misgurnus*
	Scaridium	*S. longicaudum*
Synchaetidae	Polyarthra	*Sp.1*
Philodinidae	*Rotaria*	*R. neptunia*[a]

[a]Indicates exclusive species
[b]Total number in parenthesis

24 species with the adjoining station II and only eight species with the remote station V. Similarly station II shares 20 species with the next station III but only eight with remote station V.

Unlike the raw figures of shared species quoted above, the similarity indices take account of the total number of species in the regions concerned. The Jaccard index that is used here incorporates total from both of the regions compared. Nonetheless, the index presents a broadly similar picture of faunal resemblance to the shared species and points that the greatest

Table 6.4 Composition of rotifer species at station IV

Family (7)[a]	Genera (10)	Species (12)
Brachionidae	*Anuraeopsis*	*A. fissa*
	Brachionus	*B. angularis*
		B. quadridentatus
	Keratella	*K. tropica*
	Plationus	*P. patulus*
Colurellidae	*Colurella*	*C. obtuse*
Dicranophoridae	*Dicranophorus*	*D. australiensis*
Filiniidae	*Filinia*	*F. longiseta*
Lecanidae	*Lecane*	*L. bulla*
		L. inermis
Synchaetidae	*Polyarthra*	*Sp.1*
Trichocercidae	*Trichocerca*	*T. braziliensis*

[a]Total number in parenthesis

Table 6.5 Composition of rotifer species at station V

Family (5)[a]	Genera (6)	Species (10)
Brachionidae	*Brachionus*	*B. angularis*
		B. quadridentatus
	Keratella	*K. tropica*
Colurellidae	Lepadella	*L. acuminate*
		L. patella
Dicranophoridae	*Dicranophorus*	*D. australiensis*
Filiniidae	*Filinia*	*F. longiseta*
Lecanidae	*Lecane*	*L. bulla*
		L. inermis
		L. pyriformis

[a]Total number in parenthesis

levels of species sharing and family sharing occur between regions that are geographically close together and the smallest levels between regions that are far apart. In other words, whether one uses the numbers of shared species or the Jaccard index, the conclusions on the rotifer faunal similarities are broadly similar (Table 6.7).

Species Diversity

Stations I, II, and III showed reasonably good rotifer species diversity, whereas stations IV and V had lower diversity of rotifers. On the whole, however, the post-monsoon season had the highest diversity of rotifers as indicated by the Shannon-Weiner and Margalef indices (Table 6.8)

Table 6.6 Number of rotifer species shared between sites

Station	I (37)	II (33)	III (40)	IV (12)	IV (10)
I	–	24	21	11	8
II	–	–	20	11	8
III	–	–	–	9	9
IV	–	–	–	–	7
V	–	–	–	–	–

Table 6.7 Rotifer community similarity (C_j) between the stations

Station	I	II	III	IV	V
I	–	0.52	0.38	0.29	0.21
II	–	–	0.38	0.32	0.23
III	–	–	–	0.21	0.22
IV	–	–	–	–	0.47
V	–	–	–	–	–

Table 6.8 Seasonal diversity of rotifers at various sampling stations of River Vishwamitri during 2002–2004

Sampling station	Species richness	Species diversity H'	D	Equitability
(a) Summer				
I	7	1.27	1.52	0.49
II	–	–	–	–
III	11	1.88	1.62	0.62
IV	1	0.17	0.11	0.24
V	1	0.19	0.12	0.08
(b) Post-monsoon				
I	23	2.56	2.91	0.63
II	17	2.30	2.63	0.57
III	14	2.31	2.21	0.57
IV	5	1.48	1.01	0.30
V	4	1.18	0.84	0.29
(c) Winter				
I	3	0.59	0.39	0.14
II	4	1.27	0.58	0.31
III	6	1.36	1.03	0.35
IV	3	0.72	0.54	0.18
V	2	0.57	0.30	0.14

of species diversity, while lowest diversity was found during the winter months at all stations except IV and V (Table 6.8). Station I recorded the highest diversity in the month of September and the lowest in January. At station II also the months of August and September high rotifer species diversity was observed which, however, began to reduce by October and reached minimum levels in the month of December. Station III showed less variation in the rotifer diversity throughout the year; however, on the whole, the post-monsoon months had the highest levels of rotifer diversity, followed by the month of May. Stations IV and V had very low levels of rotifer diversity as compared to the other three stations.

Physicochemical Parameters

Temperature

The temperature of the river water varied with changes in the ambient temperature at all the stations. As expected the highest values were obtained in the summer months with April having the maximum temperature values (Table 6.9). Station V showed the highest mean summer temperature followed by station IV and then by station I and lastly by station III. The lowest temperature values were recorded during winter and ranged from 13.0 to 19.7 °C (Table 6.9). At all the stations, the month of January recorded the least temperature values. The temperature during the post-monsoon season was moderate and ranged between the summer and the winter values. Station I recorded the lowest mean post-monsoon value, while station IV recorded the highest mean post-monsoon temperature (Table 6.9).

pH

The mean pH values of the river varied between 7.51 and 9.01 during the study period. Station I did not show much variation in the pH levels, the maximum value of 7.89 was obtained during the month of April, while the lowest value was observed in August and September. Likewise at station II, the values varied only between 7.60 in August and September and 7.91 in December. At station III, slight increase in the variation was observed with values ranging from 7.49 to 8.05. The highest pH value of 9.01 was recorded from station IV in the month of May. Here the lowest recorded pH value was 7.59 in the month of September. The pH values at station V ranged

Table 6.9 Monthly and seasonal temperature of water at various stations of River Vishwamitri during 2002–2004

	Temperature (°C)			
Sites	Month		Season	
Station I	March	25.50 ± 0.50*	Summer	26.95 ± 1.61*
	April	28.40 ± 0.55		
	May	Dry		
	August	23.20 ± 0.84	Post-monsoon	24.87 ± 1.41
	September	25.40 ± 0.55		
	October	26.00 ± 0.71		
	December	15.20 ± 0.91	Winter	15.70 ± 1.98
	January	13.80 ± 0.57		
	February	18.10 ± 0.74		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	24.20 ± 0.84	Post-monsoon	25.20 ± 1.08
	September	25.10 ± 0.74		
	October	26.30 ± 0.27		
	December	14.00 ± 0.71	Winter	14.00 ± 0.71
	January	Dry		
	February	Dry		
Station III	March	25.90 ± 0.55	Summer	27.07 ± 1.13
	April	28.30 ± 0.45		
	May	27.00 ± 0.61		
	August	24.60 ± 0.55	Post-monsoon	25.53 ± 0.99
	September	25.40 ± 0.55		
	October	26.60 ± 0.55		
	December	14.30 ± 0.45	Winter	15.13 ± 2.22
	January	13.10 ± 0.55		
	February	18.00 ± 0.71		
Station IV	March	26.20 ± 0.27	Summer	27.40 ± 1.12
	April	28.70 ± 0.45		
	May	27.30 ± 0.45		
	August	24.20 ± 0.84	Post-monsoon	25.93 ± 1.43
	September	26.40 ± 0.55		
	October	27.20 ± 0.27		
	December	14.80 ± 0.84	Winter	15.20 ± 2.14
	January	13.00 ± 0.71		
	February	17.80 ± 0.45		
Station V	March	26.40 ± 0.42	Summer	27.57 ± 1.16
	April	28.90 ± 0.55		
	May	27.40 ± 0.55		
	August	24.40 ± 0.89	Post-monsoon	25.80 ± 1.42
	September	25.60 ± 0.55		
	October	27.40 ± 0.55		
	December	15.60 ± 0.89	Winter	16.57 ± 2.48
	January	14.40 ± 0.96		
	February	19.70 ± 0.76		

*Values are expressed as Mean ± SD

from 7.67 in September to 8.98 during May. By and large, the pH values were lower in initial stations and gradually increased downstream. Also the summer values were in general highest and the post-monsoon values were the lowest (Table 6.10).

Dissolved Oxygen

The levels of dissolved oxygen fluctuated from season to season at all the sampling stations. During the sampling period, mean DO values, as low as 0 mg/L to as high as 7.8 mg/L, were obtained (Table 6.11). On the whole, however, stations I, II, and III showed fairly good amount of dissolved oxygen, while stations IV and V had very low levels of oxygen throughout the year (Table 6.11). As expected the dissolved oxygen levels were highest during the winter season at almost all the stations (Table 6.11) except at station V. Station III had the highest mean value (7.8 mg/L) of DO in the month of January. The lowest levels at all the stations were encountered during the hot summer season (Table 6.11). In fact during the month of April, stations IV and V had mean DO levels equal to 0.48 mg/L and 0 mg/L, respectively. Station II had dried up completely by the summer season. Station III showed fairly good amount (3.79 mg/L) of DO even in summer. Though station I had the highest dissolved oxygen values for the early summer season, it dried up by the end of April. Owing to the proper mixing of water during the post-monsoon period, most stations showed reasonably good amount of dissolved oxygen (Table 6.11). In fact highest mean value (1.44 mg/L) of dissolved oxygen for station V was recorded during the post-monsoon season in the month of August (Table 6.11). Similarly the other stations also showed good amount of dissolved oxygen during this period.

The DO values must also be seen in comparison with the BOD values. As the DO values fall, there is a concomitant rise in the BOD levels. This is clearly seen in (Table 6.16). Since biologically degradable organic matter constitutes 7 % of sewage, it has a direct influence on the dissolved oxygen content of the water (Hynes 1978) resulting in the "oxygen-sag curve." As indicated in Table 6.11, the DO levels fall to such an extent that the river water nearly becomes devoid of any dissolved oxygen in the downstream direction at stations IV and V, causing anoxic conditions.

Total Suspended Solids

Much variation in the levels of TSS was recorded from all the stations (Table 6.12). Stations I and II had relatively low levels of TSS as compared to stations III, IV, and V. The values of TSS increased from station I to station V (Table 6.12). Thus, station I recorded the lowest values of TSS, while the highest values were met with at station V. The post-monsoon season recorded the highest values of suspended solids (Table 6.12) from all the stations. The highest mean value of 685.20 mg/L was recorded from station V in the month of August. The lowest value recorded at this station was in the month of December (Table 6.12). Overall the winter season had the least values of suspended solids (Table 6.12). The mean summer values were just a little higher than the winter values and thus ranged between the winter and the summer levels.

Chlorophyll-a

The chlorophyll-a content varied throughout the study period with the maximum being recorded during the post-monsoon period and the minimum in summer at all the stations (Table 6.13). Stations IV and V showed very low chlorophyll-a content throughout the year, while stations I, II, and II had a good level of chlorophyll-a (Table 6.13). The mean chlorophyll-a values at station IV ranged from 4.20 in April to 21.90 in October (Table 6.13). Similarly the mean chlorophyll-a content at station V ranged from 6.10 in April to 22.10 in October (Table 6.13). Stations I and III showed drastic fluctuations in the level of chlorophyll-a throughout the year (Table 6.13).

Total Reactive Phosphate

Stations I and II showed low levels of total reactive phosphate in comparison to station IV and V (Table 6.14). Station III showed moderate values of total reactive phosphate. Throughout the year, highest values were obtained in summer, while the lowest during the post-monsoon season at all the stations (Table 6.14).

Table 6.10 Monthly and seasonal values of pH at various stations of River Vishwamitri during 2002–2004

	pH			
Sites	Month		Season	
Station I	March	7.59 ± 0.06	Summer	7.74 ± 0.17
	April	7.89 ± 0.06		
	May	Dry		
	August	7.51 ± 0.07	Post-monsoon	7.52 ± 0.07
	September	7.51 ± 0.07		
	October	7.53 ± 0.10		
	December	7.60 ± 0.03	Winter	7.70 ± 0.10
	January	7.69 ± 0.06		
	February	7.81 ± 0.04		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	7.60 ± 0.07	Post-monsoon	7.67 ± 0.11
	September	7.60 ± 0.05		
	October	7.81 ± 0.03		
	December	7.91 ± 0.04	Winter	7.91 ± 0.04
	January	Dry		
	February	Dry		
Station III	March	7.99 ± 0.04	Summer	8.01 ± 0.07
	April	7.99 ± 0.07		
	May	8.05 ± 0.08		
	August	7.50 ± 0.07	Post-monsoon	7.60 ± 0.16
	September	7.49 ± 0.06		
	October	7.81 ± 0.04		
	December	7.78 ± 0.06	Winter	7.85 ± 0.08
	January	7.88 ± 0.07		
	February	7.90 ± 0.05		
Station IV	March	8.61 ± 0.06	Summer	8.80 ± 0.18
	April	8.79 ± 0.06		
	May	9.01 ± 0.07		
	August	7.60 ± 0.05	Post-monsoon	7.67 ± 0.12
	September	7.59 ± 0.06		
	October	7.81 ± 0.04		
	December	8.18 ± 0.06	Winter	8.35 ± 0.15
	January	8.39 ± 0.07		
	February	8.48 ± 0.07		
Station V	March	8.70 ± 0.06	Summer	8.86 ± 0.13
	April	8.88 ± 0.05		
	May	8,98 ± 0.06		
	August	7.70 ± 0.04	Post-monsoon	7.76 ± 0.11
	September	7.67 ± 0.4		
	October	7.89 ± 0.06		
	December	8.00 ± 0.06	Winter	8.31 ± 0.24
	January	8.41 ± 0.05		
	February	8.53 ± 0.06		

*Values are expressed as mean ± SD

Table 6.11 Monthly and seasonal concentration of dissolved oxygen at various stations of River Vishwamitri during 2002–2004

	Dissolved oxygen (mg/L)			
Sites	Month		Season	
Station I	March	4.18 ± 0.19*	Summer	4.07 ± 0.22*
	April	3.96 ± 0.21		
	May	Dry		
	August	5.32 ± 0.15	Post-monsoon	4.85 ± 0.59
	September	5.14 ± 0.15		
	October	4.08 ± 0.19		
	December	5.84 ± 0.17	Winter	6.12 ± 0.67
	January	7.00 ± 0.16		
	February	5.52 ± 0.13		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	5.20 ± 0.16	Post-monsoon	4.67 ± 0.65
	September	4.98 ± 0.15		
	October	3.82 ± 0.25		
	December	7.08 ± 0.19	Winter	7.08 ± 0.19
	January	Dry		
	February	Dry		
Station III	March	4.02 ± 0.18	Summer	3.79 ± 0.27
	April	3.52 ± 0.19		
	May	3.82 ± 0.18		
	August	4.98 ± 0.13	Post-monsoon	4.19 ± 0.69
	September	4.20 ± 0.16		
	October	3.40 ± 0.29		
	December	5.98 ± 0.19	Winter	6.42 ± 1.05
	January	7.80 ± 0.21		
	February	5.48 ± 0.19		
Station IV	March	1.72 ± 0.13	Summer	1.11 ± 0.53
	April	0.48 ± 0.08		
	May	1.14 ± 0.11		
	August	2.10 ± 0.16	Post-monsoon	1.71 ± 0.47
	September	1.92 ± 0.19		
	October	1.12 ± 0.19		
	December	2.92 ± 0.08	Winter	2.84 ± 0.31
	January	3.12 ± 0.08		
	February	2.48 ± 0.22		
Station V	March	0.88 ± 0.08	Summer	0.53 ± 0.40
	April	00		
	May	0.72 ± 0.08		
	August	1.44 ± 0.11	Post-monsoon	1.00 ± 0.34
	September	0.88 ± 0.08		
	October	0.68 ± 0.08		
	December	0.90 ± 0.07	Winter	0.90 ± 0.14
	January	1.04 ± 0.07		
	February	0.75 ± 0.06		

*Values are expressed as Mean ± SD

Table 6.12 Monthly and seasonal levels of total suspended solids at various stations of River Vishwamitri during 2002–2004

	Total suspended solids (mg/L)			
Sites	Month		Season	
Station I	March	63.00 ± 2.24*	Summer	66.90 ± 4.63*
	April	70.80 ± 2.28		
	May	Dry		
	August	102.80 ± 3.83	Post-monsoon	92.40 ± 9.42
	September	92.60 ± 3.13		
	October	81.80 ± 3.19		
	December	42.40 ± 3.05	Winter	52.13 ± 8.97
	January	51.60 ± 2.97		
	February	62.40 ± 3.58		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	141.40 ± 4.51	Post-monsoon	125.13 ± 13.57
	September	123.00 ± 4.74		
	October	111.00 ± 4.00		
	December	66.20 ± 3.49	Winter	66.20 ± 3.49
	January	Dry		
	February	Dry		
Station III	March	122.00 ± 3.16	Summer	144.87 ± 20.38
	April	143.20 ± 3.35		
	May	169.40 ± 4.77		
	August	306.80 ± 5.76	Post-monsoon	243.33 ± 47.94
	September	223. 40 ± 9.58		
	October	199.80 ± 4.44		
	December	131. 60 ± 3.85	Winter	145.07 ± 12.86
	January	143.60 ± 4.04		
	February	160.00 ± 6.32		
Station IV	March	234.40 ± 6.69	Summer	285.93 ± 48.38
	April	276.60 ± 6.07		
	May	346.80 ± 7.26		
	August	475.60 ± 10.69	Post-monsoon	406.87 ± 51.79
	September	382.60 ± 9.55		
	October	362.40 ± 8.29		
	December	218.60 ± 6.35	Winter	262.13 ± 38.97
	January	258.80 ± 6.22		
	February	309.00 ± 10.34		
Station V	March	352.00 ± 8.00	Summer	392.53 ± 34.38
	April	394.20 ± 7.01		
	May	431.40 ± 8.88		
	August	685.20 ± 16.51	Post-monsoon	590.60 ± 75.32
	September	575.60 ± 10.99		
	October	511.00 ± 8.60		
	December	290.20 ± 7.95	Winter	330.27 ± 32.03
	January	339.20 ± 8.70		
	February	361.40 ± 11.52		

*Values are expressed as Mean ± SD

Table 6.13 Monthly and seasonal levels of chlorophyll-a at various stations of River Vishwamitri during 2002–2004

	Chlorophyll-a (μg/L)			
Sites	Month		Season	
Station I	March	72.20 ± 2.68*	Summer	54.20 ± 19.08*
	April	36.20 ± 1.30		
	May	Dry		
	August	132.00 ± 3.16	Post-monsoon	146.20 ± 14.12
	September	142.60 ± 3.29		
	October	164.00 ± 3.61		
	December	21.40 ± 0.84	Winter	17.13 ± 3.29
	January	14.20 ± 0.84		
	February	15.80 ± 0.84		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	103.00 ± 3.16	Post-monsoon	103.93 ± 13.00
	September	119.40 ± 3.85		
	October	89.40 ± 1.52		
	December	56.60 ± 1.52	Winter	56.60 ± 1.52
	January	Dry		
	February	Dry		
Station III	March	62.40 ± 2.51	Summer	64.40 ± 19.00
	April	87.60 ± 3.91		
	May	43.20 ± 1.30		
	August	110.20 ± 2.28	Post-monsoon	104.80 ± 5.44
	September	98.40 ± 2.07		
	October	105.80 ± 2.28		
	December	70.49 ± 2.74	Winter	75.33 ± 13.96
	January	93.46 ± 3.15		
	February	62.04 ± 2.09		
Station IV	March	11.80 ± 0.76	Summer	8.47 ± 2.33
	April	4.60 ± 0.55		
	May	6.20 ± 0.84		
	August	14.50 ± 0.50	Post-monsoon	18.58 ± 2.80
	September	17.80 ± 0.84		
	October	21.90 ± 0.74		
	December	11.10 ± 0.74	Winter	12.93 ± 1.44
	January	12.10 ± 0.65		
	February	14.00 ± 0.79		
Station V	March	11.30 ± 0.76	Summer	7.53 ± 3.27
	April	6.10 ± 0.42		
	May	8.00 ± 1.00		
	August	22.10 ± 1.08	Post-monsoon	18.07 ± 3.20
	September	16.84 ± 0.93		
	October	16.80 ± 1.48		
	December	14.00 ± 1.58	Winter	12.40 ± 1.42
	January	11.80 ± 1.58		
	February	13.00 ± 1.00		

*Values are expressed as mean ± SD

Table 6.14 Monthly and seasonal concentration of total reactive phosphate at various stations of River Vishwamitri during 2002–2004

	Total reactive phosphate (mg/L)			
Sites	Month		Season	
Station I	March	1.10 ± 0.09*	Summer	1.17 ± 0.10*
	April	1.24 ± 0.06		
	May	Dry		
	August	0.45 ± 0.03	Post-monsoon	0.53 ± 0.09
	September	0.51 ± 0.04		
	October	0.62 ± 0.06		
	December	0.79 ± 0.05	Winter	0.88 ± 0.10
	January	0.86 ± 0.04		
	February	1.00 ± 0.06		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	0.61 ± 0.04	Post-monsoon	0.68 ± 0.07
	September	0.67 ± 0.05		
	October	0.75 ± 0.04		
	December	1.15 ± 0.05	Winter	1.15 ± 0.05
	January	Dry		
	February	Dry		
Station III	March	1.51 ± 0.06	Summer	1.69 ± 0.17
	April	1.67 ± 0.07		
	May	1.88 ± 0.10		
	August	0.64 ± 0.04	Post-monsoon	0.73 ± 0.09
	September	0.72 ± 0.06		
	October	0.82 ± 0.05		
	December	1.27 ± 0.04	Winter	1.40 ± 0.13
	January	1.40 ± 0.05		
	February	1.54 ± 0.08		
Station IV	March	2.63 ± 0.12	Summer	2.88 ± 0.24
	April	2.89 ± 0.09		
	May	3.13 ± 0.12		
	August	1.09 ± 0.06	Post-monsoon	1.23 ± 0.13
	September	1.22 ± 0.04		
	October	1.39 ± 0.04		
	December	1.46 ± 0.04	Winter	1.95 ± 0.63
	January	1.59 ± 0.07		
	February	2.80 ± 0.08		
Station V	March	2.82 ± 0.10	Summer	3.30 ± 0.46
	April	3.22 ± 0.08		
	May	3.87 ± 0.13		
	August	1.38 ± 0.05	Post-monsoon	1.55 ± 0.16
	September	1.54 ± 0.05		
	October	1.73 ± 0.07		
	December	2.31 ± 0.08	Winter	2.70 ± 0.41
	January	2.57 ± 0.12		
	February	3.23 ± 0.11		

*Values are expressed as mean ± SD

Nitrate Nitrogen

Stations IV and V showed high levels of nitrate nitrogen in comparison to stations I and II. An increase in the level of nitrate nitrogen was observed from station I to station V (Table 6.15). By and large, the highest values were obtained during the post-monsoon season at all the stations (Table 6.15). The winter season showed the lowest values of nitrate nitrogen at all the stations.

Biological Oxygen Demand

Post-monsoon season recorded the lowest values of BOD at all the stations, while summer had the highest values (Table 6.16). The upstream stations I and II had lower BOD values as compared to the downstream stations (Table 6.16). Highest BOD value was recorded at station V in the month of May, while the lowest value was recorded at station I in August.

Discussion

Understanding rotifer community structure and the factors affecting its diversity, abundance, and richness is very complex. Contradictory reports exist on various factors that could be affecting it. Even the question of whether or not seasonality exists in the rotifer community is riddled with contradictions. Pennak (1955) from his observations concluded that there is no seasonal periodicity in North American Rotifers. Wesenberg-Lund (1908, 1930) has shown that these seasonal variations are not very marked in Danish waters. Mengestou et al. (1991) based on their study of rotifer dynamics in Ethiopia did not observe a consistent seasonal pattern or generalized scheme of succession in Rotifers. In a long-term study across four Polish lakes, Steinberg et al. (2009) observed a relatively stable species composition among these lakes within years and within the lakes between years, but they also report variation in the species abundance patterns that seem to be most affected by season. Nayar (1965) based on his study concluded that periodicity of occurrence cannot be assigned to a particular season. However, there are few reports that conclude that rotifers from India follow a marked periodicity. George (1961) attributed a summer periodicity to the rotifers in Delhi waters. Chacko and Rajagopal (1962) found that rotifers were dominant in the month of May and August. Michael (1968) observed different peaks in slightly different periods during his 2-year study period. Dhanapathi (1997) observed a bimodal curve of rotifer abundance from two ponds in Andhra Pradesh. In their study on the seasonal dynamics of rotifers of the river Yamuna in Delhi, Arora and Mehra (2003) reported to no seasonal variation in the species diversity. During the present study, a remarkable alteration in the rotifer community was observed with change in the various seasons. A less obvious change was observed on a monthly basis (Table 6.17), and hence only the seasonal data compiled by combining the monthly data has been discussed here. In the present study, rotifer diversity, richness, and equitability were found to be highest during the post-monsoon season. Similar results were obtained by Fernando and Rajapaksa (1983), who found rotifers in high numbers both during the dry and rainy seasons in tropical lakes. Green (1960) and Duncan and Gulati (1981) found high rotifer numbers during the flushing periods or flood cycle, while Robinson and Robinson (1971) and Burgis (1974) found that rotifer numbers were highest during warm dry months and lowest during the cold period. This is only partially in agreement with the results obtained in the present study wherein too the rotifer numbers in the winter season were low.

The seasonality of rotifers can be ascribed to a number of climatological and biological factors (Mengestou et al. 1991). Herzig (1987) from an intensive study of the Rotifera from temperate lakes observed that some central factors such as physical, chemical limitations, food and mechanical interference, competition, predation, and parasitism regulate rotifer succession. Many studies have been conducted to find the causative factors for the seasonal variations. Studies conducted by Sarma et al. (2011) revealed that a wide range of physicochemical factors influence the seasonal variation in zooplankton abundances including

Table 6.15 Monthly and seasonal concentration of nitrate nitrogen at various stations of River Vishwamitri during 2002–2004

	Nitrate nitrogen (mg/L)			
Sites	Month		Season	
Station I	March	0.50 ± 0.02*	Summer	0.54 ± 0.05*
	April	0.58 ± 0.03		
	May	Dry		
	August	0.87 ± 0.02	Post-monsoon	0.82 ± 0.05
	September	0.82 ± 0.02		
	October	0.76 ± 0.03		
	December	0.39 ± 0.02	Winter	0.49 ± 0.08
	January	0.48 ± 0.02		
	February	0.59 ± 0.03		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	0.92 ± 0.03	Post-monsoon	0.84 ± 0.08
	September	0.84 ± 0.03		
	October	0.74 ± 0.02		
	December	0.58 ± 0.03	Winter	0.58 ± 0.03
	January	Dry		
	February	Dry		
Station III	March	0.75 ± 0.03	Summer	0.82 ± 0.06
	April	0.83 ± 0.03		
	May	0.87 ± 0.05		
	August	1.10 ± 0.07	Post-monsoon	0.92 ± 0.14
	September	0.87 ± 0.04		
	October	0.79 ± 0.02		
	December	0.62 ± 0.02	Winter	0.64 ± 0.03
	January	0.64 ± 0.02		
	February	0.68 ± 0.02		
Station IV	March	1.10 ± 0.03	Summer	1.22 ± 0.12
	April	1.20 ± 0.03		
	May	1.35 ± 0.11		
	August	1.40 ± 0.05	Post-monsoon	1.33 ± 0.09
	September	1.37 ± 0.04		
	October	1.23 ± 0.06		
	December	0.94 ± 0.02	Winter	0.96 ± 0.05
	January	0.94 ± 0.03		
	February	1.01 ± 0.05		
Station V	March	1.20 ± 0.03	Summer	1.30 ± 0.08
	April	1.31 ± 0.02		
	May	1.39 ± 0.02		
	August	1.48 ± 0.05	Post-monsoon	1.41 ± 0.09
	September	1.45 ± 0.04		
	October	1.30 ± 0.03		
	December	1.12 ± 0.07	Winter	1.25 ± 0.12
	January	1.25 ± 0.05		
	February	1.37 ± 0.04		

*Values are expressed as mean ± SD

Table 6.16 Monthly and seasonal values of biological oxygen demand (BOD) at various stations of River Vishwamitri during 2002–2004

Sites	Biological oxygen demand (mg/L)			
	Month		Season	
Station I	March	16.20 ± 1.30*	Summer	17.90 ± 2.13*
	April	19.60 ± 1.14		
	May	Dry		
	August	8.40 ± 1.14	Post-monsoon	9.47 ± 1.36
	September	9.40 ± 1.14		
	October	10.60 ± 0.89		
	December	9.40 ± 1.67	Winter	11.24 ± 1.94
	January	11.04 ± 0.62		
	February	13.28 ± 0.73		
Station II	March	Dry	Summer	Dry
	April	Dry		
	May	Dry		
	August	31.20 ± 1.64	Post-monsoon	35.47 ± 5.24
	September	33.20 ± 2.17		
	October	42.00 ± 2.45		
	December	26.40 ± 1.67	Winter	26.40 ± 1.67
	January	Dry		
	February	Dry		
Station III	March	98.80 ± 2.28	Summer	117.20 ± 16.02
	April	116.80 ± 2.39		
	May	136.00 ± 4.69		
	August	60.20 ± 2.86	Post-monsoon	92.15 ± 30.39
	September	85.84 ± 2.75		
	October	130.80 ± 4.15		
	December	74.00 ± 2.92	Winter	107.07 ± 29.13
	January	104.80 ± 3.70		
	February	142.40 ± 3.85		
Station IV	March	222.80 ± 4.60	Summer	246.93 ± 21.82
	April	245.80 ± 5.59		
	May	272.20 ± 9.31		
	August	92.40 ± 3.29	Post-monsoon	140.13 ± 51.63
	September	119.40 ± 3.97		
	October	208.60 ± 7.54		
	December	170.40 ± 6.23	Winter	176.40 ± 14.86
	January	163.60 ± 4.56		
	February	195.20 ± 4.60		
Station V	March	263.80 ± 6.80	Summer	324.40 ± 64.18
	April	301.20 ± 8.32		
	May	408.20 ± 16.19		
	August	178.00 ± 5.83	Post-monsoon	220.80 ± 42.08
	September	209.80 ± 6.87		
	October	274.60 ± 7.54		
	December	235.40 ± 5.18	Winter	261.33 ± 33.18
	January	242.80 ± 5.40		
	February	305.80 ± 7.50		

*Values are expressed as mean ± SD

Table 6.17 Linear relationship between seasonal values of Shannon-Wiener diversity index and physicochemical parameters

	Correlation coefficient (*r*)	Slope (*b*)
Temperature	0.237	0.0334
pH	−0.784**	−1.4066
Dissolved oxygen	0.456	0.1606
Total suspended solids	−0.328	−0.0016
Chlorophyll-a	0.903**	0.0159
Biological oxygen demand	−0.646*	−0.0048
Nitrate nitrogen	−0.300	−0.7375
Total relative phosphate	−0.800**	−0.7214

*$p \leq 0.05$; **$p \leq 0.001$

rotifers. Various physicochemical factors have been studied to find the changes, if any, caused by these factors on the rotifer community.

Temperature is one such factor, which is often considered to be the most important, in determining the population dynamics of rotifers (Ruttner-Kolisko 1975; Hofmann 1977). In the present study, it was observed that rotifers were maximum in the post-monsoon season when the temperature was between 24.8 and 25.8 °C. However, when the water temperature increased in summer, in the range of 26.9–27.5 °C, a decrease in the rotifer population was observed. In winter and also when the water temperatures fell drastically, a subsequent decrease in the rotifer population was observed. It may be believed that the rotifers need an optimum temperature for survival, and when the temperature varies from the optimum, the rotifer population decreases drastically. Pejler (1977), Dumont (1983), and De Ridder (1984), however, stated that most species of planktonic rotifers have a global distribution and are characterized by wide temperature tolerances, most of them occurring from close to zero up to about 20 °C or more (Berzins and Pejler 1989). The effects of temperature on zooplankton populations are often linked with biotic effects such as increase in filamentous cyanophytes or predators (Threlkeld 1987). More direct mechanisms include temperature sensitivity of metabolism or life history characteristics (Hebert 1978; Taylor and Mahoney 1988). Temperature has also been positively correlated with zooplankton birth rates and mortality in laboratory experiments (Wolfinbarger 1999). Rotifers are able to reproduce over a wide temperature range, providing that other factors are not limiting. It is, however, difficult to determine the effect of temperature on an individual or population, as temperature influences other processes which in turn affect the rotifers. Additionally, the rate of biological processes is seldom influenced by temperature alone but also by a number of other factors too. It is nearly impossible to separate the direct and indirect effects of the environmental factor of temperature (Galkovskaja 1987). Berzins and Pejler (1989) designated some species, which peaked during the winter months as "winter species" and those that peaked in summer as "summer species." However, they opined that the range of occurrence is often so wide that it is difficult to designate these as "warm-stenothermal species." Pejler (1957) suggested that genetic differences could be suspected between populations and geographic areas, where *Anuraeopsis fissa* and *Pompholyx sulcata*, for instance, otherwise known as pronounced summer forms, were only found at comparatively low temperatures in northern Swedish Lapland. Berzins and Pejler (1989) found that many non-planktonic species had their peaks at comparatively high temperatures, and this could be because most of them could be periphytic and dependent on macrophytes and their epiphytic flora, which develops during summer. Persuad and Williamson (2005) have observed that changes in underwater UV and temperature can significantly influence the composition of the zooplankton community and ultimately food web dynamics. Thus, it can be that temperature does not solely decide when and where a species will occur. Its influence is mainly indirect, enhancing or retarding development and cooperating with other biotic and abiotic factors.

Another environmental factor that could affect the composition of rotifer community is the pH of water in which they live. According to Hofmann (1977), little is known about its influence on population dynamics of rotifers. However, according to Edmondson (1944) and Skadowsky (1923), pH plays a major role in the distribution of rotifers. In the present study, it was observed that the pH values ranged between 7.51 and 9.01, showing that the pH was alkaline. This observation is in agreement with the observations of Subramanian et al. (1987) who suggested that irrespective of the geology, climate, etc., the pH of Indian River waters is predominantly alkaline. Similar observations have also been made by Somashekar (1988), Venkateswarlu (1986), Bhargava (1985), and Mitra (1982). The pH values were the lowest during the post-monsoon season and ranged between 7.52 and 7.76 at all the stations. This was also the season when the rotifer diversity was at its maximum. During summer, the pH ranged between 7.74 and 8.80, while the rotifer diversity was moderate. Least diversity was seen in the winter months when the pH ranged between 7.70 and 8.35. When pH and rotifer diversity were correlated, a significant negative correlation (Table 6.17) was observed. Moreover, as evidenced from the elevated slope value (Table 6.17), even a slight alteration in the pH may lead to perceivable changes in the rotifer community. Contradictorily, Berzins and Pejler (1987) could not determine any correlation between peak rotifer abundance and pH and stated that rotifers as a group exhibit a very wide range of pH tolerance. They have been found in waters with pH values spanning at least 2.0 units, and many are found in waters, which defer by as much as 5.0 units (Berzins and Pejler 1987). Haque et al. (1988) from their study observed rotifers to be insensitive to pH. However, Green (1960) stated that there could be an optimum pH for the growth and development of a particular species. Supporting this statement, Yin and Nui (2008) demonstrated through their laboratory experiments that pH exerted a major influence on egg viability and growth rate of five closely related rotifer species of the genus *Brachious.* According to Berzins and Pejler (1987), several species have peak abundances in the acidic range (pH < 6) and thus may be adapted to these conditions. According to Brett (1989), rotifer genera found below pH 3 can also be found in less acidic soft waters. Deneke (2000) found species richness to be generally low in highly acidic environments of pH values 3. His studies also suggested that small littoral or benthic rotifers predominate over crustaceans under highly acidic environments. Wiszniewski (1936) suggested that the most important factor influencing psammic rotifer communities is pH of the lake water. Bielanska-Grajner (2001) observed larger number of rotifer species and their higher abundance in slightly acidic to neutral waters, and the lowest quantity and the number of rotifers were observed in waters with the lowest pH waters among psammic rotifers. On the contrary, Prabhavathy and Sreenivasan (1977), Sampath et al. (1979), and Mishra and Saksena (1998) have shown rotifers dominating in alkaline waters. Finally, it may be stated from the present study that even a slight alteration in pH value will significantly affect the rotifer diversity.

Dhanapathi (2000) stated that dissolved oxygen (DO) plays an important role in determining the occurrence and abundance of rotifer communities. Arora (1966) has shown that dissolved oxygen can influence the survival of rotifers. Nayar (1964) suggested that dissolved oxygen could be an important factor influencing the growth and reproduction of *Brachionus calyciflorus*. In the present study, it was observed that the rotifer population was at its lowest during the winter season when DO levels were at its maximum. Similarly, Mishra and Saksena (1998) from their studies also found that rotifer numbers were inversely proportional to the dissolved oxygen. Prabhavathy and Sreenivasan (1977) suggested that rotifers are tolerant to low dissolved oxygen values. In the current study, when the dissolved oxygen levels were the lowest in the summer season, the rotifer population was not at its highest, in fact moderate rotifers counts were recorded in this season. Nevertheless, it was observed that River Vishwamitri supports the highest rotifer number during the post-monsoon season when the dissolved oxygen levels were moderate. The findings of the current work are in agreement with that of Zhou et al. (2007), who reported no relationship of dissolved oxygen with the vertical distribution of rotifers in Xiangxi Bay of China. This suggests that there is no direct correlation between the dissolved oxygen levels and rotifer population. However, Green (1956) has shown that dissolved oxygen plays an important role in controlling the growth of zooplankton. Berzins and Pejler (1989) suggested that though some species may be encountered in high abundance at low oxygen values, no true anoxybiosis ought to exist.

One of the effects of high suspended solid levels is increased turbidity. Increased turbidity has been shown to have a variety of influences on biota, affecting characteristics such as ecological conditions, resource availability, and species interaction (Hart 1990). Cottenie et al. (2001) from their study found that differences in zooplankton communities are strongly related to factors such as macroinvertebrate densities and turbidity. In the present study, it was observed that the post-monsoon season had the highest suspended solid levels throughout the river and the rotifers were also present in high. This is in complete agreement with Telesh (1995) who described rotifer diversity to be inversely proportional to transparency in highly turbid waters. Transparency in River Vishwamitri gets highly reduced in the post-monsoon season when the waters carry heavy loads of sediments from the surrounding areas. Telesh (1995) also observed that the contribution of rotifers to total zooplankton biomass was lower in less turbid waters. He described density of rotifers to be highest in the turbid section and low in regions with greater transparency. In the present study, the levels of crustaceans and copepods were low during the post-monsoon season (Suresh et al., unpublished). Thus, predation upon the rotifers is greatly reduced. Threlkeld (1979) also suggested that biotic mechanisms in the seasonal changes of zooplankton assemblages involve changes in predation. Increased turbidity altered predator efficiency, which might indirectly impact zooplankton community dynamics. In fact laboratory experiments illustrated asymmetrical exploitative competition between rotifers and Daphnia, leading to Daphnia dominance in zooplankton community (Gilbert 1985). Hart (1987) reported lower crustacean abundance in years of high turbidity. McCabe and O' Brien (1983) found *Daphnia pulex* population growth rates were diminished in the presence of suspended silt. On the other hand, however, Kirk and Gilbert (1990) observed that inorganic turbidity inhibited the competitive abilities of Daphnia and this competitive inhibition may have lead to a decline of cladocerans, causing a competitive lease of rotifer population.

In all, however, it can be seen that stations I, II, and III, which have the highest rotifer diversity, have comparatively low suspended solids in comparison to stations IV and V. Thus, it would not be completely right to believe that the rotifer diversity is directly proportional to the suspended solids. Pollard et al. (1998) observed that turbidity had a minimum role in regulation of zooplankton population. They found that rotifer abundance patterns and species composition as well as rotifer population dynamics were similar at low and high turbidity sites. Contrary to all the above observations, Egborge (1981) observed highest rotifer numbers during periods of high water transparency.

Gulati et al. (1992) indicated that the important factors to be examined for changes in zooplankton composition and abundance are its food and predators. Threlkeld (1979) also suggested that biotic mechanisms in the seasonal changes of zooplankton assemblages involve changes in resource availability. Cecchine and Snell (1999) stated that food limitation may be an important factor in community structuring of rotifers. In oligotrophic systems, declines in cladoceran populations are often associated with decreased total phytoplankton biomass (Sommer et al. 1986). Restrictions associated with lack of optimal food (Pejler 1977) or diverse phytoplankton as food items (Burgis 1974) are known to be the reason for low rotifer diversity in low-latitude lakes (Lewis 1979; Fernando 1980). Rotifers feed on detritus, algae, etc., while some are predatory. In the present study, most of the recorded rotifers are herbivorous or detritivorous, suggesting that the phytoplankton constitute the major source of food. Any changes in the composition of these would lead to subsequent changes in the rotifer community. During the present study, a high positive correlation (Table 6.17) was observed between the chlorophyll-a content and the rotifer diversity. During the post-monsoon season, the chlorophyll-a levels were maximum, as was the rotifer diversity. And the lowest chlorophyll-a levels were encountered in the winter season. The summer months showed a moderate chlorophyll-a level and concomitantly moderate rotifer diversity (Table 6.13). Mishra and Saksena (1998) have also observed a high positive correlation between rotifer number and total phytoplankton population. It is evident from the results that stations I, II, and III have higher chlorophyll-a content as compared to stations IV and V; similarly the rotifer diversity at these stations is also low as compared to stations I, II, and III throughout the year. Yet another reason for low rotifer diversity downstream could be attributed to the fact that the cyanophytes are disproportionately high at these stations (Dhuru et al. 2003). It has been stated that blue-green algae are not edible as they are toxic to rotifers (Fulton and Pearl 1987). Threlkeld (1979, 1986) has attributed the decline in rotifer community in mesotrophic and eutrophic systems, to the replacement of palatable forms of phytoplankton with the less palatable filamentous cyanophytes. Moreover, filamentous cyanophytes, at high densities, are reported to affect the zooplankton adversely by mechanical interference with its filtering mechanism (Webster and Peters 1978; Porter and Orcutt 1980). Apart from food, availability of proper shelter is also an important factor determining the community structure of plankton.

Factors affecting the phytoplankton community would also indirectly affect the rotifer dynamics. In most freshwaters, phosphorous and nitrogen are limiting nutrient for phytoplankton growth (Plath and Boersma 2001). Even in marine waters, zooplankton substantially mediates the recycling of nutrients such as phosphorous and nitrogen that directly influences the phytoplankton therein (Trommer et al. 2012). Phosphate is an important nutrient, which controls plant growth (Hynes 1978). Tebutt (1992) and Dean and Lund (1981) mention that phosphorous occur in sewage effluents due partly to human excretion and partly due to their use in synthetic detergents. Consequently in Vishwamitri River, the values of phosphate increases as sewage gets dumped into the river from station III onwards. This can be seen clearly in Table 6.14, wherein the phosphate values are lowest at station I and gradually increase from there onwards. The highest values are found at station V. This trend is seen during all the seasons. The lowest total reactive phosphate levels were encountered during the post-monsoon season, while the highest values during summer. Thus, it would be expected that phytoplankton diversity and consequently rotifer diversity would be highest in the downstream stations in the summer season. This is, however, not the case. Both the phytoplankton levels (Suresh et al., unpublished) and the rotifer diversity in the downstream stations are low. This could probably be due to the very low dissolved oxygen content in this stretch of the river.

In case of nitrate nitrogen, the highest values are seen at the downstream stations, while low values in the upstream stations (Table 6.15). On basis of the seasons, the highest values are seen during the post-monsoon, while the lowest during the winter season (Table 6.15). Accordingly high rotifer diversity is seen during post-monsoon season and low during winter. However, as far as the stations are concerned where high nitrate nitrogen values are present (downstream stations), the rotifer diversity is not correspondingly high. This could again be attributed to low DO levels at these stations.

Water pollution also affects the rotifer community. Archibald (1972), Verma et al. (1984), and Kulshreshtra et al. (1989) observed that the species diversity is high in clean waters and low in polluted waters. Banerjea and Motwani (1960) reported an appreciable fall in the rotifer species just below the effluent outfall and further reduction in the septic zone of Suvaon stream. However, Prabhavathy and Sreenivasan (1977), Gannon and Stemberger (1978), Sampath et al. (1979), and Mishra and Saksena (1998) found that rotifer population was enhanced by increased load of pollution. Similarly Venkateswarlu and Jayanti (1968) recorded high counts of rotifers at polluted stations of Sabarmati River in comparison to clean stations. In River Vishwamitri, the sewage pollution begins from station III, and as is evident from the data, this station on the whole has a greater diversity of rotifers throughout the year. However, towards station IV and station V, the pollution load increases drastically as evidenced by the biological oxygen demand values (Table 6.16), and the dissolved oxygen levels are too low to support many organisms. At these sites, the suspended solid levels are also very high which greatly reduces the transparency. This would in turn affect the light penetration required by the primary producers. All these factors combined probably account for the low diversity at these stations.

Apart from the physicochemical factors, biotic factors might also play an important role in controlling the zooplankton community structure. The presence or absence of predators also affects the rotifer populations. The negative relation between the presence of *Daphnia* and rotifers has been well documented (Fussmann 1996). As already discussed earlier during the postmonsoon period, the cladoceran density is quite low, probably affected by the high levels of suspended solids, as the result of which the rotifers are found in high numbers.

Presence of macrophytes also affects the zooplankton diversity. Lougheed et al. (1998) stated that patchy distribution of aquatic vegetation contributes to seasonal variability in water quality characteristics and the amount of habitat available for aquatic invertebrates. Development of vegetation increases structural complexity, so providing more niches for rotifers. In a large body with a complex littoral zone, the numbers of rotifer species can reach over 200 (Segers and Dumont 1995; Dumont and Segers 1996). The macrophytes provide more diverse habitat (Van den Berg et al. 1997). This was well observed by Kuczyriska-Kippen (2007) that shallow lakes with a good macrophyte density offered a wide choice of habitat for the rotifer community, thus enhancing their diversity and density in such habitats.

In River Vishwamitri, macrophytes are present in highest numbers at station III followed by station II and station I. Station IV and station V have negligible macrophyte population (Dhuru et al., 2003). This could be yet another reason for higher diversity in the first three stations. Telesh (1995) also found rotifer diversity high in reed beds, the most common type of aquatic vegetation. *Typha angustata* beds seen at stations II and III of River Vishwamitri could be another factor contributing to the higher rotifer number often present in these stations. Telesh (1995) further describes that species like *Brachionus calyciflorus*, *B. quadridentatus*, and *Filinia longiseta* are commonly found in areas where macrophytic vegetations are plenty. All the above species were found at sampling stations II and III. Phytophilous species like *Platyias quadricornis* and *Mytilina ventralis* are abundant in macrophyte beds (Telesh 1995). *Platyias quadricornis* was found at station III, while *Mytilina ventralis* was located at station II of Vishwamitri.

Thus, it can be seen that by and large station III seems to provide a better habitat with diverse niche for the rotifer community. This station besides receiving domestic sewage has relatively good levels of dissolved oxygen throughout the year. Moreover, there is water throughout the year at this station. The reed beds provide more varied microhabitat which is needed for the survival of the periphytic rotifers. This could be the reason for a high number of exclusive species found at this station.

From the above discussion, it could be concluded that pH and chlorophyll-a play a major role in influencing the rotifer community structure. Additionally, both abiotic and biotic factors could be interacting with each other and their combined effect may be influencing the rotifer community structure.

References

APHA, AWWA, WEF (1998) Standard methods for the examination of water and wastewater. American Public Health Association, Washington, DC

Archibald M (1972) Diversity in some South African diatom associations and its relation to water quality. Water Res 6:1229–1238

Arora HC (1966) Studies on Indian Rotifera – Part III. On *Brachionus calyciflorous* and some varieties of the species. J Zool Soc India 16:1–6

Arora J, Mehra NK (2003) Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamuna (Delhi). India Hydrobiol 491:101–109

Banerjea S, Motwani MP (1960) Some observations on pollution of the Suvaon stream by the effluents of a sugar factory, Balrampur (UP). Ind J Fish 7:107–128

Berzins B, Pejler B (1987) Rotifer occurrence in relation to pH. Hydrobiologia 147:107–116

Berzins B, Pejler B (1989) Rotifer occurrence in relation to temperature. Hydrobiology 175:223–231

Bhargava DS (1985) Water quality variation and control technology of Yamuna river. Environ Pollut 37(series B):355–376

Bielanska-Grajner I (2001) The psammic rotifer structure in three Lobelian Polish lakes differing in pH. Hydrobiology 446/447:149–153

Brett MT (1989) Zooplankton communities and acidification process (a review). Wat Air Soil Pollut 44:387–414

Burgis MJ (1974) Revised estimates for the biomass and production of zooplankton in lake George, Uganda. Freshw Biol 4:535–541

Cecchine G, Snell TW (1999) Toxicant exposure increases threshold food levels in freshwater rotifer populations. Environ Toxicol 14:523–530

Chacko PI, Rajagopal A (1962) Hydrobiology and fisheries of the Ennore river near Madras from April 1960 to March 1961. Madras J Fish 1:102–104

Cottenie K, Nuytten N, Michels E, Meester LD (2001) Zooplankton community structure and environmental conditions in a set of interconnected ponds. Hydrobiology 442:339–350

De Ridder M (1984) A review of rotifer fauna of Sudan. Hydrobiology 110:1113–1130

Dean RB, Lund E (1981) Water reuse: problems and solutions. Academic, London

den Berg V, Coops MSH, Noordhius R, Van Schie J, Simons J (1997) Macro invertebrate communities in relation to submerged vegetation in two Chara-dominated lakes. Hydrobiology 342/343:143–150

Deneke R (2000) Review of rotifers and crustaceans in highly acidic environments of pH values 3. Hydrobiology 433:167–172

Desai GH, Clarke AB (1923) Gazette of Baroda state, vol 1. General Information, Bombay

Dhanapathi MVSS (1997) Variations in some rotifers of the family Brachionidae. J Aquat Biol 12:35–38

Dhanapathi MVSS (2000) Taxonomic notes on the rotifers from India (1889–2000). Indian Association of Aquatic Biologists, Hyderabad

Dhuru S, Suresh B, Pilo B (2003) Additions to the rotifer fauna of Gujarat. J Aqua Biol 18(1):35–39

Dumont HJ (1983) Biogeography of rotifers. Hydrobiology 104:19–30

Dumont HJ, Segers H (1996) Estimating lacustrine zooplankton species richness and complementarity. Hydrobiology 341:125–132

Duncan AA, Gulati RD (1981) Parakrama Samudra (Sri Lanka) project, a study of a tropical lake ecosystem. III. Composition, density and distribution of the zooplankton in 1979. Verh Int Ver Limnol 21:1007–1014

Edmondson WT (1944) Ecological studies of the sessile Rotatoria. Part I. Factors affecting distribution. Ecol Monogr 14:31–66

Egborge ABM (1981) The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. Rev Zool Afr 95(1):136–180

Fernando CH (1980) The species and size composition of tropical freshwater zooplankton with special reference to the Oriental region (South East Asia). Int Revue Ges Hydrobiol 65:411–426

Fernando CH, Rajapaksa R (1983) Some remarks on long-term and seasonal changes in the zooplankton of *Parakrama Samudra*. In: Schiemer F (ed) Limnology of Parakrama Samudra – Sri Lanka. Dr. W. Junk, Hague

Fulton RS, Pearl HS (1987) Toxic and inhibitory effects of the blue green alga *Microcystis aeruginosa* on herbivorous zooplankton. J Plankton Res 9:837–856

Fussmann G (1996) The importance of crustacean zooplankton in structuring rotifer and phytoplankton communities: an enclosure study. J Plankton Res 10:1897–1915

Galkovskaja GA (1987) Planktonic rotifers and temperature. Hydrobiology 147:307–317

Gannon JE, Stemberger RS (1978) Zooplankton especially crustaceans and rotifers as indicators of water quality. Trans Am Micros Soc 77:16–35

George MG (1961) Observations on the rotifers from shallow ponds in Delhi. Curr Sci 30:268–269

Gilbert JJ (1985) Competition between rotifers and Daphnia. Ecology 66:1943–1950

Green J (1956) Growth, size and reproduction in Daphnia (Crustacea: Cladocera). Proc Zool Soc Lond 126:173–204

Green J (1960) Zooplankton of river Sokoto. The rotifers. Proc Zool Soc Lond 135:491–523

Green J (2001) Variability and instability of planktonic rotifer associations in Lesetho, Southern Africa. Hydrobiology 446/447:187–194

Gulati RD, Ooms-Wilms AL, Van Tongeren FR, Postema G, Siewetsen K (1992) The dynamics and role of limnetic zooplankton in the Loosdrecht (The Netherlands). Hydrobiology 233:69–86

Haque N, Khan AA, Fatima M, Barbhuyan SI (1988) Impact of some ecological parameters on rotifer population in a tropical perennial pond. Environ Ecol 6:998–1001

Hart RC (1987) Population dynamics and production of five crustaceans zooplankton in subtropical reservoir during years of contrasting turbidity. Freshw Biol 18:287–318

Hart RC (1990) Zooplankton distribution in relation to turbidity and related environmental gradient in a large subtropical reservoir: patterns and implications. Freshw Biol 24:241–263

Hebert PDN (1978) The population biology of Daphnia (Crustaceae: Daphnidae). Biol Rev 53:387–426

Herzig A (1987) The analysis of planktonic rotifer populations: a plea for long term investigations. Hydrobiology 147:163–180

Hofmann W (1977) The influence of abiotic environmental factors on population dynamics in planktonic rotifers. Arch Hydrobiol Beih Ergebn Limnol 8:77–83

Hynes HBN (1978) The ecology of running waters. Liverpool University Press, Liverpool

Kaushik S, Saksena DN (1995) Trophic status and rotifer fauna of certain water bodies in central India. J Environ Biol 16:283–291
Kirk KL, Gilbert JJ (1990) Suspended clay and population dynamics of planktonic rotifers and cladocerans. Ecology 71:1741–1755
Kuczyriska-Kippen N (2007) Habitat choice in rotifer communities of three shallow lakes: impacts of macrophyte substratum and season. Hydrobiology 593(1):27–37
Kulshreshtra SK, Adholia UN, Bhatnagar A, Khan AA, Saxena M, Bhagail M (1989) Studies on the pollution in river Kshipra: zooplankton in relation to water quality. Int J Ecol Environ Sci 15:27–36
Lewis WM Jr (1979) Zooplankton community analysis: studies on a tropical stream. Springer, New York/ Berlin
Lougheed VL, Crosbie B, Chow-Fraser P (1998) Predictions on the effect of carp exclusion on water quality, zooplankton and submergent macrophytes in a Great Lakes wetland. Can J Fish Aquat Sci 55(5):1189–1197
Ludwig JA, Reynolds JE (1988) Diversity indices in statistical ecology. Wiley, New York
Marneffe Y, Comblin S, Thome J (1998) Ecological water quality assessment of the Butgenbach lake (Belgium) and its impact on the river Warche using rotifers as bioindicators. Hydrobiology 387/388:459–467
McCabe GD, O' Brien WJ (1983) The effects of suspended silt on feeding and reproduction of *Daphnia pulex*. Am Midl Nat 110:324–337
Mengestou S, Green J, Fernando CH (1991) Species composition, distribution and seasonal dynamics of Rotifera in a Rift Valley lake in Ethiopia (Lake Awasa). Hydrobiology 209:203–214
Michael RG (1968) Studies on the zooplankton of a tropical fish pond, India. Hydrobiology 32:47–68
Mishra SR, Saksena DN (1998) Rotifers and their seasonal variation in a sewage collecting Morar (Kalpi) river, Gwalior, India. J Environ Biol 19:363–374
Mitra AK (1982) Chemical characteristics of surface water at selected gauging stations in the river Godavari, Krishna and Tungabhadra. Ind J Environ Health 24:165–179
Nayar CKG (1964) Morphometric studies on the rotifer, *Brachionus calyciflorous* Pallas. Curr Sci 33:469–470
Nayar CKG (1965) Cyclomorphosis of *B. calyciflorus*. Hydrobiology 25:538–544
Pejler B (1957) Taxonomical and ecological studies on planktonic Rotatoria from northern Swedish Lapland. K. svenska Vetensk Akad Handl., Ser. 4, bd 6 no 68 pp
Pejler B (1977) On the global distribution of family Brachionidae (Rotatoria). Arch Hydrobiol (Suppl) 53:255–306
Pennak WR (1955) Comparative limnology of eight Colorado mountain lakes, University of Colorado studies, series of biology. University of Colorado Press, Boulder, 255 pp
Persuad AD, Williamson CE (2005) Ultraviolet and temperature effects on planktonic rotifers and crustaceans in northern temperature lakes. Freshw Biol 50(3):467–476
Plath K, Boersma M (2001) Mineral limitation of zooplankton: stoichiometric constraints and optima foraging. Ecology 82:1260–1269
Pollard AI, Gonzalez MJ, Vanni MJ, Headworth JL (1998) Effects of turbidity and biotic factors on the rotifer community in a Ohio reservoir. Hydrobiology 387/388:215–223
Porter KG, Orcutt JD (1980) Nutritional adequacy, manageability and toxicity as factors that determine the food quality of green and blue green algae for *Daphnia*. In: Kerfoot WC (ed) Evolution and ecology of zooplankton communities. University Press of New England, Hanover, pp 268–281
Prabhavathy G, Sreenivasan A (1977) Ecology of warm freshwater zooplankton of Tamil Nadu. In: Proceedings of the symposium on warm water zooplankton, Goa special publication. NIO, Goa, pp 319–329
Robinson AH, Robinson PK (1971) Robinson. seasonal distribution of zooplankton in northern basin of Lake Chad. J Zool (Lond) 163:25–61
Ruttner-Kolisko A (1975) The influence of fluctuating temperature on plankton rotifers. A graphical model based on life data of *Hexarthra fennica* from Neusiedlersee, Austria. Symp Biol Hung 15:197–204
Sampath V, Sreenivasan A, Ananthanarayanan R (1979) Rotifers as biological indicators of water quality in Cauvery river. Proc Symp Environ Biol 441–452
Sarma SSS, Osnaya-Espinosa LR, Aguilar-Acosta CR, Nandini S (2011) Seasonal variations in zooplankton abundances in the Iturbide reservoir (Isidro Fabela, State of Mexico, Mexico). J Environ Biol 32:473–480
Sawyer CN, McCarty PL, Parkin GF (1994) Chemistry of environmental engineering. McGraw – Hill International Education, New York, p 658
Segers H, Dumont HJ (1995) 102+ rotifer species (Rotifera: Monogononta) in Broa Reservoir (S.P. Brasil) on 26 August 1994, with a description of three new species. Hydrobiology 316:183–197
Skadowsky SN (1923) Hydrophysiologische und hydrobiologische Beobachtungen uber die Bedeutung der Reaktion des Mediums fur die Susswasserorganismen. Ver Int Ver Limnol 1:341–358
Sladecek V (1983) Rotifers as bioindicators of water quality. Hydrobiology 100:169–201
Somashekar RK (1988) Ecological studies on the two major rivers of Karnataka. In: Trivedy RK (ed) Ecology and pollution of Indian rivers. Ashish Publishing House, New Delhi
Sommer U, Gliwicz WL, Duncan A (1986) The PEG-model of seasonal succession of planktonic events in fresh waters. Arch Hydrobiol 106:433–471
Steinberg AJ, Ejsmont-Karabin J, Muirhead JR, Harvey CT, MacIssac HJ (2009) Consistent, long-term change in rotifer community composition across four Polish lakes. Hydrobiology 624:107–114

Subramanian V, Biksham G, Rames R (1987) Environmental geology of peninsular river basins of India. J Geol Soc Ind 30:393–401

Taylor BE, Mahoney DL (1988) Extinction and recolonization: processes regulating zooplankton dynamics in a cooling reservoir. Verh Int Ver Limnol 23:1536–1541

Tebutt THY (1992) Principles of water quality control, 4th edn. Pergamon Press, Oxford

Telesh IV (1995) Rotifer assemblages in the Neva Bay, Russia: principles of formation, present state and perspectives. Hydrobiology 313/314:57–62

Threlkeld ST (1979) The midsummer dynamics of two *Daphnia* species in Wintergreen lake, Michigan. Ecology 60:165–179

Threlkeld ST (1986) Resource mediated demographic variation during the midsummer succession of a cladoceran community. Freshw Biol 16:673–683

Threlkeld ST (1987) *Daphnia* population fluctuations: patterns and mechanisms. In: Peters RH, de Bernardi R (eds) Daphnia. Mem Ist Ital Idrobiol 45:367–388

Trivedi RK, Goel PK (1986) Chemical and biological methods for water pollution studies. Environmental Publications, Karad

Trommer G, Pondaven P, Siccha M, Stibor H (2012) Zooplankton-mediated nutrient limitation patterns in marine phytoplankton: an experimental approach with natural communities. Mar Ecol Prog Ser 449:83–94

Venkateswarlu V (1986) Ecological studies on the rivers of Andhra Pradesh with special reference to water quality and pollution. Proc Ind Sci Acad 96:495–508

Venkateswarlu T, Jayanti TV (1968) Hydrobiological studies of the river Sabarmati to evaluate water quality. Hydrobiology 31:442–448

Verma SR, Sharma P, Tyagi A, Rani S, Gupta AK, Dalela RC (1984) Pollution and saprobic status of eastern Kali nadi. Limnol (Berlin) 15:69–133

Webster KE, Peters RH (1978) Some size dependent inhibitions of larger cladoceran filterers in filamentous suspensions. Limnol Oceanogr 23:1238–1245

Wesenberg-Lund C (1908) Plankton investigations of the Danish lakes. Gyldendalske Boghandel, Copenhagen

Wesenberg-Lund C (1930) Contributions to the biology of Rotifera. Part II. The periodicity and sexual periods. Kgl Danske Vidensk Slesk Skifter Naturv Mathem 2:1–230

Wiszniewski J (1936) Notes sur le psammon III. Deux tourbieres aux environs de Varsovie. Arch Hydrobiol 10:173–187

Wolfinbarger WC (1999) Influences of biotic and abiotic actors on seasonal succession of zooplankton in Hugo Reservoir, Oklahoma, USA. Hydrobiology 400:13–31

Yin XW, Nui CJ (2008) Effect of pH on survival, reproduction, egg viability and growth rate of five closely related rotifer species. Aquat Ecol 42(4):607–616

Yoshinaga T, Atsushi H, Tsukamoto K (2001) Why do rotifer populations present a typical sigmoid curve? Hydrobiology 446/447:99–105

Zhou S, Huang X, Cai Q (2007) Vertical distribution and migration of planktonic rotifers in Xiangxi Bay of the three Gorgers reservoir. China J Freshw Ecol 22(3):441–449

Aquatic Insect Diversity of Baitarani Estuary of Odisha

7

Swetapadma Dash

Abstract

Studies on the aquatic Hemiptera of northern estuaries of Odisha were made during a period of 12 months in 2008–2009. Results revealed that insect population of Baitarani estuary mainly comprised of Hemiptera, Diptera, Coleoptera and Odonata. Some Hemipterans were surface dwellers (Gerridae, Nepidae, Hydrometridae). Notonectidae were middle dweller and Belostomatidae were bottom dweller. Coleopteran group has been identified as Dytiscidae and Gyrinidae. The diversity of the estuarine Hemiptera and Coleopteran found to be very much low in comparison to freshwater Hemipteran and Coleopteran community. The ecological factors were also evaluated and showed their affinity with salinity and water current. The objective of this paper is to summarize the occurrence, diversity and specific adaptations of Hemiptera and Coleopteran in Baitarani estuary of Odisha for the first time.

Keywords

Estuary • Aquatic • Hemiptera • Coleoptera • Salinity

Introduction

The Baitarani river is one of six major rivers of Odisha, India. The Baitarani originates from the Guptaganga hills in Gonasika of Keonjhar district in Odisha state of India at an elevation of 900 m above sea level. The uppermost part of the river is about 80 km in length and flows in a northern direction after that it changes its path suddenly by 90º and flows eastward. The beginning portion of Baitarani acts as the boundary between Odisha and Jharkhand. The river enters to the plains at Anandpur and creates a deltaic zone at Akhuapada. The river travels a distance of 360 km to drain into the Bay of Bengal after the joining of the Brahmani at Dhamra mouth near Chandbali. The river has 65 tributaries out of which 35 join from the left side and 30 join from the right side. The river basin is spread in 42 blocks of eight districts.

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The aquatic insects are taxonomically diverse and fascinating in structure and biology, and some of them have great importance to public health and aquaculture. The aquatic insect may be considered model organisms in analyzing the structure and function of the inland waters because of their high abundance, high birth rate with short-generation time, large biomass and rapid colonization of freshwater habitats. They constitute a dominating group of benthic, limnetic and littoral fauna of aquatic ecosystems (Sharma and Agrawal 2012).

Aquatic Hemiptera holds an important position in the ecology of aquatic ecosystem (Hazarika and Goswami 2010). Certain families of the bugs are utilized in the biological control of mosquitoes larvae (Ohba and Nakasuji 2006; Saha et al. 2007). Out of 11 globally recognized families, five major families of true aquatic bugs belong to infra order Nepomorpha (Belostomatidae, Corixidae, Notonectidae Naucoridae and Nepidae) are chiefly represented from India. They are characterized by their short antennae that are usually hidden. Nepomorpha bugs occupy diverse ecological niches ranging from saltwater pools to torrential streams and rivers. In India, five families of aquatic Coleoptera belong to 55 genera, and only 210 species are known till now. The earlier knowledge and scientific contribution on aquatic beetles (Vazirani 1977, 1973, 1984; Deepa 2010) are noteworthy to understand the present fauna. The major studies on aquatic Coleoptera also include the works of Jäch (1998), Balfour-Brown (1939) and Mukhopadhyay and Ghosh (2003); Michael et al. (2001).

The entomofauna of estuaries in India is rather poorly documented, and limited number of studies has been carried out on the ecological aspects of this group. Few studies (Chakraborty and Naskar 1988; Chakraborty 1996; Khan 2002; Subramanian and Sivaramakrishnan 2007) on estuarine Hemiptera group have been carried out on some specific wetlands in India. In the above-mentioned context, the present study was carried out with the objective to identify the commonly occurring insect fauna of this estuary which has not been studied so far in detail. The systematic list of distribution of aquatic Hemiptera and Coleoptera of Odisha has been given in the present paper, and systematic account of the species identified during the study has been incorporated.

Methods

The present study was carried out during April 2008 to March 2009 in selected localities of Brahmani-Baitarani estuarine ecosystems (Figs. 7.1 and 7.2). In order to cover maximum part of the water bodies, seven spots on the estuary and upper river stream were selected for collections. Collections of insect were made with help of hand-operated nets of varying sizes depending upon the area of the water bodies. The design and operation of the nets was approximately based on those described by Junk (1977). Insects collected for study were preserved in 70 % alcohols. Only Hemiptera and Coleoptera collections were identified by using the standard literature on the group (Thirumalai 1994, 1999, 2007; Deepa and Rao 2007; Bal and Basu 1994a, b). The physicochemical parameters were taken from all the sites. The water surface temperature ranged from 26 to 28 °C and sub-surface data ranged from 25 to 27 °C. The pH of water ranged from 6.9 to 7.4 and salinity ranged from 4 to 14 ppt.

Systematic List: Hemiptera

ORDER: HEMIPTERA
Suborder: Heteroptera
Infraorder: Nepomorpha Popov, 1968
Superfamily: Nepoidea Latreille, 1802
Family: Nepidae Latreille, 1802
Subfamily: Nepinae Latreille, 1802
Tribe: Nepini Latreille, 1802
Genus: *Laccotrephes* Stal, 1866
Subgenus: *Laccotrephes* Stal, 1866
1. *Laccotrephes griseus* (Guerin-Meneville, 1844)
2. *Laccotrephes ruber* (Linnaeus, 1764)

Subfamily: Ranatrinae Douglas & Scott, 1865
Tribe: Ranatrini Douglas & Scott, 1865
Genus: *Ranatra* Fabricius, 1790
Subgenus: *Ranatra* Fabricius, 1790

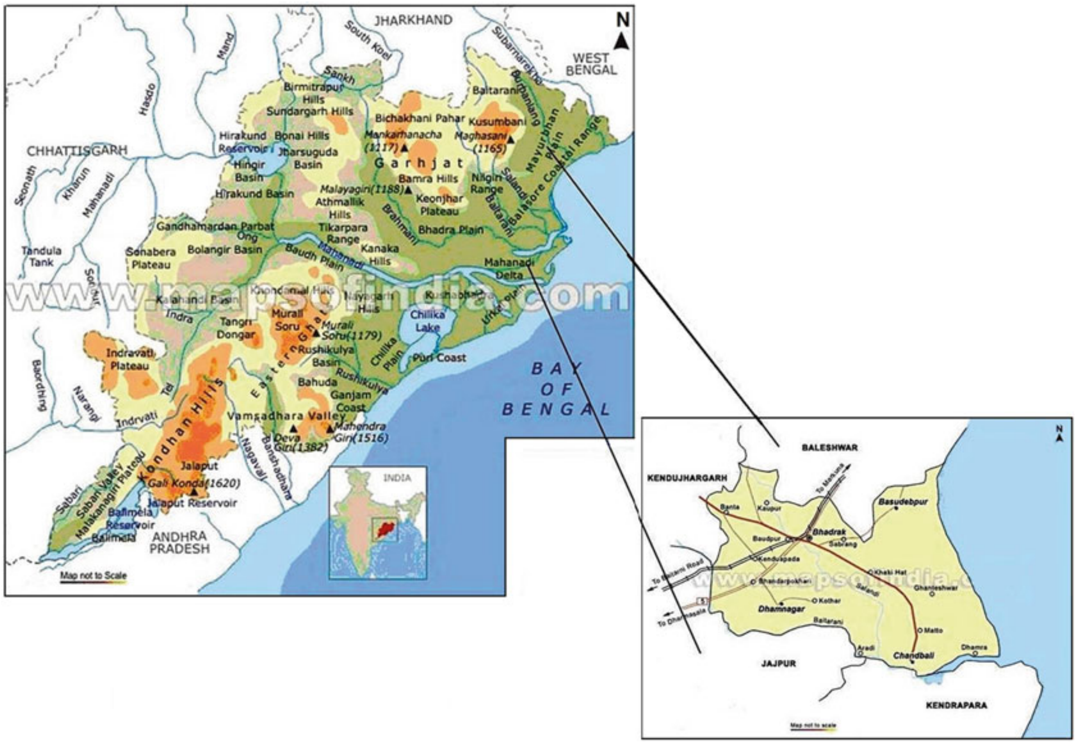

Fig. 7.1 Map of Bhadrak District, Odisha

3. *Ranatra elongata* Fabricius, 1790
4. *Ranatra filiformis* Fabricius, 1790
5. *Ranatra varipes varipes* Stal, 1861

Family: Belostomatidae Leach, 1815
Subfamily: Belostomatinae Leach, 1815
Genus: *Diplonychus* Laporte, 1833

6. *Diplonychus annulatus* (Fabricius, 1781)
7. *Diplonychus molestus* (Dufour, 1863)
8. *Diplonychus rusticus* (Fabricius, 1781)

Subfamily: Lethocerinae Lauck & Menke, 1961
Genus: *Lethocerus* Mayr, 1853
Subgenus: *Lethocerus* Mayr, 1853

9. *Lethocerus indicus* (Lepeletiler & Serville, 1825)

Family: Ochteridae Kirkaldy, 1906
Genus*: Ochterus* Latreille, 1807
Subgenus: *Ochterus* Latreille, 1807

10. *Ochterus marginatus marginatus* (Latreille, 1804)

Superfamily: Corixoidea Leach, 1815.
Family: Corixidae Leach, 1815
Subfamily: Corixinae Leach, 1815
Tribe: Agraptocorixini Hungerford, 1948
Genus: *Agraptocorixa* Kirkaldy, 1898

11. *Agraptocorixa hyalinipennis hyalinipennis* (Fabricius, 1803)

Tribe: **Corixini** Leach, 1815
Genus: *Sigara* Fabricius, 1775
Subgenus: *Sigara* Fabricius, 1775

12. *Sigara promontoria* (Distant, 1910)

Subgenus: *Vermicorixa* Walton, 1940

13. *Sigara annandalei* (Paiva and Dover, 1922)
14. *Sigara rambhaensis* (Paiva and Dover, 1922)

Subfamily: Cymatinae Walton, 1940
Subfamily: Micronectinae Jaczewski, 1924
Genus: *Micronecta* Kirkaldy, 1897
Subgenus: *Basilonecta* Hutchinson, 1940

15. *Micronecta scutellaris scutellaris* (Stal, 1858)
16. *Micronecta siva* (Kirkaldy, 1897)

Subgenus: *Dichaetonecta* Hutchinson, 1940

17. *Micronecta albifrons* (Motschoulsky, 1863)

Subgenus: *Indonectella* Hutchinson, 1940

18. *Micronecta grisea* (Fieber, 1844)

Subgenus: *Pardanecta* Wroblewski, 1962

Fig. 7.2 Collection sites of Baitarani estuary

19. *Micronecta punctata* Horvath, 1904
Subgenus: *Sigmonecta* Wroblewski, 1962
20. *Micronecta quadristrigata* Breddin, 1905
Superfamily: Naucoroidea Leach, 1815
Family: Naucoridae Leach, 1815
Superfamily: Notonectoidae Latreille, 1802
Family: Notonectidae Latreille, 1802
Subfamily: Anisopinae Hutchinson, 1929
Tribe: Anisopini Hutchinson, 1929
Genus: *Anisops* Spinola, 1837
21. *Anisops barbatus* Brooks, 1951
22. *Anisops bouvieri* Kirkaldy, 1904
23. *Anisops breddini* Kirkaldy, 1901
24. *Anisops crinitus* Brooks, 1951
25. *Anisops naustus* Fieber, 1851
26. *Anisops niveus* (Fabricius, 1775)
27. *Anisops sardeus sardeus* Herrich – Shaffer, 1850
Superfamily: Pleoidea Fieber, 1851
Family: Pleidae Fieber, 1851
Genus: *Paraplea* Esaki & China, 1928
28. *Paraplea frontalis* (Fieber, 1844)
29. *Paraplea indistinguenda* (Matsumura, 1905)
Family: **Gerridae**
Subfamily: Gerrinae
30. *Limnogonus (Limnogonus) fossarum fossarum* (Fabricius)
31. *Limnogonus (Limnogonus) nitidus* (Mayr)
32. *Aqurius adelaidis* (Dohrn)
Family: Nepidae
Subfamily: Ranantrinae Latereille, 1802
Tribe: Ranatrini Latereille, 1802
Genus: *Ranatra* Fabricius, 1790
1. *Ranatra elongata* Fabricius, 1790
1790 *Ranatra elongata* Fabricius, *Skirf Nat. Selesk* 227–228
***1994 Ranatra elongata* Fabricius*:* Thirumalai *Rec. Zool. Surv.* India Occ. Pap. No. 165: 22**

Materials Examined 8 exs 21.vi.2008. Ghe Koili, Chandbali, Bhadrak District, Orissa, S. Dash & Party.

Diagnostic Characters The species can be identified by a triangular tooth present in the femur beyond the middle of its length. Metasternal process is subtriangular.

Distribution India: Andhra Pradesh, Bihar, Delhi, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal.

Elsewhere Australia, Nepal, Sri Lanka.

2. *Ranatra filiformis* Fabricius, 1790

1790 *Ranatra filiformis* Fabricius, *Skirf Nat. Selesk* 227–228

***1989 Ranatra elongata* Fabricius*:* Thirumalai *Rec. Zool. Surv. of India* Occ. Pap. No. 118: 31**

Materials Examined 10 exs, 23.vi. 08. Similia Bridge (Hanuman Nagar) and Haripur, Chandbali, Bhadrak District, Orissa, S. Dash & Party; 3 exs 21.vi.2008. Ghe Koili, Chandbali, Bhadrak District, Orissa, S. Dash & Party.

Diagnostic Characters *R. filiformis* mostly occurs in the shallower parts of the waterbodies, where it clings to the submerged vegetation. It is smaller in size than *R. elongata.* The respiratory syphon is shorter than the body.

Distribution India: Andhra Pradesh, Arunachal Pradesh, Bihar, Delhi, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Manipur, Meghalaya, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal.

Elsewhere China, Nepal, Pakistan, Philippines, Sri Lanka.

Subfamily: **Nepinae** Latereille, 1802

Tribe: Nepini Latereille, 1802

Genus: *Laccotrephus* Stal, 1866

3. *Laccotrephus griseus* Guerin-Meneville, 1844

1844. *Nepa griseus* Guerin, Icongr. Regne. Anim. Ins., 352

***1910b. Laccotrephus griseus* (Guerin): Distant, Fauna British India, 5 :314**

***1994 Laccotrephus griseus* (Guerin*: Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 165: 21**

Materials Examined 15 exs. 22.vi. 2008, Similia Bridge (Hanuman Nagar), Chandbali District: Bhadrak, Orissa, S. Dash & Party

Diagnostic Characters This species is found near the lower current of water flow where it is equal to stagnation under the weeds. The abdominal appendages are shorter than the body. Slightly hooked and symmetrical parameters. It is very common in southern India waterbodies.

Distribution India: Andhra Pradesh, Arunachal Pradesh, Bihar, Delhi, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Manipur, Meghalaya, Nagaland, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal.

Elsewhere Malaysia, Myanmar, Seychelles, Sri Lanka, Thailand.

4. *Laccotrephus ruber* Linnaeus, 1764

1764. *Nepa ruber*, Linnaeus., *Mus. Lud. Ulr*., 165

***1906. Laccotrephus ruber* (Linnaeus): Distant, Fauna British India,3 :18.**

***1994. Laccotrephus ruber* (Linnaeus): *Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 165: 22**

Material Examined 5 exs, 23.vi. 2008 Similia Bridge (Hanuman Nagar) and Haripur, Chandbali, District Bhadrak, Orissa. S. Dash and Party.

Diagnostic Characters It is a species with a medium length of about 3–5 cm with dark brown to black. Long, pointed shape with a long-tailed pair front leg near the mouth used for capturing prey. Abdominal appendices slightly longer than the body.

Distribution India: Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Manipur, Meghalaya, Nagaland, Orissa, Tamil Nadu, Uttar Pradesh, West Bengal.

Elsewhere China, Japan, Nepal, Pakistan, Taiwan.

Family: Belostomatidae Leach, 1815

Subfamily: Belostomatinae Leach, 1833

Genus: *Diplonychus* (Laporte, 1833)

5. *Diplonychus rusticus* Fabricius, 1781

1781. *Nepa rustica* Fabricius., *Ent. Syst*., 4 : 62

***1994. Diplonychus rusticus* (Fabricius)*: Thirumalai Rec. Zool. Surv. India,* Occ Pap. No. 165: 25**

Material Examined 18 exs, 25.vi.2008. Laxmi Chadha, Dhamra: District: Bhadrak, Orissa, S. Dash & Party; 4 exs, 19.xii.2008, Baradia, Chandbali, District: Bhadrak, Orissa D.V. Rao & Party

Diagnostic Characters Body (less than 20 mm) long. Single segmented fore tarsus with a small claw. It is a voracious feeder of fish and mosquito larvae.

Distribution India: Andaman and Nicobar Island, Andhra Pradesh, Arunachal Pradesh, Bihar, Delhi, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Rajasthan, Tamil Nadu, West Bengal.

Elsewhere Malaysia, Myanmar, China, Indonesia, Japan, New Guinea, New Zealand, Sri Lanka, Thailand.

Subfamily: Lethocerinaea Lauck & Menke, 1961

Genus: *Lethocerus* Mayr, 1853

Subgenus: *Lethocerus* Mayr, 1853

6. *Lethocerus indicus* (Lepeletier & Serville, 1825)

1825. *Belostoma indica* Lepeletier & Serville, *Encycl. Meth.*, X: 272

1906. *Belostoma indicum* (Lep. & Serv.), Distant, *Fauna British India*, 3: 38.

1927. *Lethocerus indicus* (Lep. & Serv.), *Torre-Bueno Bull. Brooklyn Entomol. Soc.*, 22: 30.

2004. *Lethocerus indicus* (Lep. & Serv.), Thirumalai *Rec. Zool. Surv. of India,* Occ Pap. No. 102 (1–2): 67

Material Examined 8 exs, 25.vi. 2008. Laxmi Chadha and Budhiachak, Dhamra, Orissa, S. Dash & Party

Diagnostic Characters *Lethocerus indicus* is a giant water bug in the family Belostomatidae. Its body length is around 11 cm. It was originally described as *Belostoma indicum* but is no longer placed in that genus. It is well known as an edible species.

Distribution India: Andaman and Nicobar Island, Andhra Pradesh, Arunachal Pradesh, Bihar, Delhi, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Rajasthan, Tamil Nadu, West Bengal.

Elsewhere Malaysia, Myanmar, China, Indonesia, Japan, New Guinea, New Zealand, Sri Lanka.

Family: Notonectidae Latereille, 1802

Subfamily: Anisopinae Hutchinson, 1929

Genus: *Anisops* Spinola, 1837

7. *Anisops breddini* Kirkaldy, 1901

1901a. *Anisops breddini* Kirkaldy, *Entomologists*, London, 34: 5.

***2007. Anisops breddini* Kirkaldy*: Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 273: 38**

Material Examined 3 exs, 22.vi. 2008, Similia Bridge (Hanuman Nagar), Chandbali: Dhamra, Orissa, S. Dash & Party

Diagnostic Characters This species distinguished by the posteriorly holoptic eyes. Hemielytra with reduced membrane. The structure of male stridulatory comb which is composed of a few flattened and spatulate combs.

Distribution India: Andhra Pradesh, Bihar, Delhi, Kerala, Madhya Pradesh, Orissa, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal.

Elsewhere Myanmar, China, Africa, Turkey, Indonesia

Infraorder: Gerromorpha Popov, 1971

Family: Gerridae Leach, 1815

Family: Gerridae

Subfamily: Gerrinae Bianchi, 1896

Genus: *Limnogonus* Stal, 1868

***8. Limnogonus (Limnogonus) nitidus* (Mayr, 1865)**

1865. *Hydrometra nitida* Mayr *Verh. Zool. Bot. Ges. Wein, 15–443*

***1994. Limnogonus (Limnogonus) nitidus* Mayr *Bal & Basu, Zool. Surv. of India State Fauna, Series 3. Fauna of West Bengal*: 525**

Materials Examined 17 exs. 21.vi.2008. Ghe Koili, Chandbali, District: Bhadrak, Orissa, S. Dash & Party.

Diagnostic Characters *Limnogonus nitidus* is a black and long-legged water strider. Anterio pronotal lobe with yellow markings. This species is having a distinct connexival spine. It is a widespread species being distributed from sea level to 1,000 m and mostly found as winged individuals.

Distribution India: Andhra Pradesh, Arunachal Pradesh, Bihar, Delhi, Chandigarh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Pondicherry, Manipur, Meghalaya, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal.

Genus: *Aquarius* **(Dohrn, 1860)**

9. *Aquarius adelaides* (Dohrn, 1860)

1860. *Gerris adelaides* Dohrn, *Stett. ent. Ztq.*, 21: 408.

1990. *Aquarius adelaides* Dohrn, Andersen, Steenstrupia, 16:61.

1994. *Aquarius adelaides* Dohrn, *Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 165: 36

Materials Examined 2 exs.*17.xii.2008,* Fresh water Creek along Baitarani river, New Dhamra, District: Bhadrak, Orissa D.V. Rao & Party.

Diagnostic Characters Colour: Dark brownish above, fore femur almost straight and slightly constricted before apex, terminated by two distinct spines. The middle tibia longer than the hind tibia; the hind femur distinctly longer than the middle femur. Abdomen: moderately slender slightly widened in the middle; Connexival spines stout and long, almost reaching abdominal end (Proctiger). Segment 8 large, subcylindrical, with a prominent, triangular tubercle on the ventral surface. Pygophore large, subovate. Parameres connate and setose. Proctiger elongate, ovate with pointed apex.

Distribution India: Andhra Pradesh, Bihar, Karnataka, Kerala, Maharashtra, Orissa, Pondicherry, Tamil Nadu, West Bengal.

Family: Mesoveliidae

Subfamily: Mesoveliinae

Genus: *Mesovelia*

10. *Mesovelia vittigera* Horvath, 1895.

1895. *Mesovelia vittigera* Horvath, Rev. *Entomologie*, 14:160.

1989. *Mesovelia vittigera* Horvath*, Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 165: 28

Materials Examined 3exs.*14.xii.2008,* West side of mouth area, Dhamra, District: Bhadrak, Orissa D.V. Rao & Party.

Diagnostic Characters *Mesovelia vittigera* is pale green. It is larger than *Microvelia douglasi atrolineata* Bergroth. It appears in two morphs, the winged and unwinged adults. The head is longer than it is wide and is acute frontally. Its eyes are not convergent. The tarsi of the legs have small basal segment. In winged species, the membrane on the hemelytron of the front wings has no closed cells and the corium has dark brown thickened veins forming three whitish cells.

Mesovelia vittigera is a solitary feeder. This species is found in slow-running water covered by emergent or floating vegetation. Of the two morphs, the wingless adults are more common.

Distribution India: Andhra Pradesh, Bihar, Karnataka, Kerala, Maharashtra, Orissa, Pondicherry, Tamil Nadu, West Bengal.

Family: Hydrometridae

Subfamily: Hydrometrinae

Genus: Hydrometra

11. *Hydrometra greeni* Kirkaldy, 1898

1898. *Hydrometra greeni* Kirkaldy, Entomologist, 31:2.

1989. *Hydrometra greeni* Kirkaldy, *Thirumalai Rec. Zool. Surv. of India,* Occ. Pap. No. 165: 29

Materials Examined 4 exs. 24.06. 08. West side of mouth area, Dhamra, District: Bhadrak, Orissa.

Diagnostic Characteristics Metatarsal length about 1.8 mm. Seg 8 with weak posterolateral corners. Body colour light to medium brown.

Distribution India: Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Maharashtra, Orissa, Pondicherry, Tamil Nadu, West Bengal.

Order: Coleoptera

I. Family: Dytiscidae

Subfamily: Hydroporinae

1. *Hydrovatus confertus* Sharp, 1882
2. *Guignotus flammulatus* Sharp, 1854
3. *Guignotus inconstans* Regimbart, 1863

Subfamily: Notorinae

4. *Canthydrus laetabilis* Walker, 1882
5. *Canthydrus morsbachi* Wehncke, 1876
6. *Hydrocoptus subvittulus* Motschulsky, 1859

Subfamily: Laccophilinae

7. *Laccophilus elegans Sharp,* 1882
8. *Laccophilus ellipticus* Regimbart, 1899
9. *Laccophilus uniformis* Motschulsky, 1859

Subfamily: Dytiscinae

10. *Cybister (Melanectes) tripunctatus asciaticus* Sharp
11. *Cybister (Melanectes) convexus* Sharp, 1882
12. *Cybister (Melanectes) pectoralis* Sharp, 1882
13. *Eretes sticticus* (Linnaeus, 1833)
14. *Hydaticus (Guignotites) fabricii* MacLeay, 1833
15. *Hydaticus (Guignotites) vittatus* (Fabricius, 1838)

II. Family: Gyrinidae

Subfamily: Enhydrinae

16. *Dineutus (Protodineutus) indicus* Aube, 1838
17. *Dineutus* (*spinosodineutus*) *spinosus* (Fabricius, 1781)

Subfamily: Gyrininae

18. *Gyrinus convexiusculus* Macleay, 1871

Subfamily: Orechtochilinae

19. *Orectochilus (Patrus) semivestitus* Guerin, 1893
20. *Orectochilus (Patrus) discifer* (Walker, 1859)

III. Family: Hydrophilidae

Subfamily: Hydrophilinae

21. *Hydrophilus olivaceous* (Fabricius, 1781)
22. *Regimbartia attenuate* Fabricius, 1801
23. *Helochares anchoralis* Sharp, 1890
24. *Helochares pallens* Macleay, 1825
25. *Enochrus esuriens* Walker, 1858
26. *Berosus indicus* Mots., 1861
27. *Berosus pulchellus* Macleay, 1825

Subfamily: Hydrochinae

28. *Hydrochus bindosus* Mots., 1859

Subfamily: Sphaeridiinae

29. *Dactylosternum abdominale* Fabricius, 1792
30. *Sphaeridium dimidiatum* Gory, 1834

IV. Family: Haliplidae

31. *Haliplus* (*Liaphlus) angustifrons* Regimbart, 1892
32. *Haliplus* (*Liaphlus) pulchellus indicus* Regimbart, 1899

Family: Dytiscidae

Subfamily: Dytiscinae

***Cybister (Melanectes) tripunctatus asciaticus* Sharp, 1899**

Materials Examined 10 exs. 24.vi.2008 West side of mouth area, Dhamra: District: Bhadrak, Orissa, S. Dash & Party.

Diagnostic Characteristics Elytra with yellow lateral stripe extending to and including the epipleurae, spices without any sexual sculpture in the female in the form of longitudinal or zigzag striations

Distribution India: Kerala, West Bengal, Andhra Pradesh, Assam, Bihar, Orissa, Rajasthan, Uttar Pradesh, Tamil Nadu.

Elsewhere Nepal, China, Philippines, Sri Lanka, Afghanistan.

II. Family: Gyrinidae
Subfamily: Enhydrinae
Genus: Dineutus MacLeay, 1825
Subgenus: *Spinosodineutes* Hatch 1925
***Dineutus* (*Spinosodineutus*) *spinosus* (Fabricius, 1781)**

Material Examined 29 exs. 22.vi.2008, Similia Bridge (Hanuman Nagar), Chandbali: District: Bhadrak, Orissa. S. Dash & Party; *16.xii.2008,* Branch of Brahmani, Iswarpur, Chandbali, District: Bhadrak, Orissa D.V. Rao & Party.

Diagnostic Characteristics *D. spinosus* is evenly dark and bronzed. Epipleural (posterolateral) angle of the elytra being produced into a distinct spine. It is found on edge of small slow-moving waterbodies.

Distribution India: Kerala, Pondicherry, Madhya Pradesh, Maharashtra, West Bengal, Manipur, Andhra Pradesh, Assam, Bihar, Orissa,

Conclusion

An extensive survey has been undertaken during the year 2008–2009 for faunal collection including the aquatic insects. The diversity of collected aquatic Hemiptera and Coleoptera has been studied. The study revealed that there is a low diversity of aquatic Hemiptera and Coleoptera exists at estuarine waterbodies. 8 genera and 11 species belonging to 6 families of Hemiptera and two genera and two species belonging to two families of aquatic Coleoptera are present in the collection, and some nymphs of Damsel flies, Odonata and Diptera are also present in the collection but were not identified. All the species are being first recorded from the study area.

References

Bal A, Basu RC (1994a) Insecta: Hemiptera: Mesovoliidae: Hydrometridae, Veliidae and Gerridae. In: State fauna Series 5, Fauna of West Bengal, Pat 5. Zoological Survey of India, Calcutta, pp 511–534

Bal A, Basu RC (1994b) Insecta: Hemiptera: Mesoveliidae: Hydrometridae, Velii, State fauna Series 5, Fauna of West Bengal, Part 5. Zoological Survey of India, Calcutta, pp 535–558

Balfour-Brown J (1939) On Copelatus Erichson and Leiopterus Stephens (Col. Dytiscidae) with description of new species. Trans R Entomol Soc Lond 88:57–88

Chakraborty SK (1996) Aquatic potential of mangrove ecosystem of Sunderbans, West Bengal, India. Bull Cent Inland Capture Fish Res Inst 34:72–83

Chakraborty PK, Naskar KR (1988) Role of mangrove in estuarine fisheries development. Bull Cent Inland Capture Fish Res Inst 17:229–33

Deepa J (2010) Checklist of aquatic Coleoptera of India. ZSI Checklist at www.zsi.gov.in

Deepa J, Rao CAN (2007) Aquatic Hemiptera of Pocharam Lake, Andhra Pradesh. Zoos' Print J 22(12):2937–39

Hazarika R, Goswami MM (2010) Aquatic Hemiptera of Gawhati University, Guwahati, Assam, India. J Threat Taxa 2(3):778–782

Jäch MA (1998) Annotated check list of aquatic and riparian/littoral beetle families of the world. In: Jäch MA, Ji L (eds) Water beetles of China, vol 2. Zoologisch-Botanische Gesellschaft in Österreich and Wiener Coleopterologenverein, Vienna, pp 25–42

Junk WJ (1977) The invertebrate fauna of floating vegetation of Bong Barapet, a reservoir in central Thailand. Hydrobiologia 53:229–238

Khan RA (2002) Diversity of freshwater macroinvertebrates communities associated with macrophytes. Rec Zool Surv India 100(Part 1–2):211–228

Michael B, Manfred AJ, Hendrich L (2001) Insecta: Coleoptera freshwater invertebrates of the Malaysian Region (Monogram)

Mukhopadhyay P, Ghosh SK (2003) Insecta: coleopteran. Fauna of Sikkim, State fauna series, 9(Part 3):19–33

Ohba S, Nakasuji F (2006) Dietary items of predacious aquatic bugs (Nepoidea: Heteroptera) in Japanese wetlands. Limnology 7:41–43

Saha N, Aditya G, Bal A, Saha GK (2007) Comparative study of functional response of common hemiptran bugs of east Calcutta wetlands, India. Int Rev Hydrobiol 92:242–257

Sharma RK, Agrawal N (2012) Faunal diversity of aquatic insects in Surha Tal of District – Ballia (U.P.). India J Appl Nat Sci 4(1):60–64

Subramanian KA, Sivaramakrishnan KG (2007) Aquatic Insects of India a field guide. Small grant programme. ATREE, Bangalore

Thirumalai G (1994) Aquatic and semi-aquatic Hemiptera (Insecta) of Tamil Nadu-Dharampuri and Pudukottai districts. Rec Zool Surv India 165:1–45

Thirumalai G (1999) In: Aquatic and semi-aquatic heteroptera of India. Indian Association of Aquatic Biologist, Hyderabad, Publication No.7, pp 1–74

Thirumalai G (2007) A synoptic list of Nepomoirpha (Hemiptera: Heteroptera) from India. Rec Zool Surv India 273:1–84

Vazirani TG (1973) Contribution to the study of aquatic beetles (Coleoptera) XII. On a collection of Dytiscidae from Gujarat. Rec Zool Surv India 67:287–302

Vazirani TG (1977) Catalogue of Oriental Dytiscidae. Records of the Zoological Survey of India, Miscellaneous publications, Occasional paper no. 6, p 111

Vazirani TG (1984) The fauna of India. Coleoptera, Family Gyrinidae and Family Haliplidae. Zoological Survey of India, Calcutta

Aquatic Entomofauna: Bug and Beetle Diversity of Hyderabad

8

Deepa Jaiswal

Abstract

The present work was taken up during 2008–2012, as a part of annual programmes of Freshwater Biology Regional Centre, Zoological Survey of India, Hyderabad assigned to the author on "Aquatic insects with special reference to Hemiptera and Coleoptera in the different lakes of Hyderabad, Andhra Pradesh", in which major lakes were selected, viz. Wyra, Pocharam, Kolleru, Hussain Sagar, Miralam, Himayat Sagar, Durgam Cheruvu and Manjeera. The study is significant due to its maiden effort to study the two orders of entomofauna, Hemiptera and Coleoptera, in the different lakes of Hyderabad, Andhra Pradesh. Insect collections were made from various surveys to the different lakes in and around Hyderabad, during April, 2008, to December, 2012. More than 223 species of aquatic Coleoptera and 275 species of Hemiptera known from India, but only 14 species of Hemiptera belonging to 5 families and 31 aquatic beetle species belonging to five families recorded. The systematic key for identification is also given to help the young researchers to easily sort and identify the vast group of entomofauna. More intensive survey spread over different seasons would be required to provide a complete picture of the aquatic insect diversity of Hyderabad. Studies aiming to improve our knowledge on water insects should focus on collecting in little known areas, revision of the still unstudied material from additional families and filling the large gaps in our knowledge regarding the diversity of water insects in some specific habitats.

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Keywords
Water beetles • Bugs • Entomofaunal diversity • Systematic • Surveys

Introduction

Insects are the most diverse group of organisms in freshwater. Estimates on the global number of aquatic insect species derived from the fauna of North America, Australia and Europe are about 45,000 species; of this, about 5,000 species are estimated to inhabit inland wetlands of India. True aquatic insects are those that spend some part of their life cycle closely associated with water, either living beneath the surface or skimming along on top of the water. Aquatic insects can be found in the taxonomic orders, viz. Collembola, Ephemeroptera, Odonata, Plecoptera, Hemiptera, Coleoptera, Neuroptera, Trichoptera, Lepidoptera and Diptera. In this chapter only Hemiptera (bugs) and Coleoptera (beetles) of Hyderabad are included.

The state of Andhra Pradesh has about 3,66,609 ha extent of inland waterbodies of India. Hyderabad has 501 lakes and 3,086 tanks and several ponds and pools. Hyderabad city in Andhra Pradesh is located in the heart of Deccan plateau of India at latitude 17° 20′ N and longitude 78° 30′ E; it is spread over 1,552 km and includes a major wetland which constitutes lentic and lotic freshwater resources. Among lotic resources, the main river Musi passes through the city.

Methods

During the course of monthly surveys in connection with studies on lakes of Hyderabad, Andhra Pradesh, major lakes were selected, viz. Wyra, Pocharam, Kolleru, Hussain Sagar, Miralam, Himayat Sagar, Durgam Cheruvu, Manjeera, etc. During 2008–2012, various surveys were made to different collection localities, and insect collections were made with the help of hand-operated nets of varying sizes by randomly netting different areas of wetland. While surface-floating/swimming insects were collected with small circular nets made of either coarsely meshed cotton cloths or finely meshed polyester mosquito curtain cloth, macrophyte-associated insects were collected with the help of hand-operated "D"-framed sweep net of the size of 50 cm length, 25 cm maximum breadth of the "D". The frame was attached to a bag net made of fine malmal cloth with mesh size of approximately 200 μ. The design and operation of the net was roughly based on those described by Junk (1977). The net was put on the bottom against the water current and then the area in front of the net was disturbed by the foot. The insects which live in the gravel and sand drifted into the sieve bag. All samples are preserved in 70 % ethanol for sorting and identification in the laboratory. The aquatic insects were sieved by using a 0.5 mm stainless steel sieve, sorted into a Petri dish and identified by using a taxonomical key.

All the aquatic insect material reported herein has been collected by the author herself. Aquatic Hemiptera in the collections were identified with the aid of standard literature on the group, viz. Thirumalai (1999) and Bal and Basu (1994a), and aquatic Coleoptera were identified in literature by Vazirani (1970, 1984) and Biswas and Mukhopadhyay (1995).

Collection Localities

Lethocerus indicus

Aquarius adelaides

Cybister tripunctatus

Dineutus spinosus

Aquatic Bugs & Beetles

Diplonychus rusticus

Hemiptera

This order includes aquatic bugs and lives throughout of their life cycle inside the waterbody, and they are placed under the series Hydrocorisae, while semiaquatic bugs are dwelling on the surface of waterbody and belong to the series Amphibicorisae. In spite of 80 genera and 275 species accommodated in 16 major families of aquatic and semiaquatic Hemiptera known from India (Thirumalai 2002), very little information on water bugs of Andhra Pradesh is available. A limited number of studies have also been carried out on general entomofauna of some specific wetlands from taxo-ecological viewpoints which include the work of Bhattacharya (2000), Ramakrishna (2000), Ghosh (1996), Bal and Basu (1994b) and Tonapi (1959), Deepa and Rao (2007, 2010, 2011) Deepa (2010), Deepa et al. (2010), Fabricius (1775), and Vazirani (1969a, b, c). Heteroptera are hemimetabolous insects, typically developing via a series of five nymphal instars. The body consists of three distinct parts (although the head and thorax are closely adjoined in Pleidae and Helotrephidae), with mouthparts specialized for piercing and sucking (except in the Corixidae).

Key to five families of adult Hemiptera from Hyderabad

01.	Antennae shorter than head	02
	Antennae as long or longer than head	08
02.	Ocelli absent, aquatic	03
03.	Front tarsi consisting of a single spatulate segment	**Corixidae**
	Front tarsi of usual form	04
04.	Front coxae inserted at the hind margin of short prosternum, legs modified for swimming	05
	Front coxae inserted at or near the front margin of the prosternum, front legs modified for grasping	06
05.	Hind tibiae and tarsi ciliate, beak four segmented, eyes very large, body elongated	**Notonectidae**
06.	Membrane of upper wings reticulately veined	07
07.	Apical appendages of the abdomen long and slender, tarsi one segmented	**Nepidae**
	Apical appendages of the abdomen short, flat and retractile, tarsi two segmented	**Belostomatidae**
08.	Head shorter than the thorax, including the scutellum; tarsal claws preapical; hind femur extending much beyond the apex of the abdomen; beak four segmented	**Gerridae**

Systematic Account
Order: Hemiptera
Suborder: Heteroptera
Infraorder: Nepomorpha, Popov, 1968
1. Family: Nepidae, Latreille, 1802

The insects belonging to this family are popularly known as "water scorpions" because of the fact that forelegs somewhat resemble to the pedipalps of scorpions. The body is dorsoventrally fattened or cylindrical with long slender legs, the anterior pair being raptorial with long and stout femur used mainly for capture of prey. One-jointed tarsi and absence of ocelli are the characteristic feature of the family. The two long slender nonretractile caudal filaments with grooves on median surface and fitted together constitute the respiratory tube. By placing its tip at the surface film, oxygen in the tracheal system is replenished. Nepids are sluggish in nature and prefer still water. They are usually found in trash and mud or remain entangled with aquatic vegetation in the shallow littoral region of wetlands. Highly predacious insect species feed mainly on live insects and their nymph. The prey is captured with the help of raptorial forelegs. The most important cosmopolitan genus *Ranatra* occurs abundantly in this region.

2. Family: Belostomatidae, Leach, 1815

These insects are commonly known as "giant water bugs" because of their large size (10–110 mm in length). The body is flat, oval or oblong and has brown or dull greenish colour. The antennae are 4 segmented and concealed in pockets beneath the head; eyes are prominent. The strong and thick front legs are raptorial and used for grasping. The middle and hind legs are broad, flat and fringed with swimming hair. The tarsi are 3 segmented and the ocelli absent. The most characteristic feature in adult is the presence of retractile strap-like appendages at the abdominal apex, which are used to obtain air. These air straps are homologous with respiratory siphon of the related family Nepidae, being derived from the 8th abdominal tergum, each bearing a basal spiracle. About 150 species of belostomatids are so far known all over the world. Adults are large (2 to 2-1/2 in. long), brownish, somewhat flattened and broad with the middle and hind legs fitted for swimming. The front legs are fitted for grasping (praying mantis-like) with two claws at the tips. The end of the abdomen bears two short, strap-like appendages for breathing. The head is broad and slightly extended beyond the eyes. They are very much attracted to lights and are known as "electric light bugs". Sometimes they leave the water and fly to street lights some distance away. These bugs feed on other insects, snails, tadpoles and small fish (sometimes several times their size). They inject a poisonous fluid into their prey after capture, sucking them dry. They occur in ponds and quiet pools, feigning death when removed from the water and ejecting a fluid from the anus. Death is quick if not able to return to the water. Eggs are laid in massed rows of 100 or more above the water on cattails and other plants, hatching 1–2 weeks later. They are vicious biters, inflicting pain when handled carelessly.

3. Family: Corixidae, Leach, 1815

The members of this family usually called "water boatmen" are medium to small insects usually 2–16 mm in length. The family Corixidae is the largest family of aquatic Hemiptera consisting of about 500 species, distributed widely in the world from below sea level to as high as 4,575 m in Himalaya, from arctic water beneath ice to hot springs with temperature around 35 °C (Thirumalai 1989), in India it is represented only 35 species belonging to 4 genera. During present investigation only one species was recorded. The body is somewhat flattened above and its colour is dark greyish with yellow or black markings. The wing membrane is without veins. The head is triangular with short, unsegmented labium. The antennae are short and concealed with 3–4 segments. The front tarsus is single jointed with scoops-like segment called "pala" which is characteristic of the family. The scutellum is concealed and the male abdominal segments are asymmetrical. A file-like plate called "strigil" is present in tergum VI of male. Abdominal terga III–IV of nymphs and adults have metathoracic scent glands opening near the 3rd coxae. Dorsum of the abdomen has an alternative dark and transverse band. Adults are about 1/4 in. long, somewhat flattened, oval, grey-brown or mottled with the top surface often finely cross lined and the hind legs elongate and oarlike (flattened and fringed with hairs) for swimming. Eyes are black (space between yellow) and legs and body underparts yellow. They swim rapidly, usually seen at the bottom in the shallow water of ponds and lakes, and feed on algae, protozoa, plankton or dead organic matter on the bottom of pools and roadside ditches. Some species are attracted to lights and swarm around them. Their life cycle takes about 6 weeks from egg to adult.

4. Family: Gerridae, Leach, 1815

These are popularly known as “water striders” or “pond skaters”. They are semiaquatic long-legged hemipterans. These insects are found skating or leaping about on the surface film of wetlands. When disturbed, they scatter widely in all directions. They feed upon a number of micro-crustaceans and insects that are caught just below the water surface. The family is represented by about 450 species in the world. The body is oval shaped and covered with a velvety hydrofuge hair pile. Both winged and nonwinged forms occur, but the latter are more common (Thirumalai 1986). Adults are between 5/16 and 5/8 in. long, dull to greyish or reddish brown above and silvery grey on the underside of the body. Many have long slender bodies with long slender legs and antennae. The front legs are short and modified for grasping, while the middle and hind legs are long, like stilts with claws. These insects creep on the surface of running water or pools in a slow deliberate gait where they feed on live and dead insects, crustacea and other organisms. They overwinter as adults. Long, cylindrical eggs are laid during spring and summer in parallel rows glued to objects at the water’s edge.

5. Family: Notonectidae

Notonectidae is a cosmopolitan family of aquatic insects in the order Hemiptera, commonly called backswimmers because they swim upside down. They are all predators, up to nearly 2 cm in size. They are similar in appearance to Corixidae (water boatmen) but can be separated by differences in their dorsal-ventral colouration, front legs and predatory behaviour. Their dorsum is convex and lightly coloured without cross striations. Their front tarsi are not scoop shaped and their hind legs are fringed for swimming. There are two subfamilies, Notonectidae and Anisopinae, each containing four genera. The most common genus of backswimmers is *Notonecta* – streamlined, deep-bodied bugs up to 16 mm long and green, brown or yellowish in colour. As the common name indicates, these aquatic insects swim on their backs, vigorously paddling with their long, hair-fringed hind legs. They inhabit still freshwater, e.g. lakes, pools and marshes, and are sometimes found in garden ponds. Although primarily aquatic, they can fly well and so can disperse easily to new habitats. Adults are about 1/2 in. long and black and white coloured, swim upside down on their backs and have triangular-like (boat-shaped) bodies and large eyes. They are kidney shaped, with a four-segmented beak and antennae of three to four segments concealed between the head and thorax. There is an irregular brown and blackish band across the wings at the base of the membranous portion. The front and middle legs are fitted for grasping, while the hind legs are flattened, fringed and fitted for swimming. They are often seen on the water surface with their long hind legs held straight out and pointed forward, poised for a fast start. They live in all kinds of water (fresh to scum-covered stagnant) and overwinter as adults. They fly long distances, often in swarms, and are attracted to lights. The life cycle requires about 40 days. They feed on insects, tadpoles and small fish. They can bite, causing pain much like a bee sting when handled carelessly.

Order: Hemiptera

Suborder: Heteroptera

Infraorder: Nepomorpha, Popov, 1968

1. Family: Nepidae, Latreille, 1802

Subfamily: Ranatrinae, Latreille, 1802

Tribe: Ranatrini, Latreille, 1802

Genus: *Ranatra*, Fabricius, 1790

1. *Ranatra elongata*, Fabricius, 1790
2. *Ranatra filiformis*, Fabricius, 1790
3. *Ranatra digitata*, Hafiz & Pradhan, 1947

Subfamily: Nepinae, Latreille, 1802

Tribe: Nepini, Latreille, 1802

Genus: *Laccotrephes*, Stal, 1866

4. *Laccotrephes griseus*, Guerin-Meneville, 1844
5. *Laccotrephes ruber*, Linnaeus, 1764
6. *Laccotrephes elongatus*, Montandon, 1907

2. Family: Belostomatidae, Leach, 1815

Subfamily: Belostomatinae, Leach, 1833

Genus: *Diplonychus*, Laporte, 1833

7. *Diplonychus rusticus*, Fabricius, 1781
8. *Diplonychus annulatus*, Fabricius, 1781

Subfamily: Lethocerinaea, Lauck & Menke, 1961

Genus: *Lethocerus*, Mayr, 1853

9. *Lethocerus indicus*, Lepeletier & Serville, 1852

3. Family: Notonectidae, Latreille, 1802

Subfamily: Anisopinae, Hutchinson, 1929

Genus: *Anisops*, Spinola, 1837

10. Anisops bouvieri, Kirkaldy, 1904
11. Anisops sardeus sardeus, Herrich-Schaffer, 1850

4. Family: Corixidae, Leach, 1815

Subfamily: Micronectinae, Leach, 1815

Genus: *Micronecta*, Kirkaldy, 1897

12. *Micronecta scutellaris scutellaris*, Stal, 1858

Infraorder: Gerromorpha, Popov, 1971

5. Family: Gerridae, Leach, 1815

Subfamily: Gerrinae, Bianchi, 1896

Genus: *Limnogonus*, Stal, 1868

13. *Limnogonus (Limnogonus) nitidus*, Mayr, 1865

Genus: *Limnometra*, Mayr, 1865

14. *Limnometra fluviorum*, Fabricius, 1798

More than 275 species of Hemiptera are known from India, but only 14 species of Hemiptera belonging to 5 families are reported from the lakes of Hyderabad.

Coleoptera

The order Coleoptera, or beetles, is represented by some 3,50,000 known species (Lawrence 1982), but recent estimates suggest there are hundreds of thousands or even millions of undescribed species. Although the vast majority of beetles are terrestrial, it is estimated that about 18,000 species of aquatic Coleoptera are present on the earth at present. About 12,600 (70 %) of these are already described. About 30 beetle families have aquatic representatives, and in 25 of these families, at least 50 % of the species are to be considered as aquatic. Six families are supposed to include 1,000 or more aquatic species: Dytiscidae (3,908 described species/5,000 estimated), Hydraenidae (1,380/2,500), Hydrophilidae (1,800/2,320), Elmidae (1,330/1,850), Scirtidae (900/1,700) and Gyrinidae (750/1,000). Scirtidae and Hydraenidae and Haliplidae are regarded as the least explored families (Jach and Balke (2008)).

Of the more than one million described species of insects, at least one-third is beetles, making the Coleoptera the most diverse order of living organisms. The order Coleoptera (beetles) is the largest order of insects. It belongs to the infraclass Neoptera and division Endopterygota. Members of this order have an anterior pair of wings (the *elytra*) that are hard and leathery and not used in flight; the membranous hindwings, which are used for flight, are concealed under the elytra when the animals are at rest. Only 10 % of the 350,000 described species of beetles are aquatic. Aquatic species occur in two major suborders: the Adephaga and the Polyphaga. Both larvae and adults of six beetle families are aquatic: Dytiscidae (predaceous diving beetles), Elmidae (riffle beetles), Gyrinidae (whirligig beetles), Haliplidae (crawling water beetles), Hydrophilidae (water scavenger beetles) and Noteridae (burrowing water beetles). Five families, Chrysomelidae (leaf beetles), Limnichidae (marsh-loving beetles), Psephenidae (water pennies), Ptilodactylidae (toe-winged beetles) and Scirtidae (marsh beetles), have aquatic larvae and terrestrial adults, as do most of the other orders of aquatic insects; adult limnichids, however, readily submerge when disturbed. Three families have species that are terrestrial as larvae and aquatic as adults, Curculionidae (weevils), Dryopidae (long-toed water beetles) and Hydraenidae (moss beetles), a highly unusual combination among insects.

Beetles are holometabolous. Eggs of aquatic coleopterans hatch in 1 or 2 weeks, with diapause occurring rarely. Larvae undergo from 3 to 8 moults. The pupal phase of all coleopterans is technically terrestrial, making this life stage of beetles the only one that has not successfully invaded the aquatic habitat. A few species have diapausing prepupae, but the most complete transformation to adults ensues in 2 to 3 weeks. Terrestrial adults of aquatic beetles are typically short-lived and sometimes nonfeeding, like those of the other orders of aquatic insects.

Unlike the Hemiptera, the larvae of Coleoptera are morphologically and behaviourally different from the adults, and their diversity is high. In temperate regions, beetles from most major groups commonly exhibit univoltine life cycles. A particularly interesting suite of aquatic and semiaquatic habitats inhabited by beetles occurs at the edge of the sea. In general, insects have not made major inroads into salt water, but a considerable number of beetles are able to tolerate such environmental conditions by either physiological tolerance or behavioural adaptation. The Coleoptera are divided into four suborders. The first two are very small relict groups, of which the Myxophaga are more or less aquatic, mainly in running water. The Adephaga or carnivorous beetles are a large suborder containing six aquatic families. In the very primitive Amphizoidae, nearly all the Dytiscidae and the Noteridae, the larvae are metapneustic, breathing by means of a single pair of abdominal spiracles. In the primitive Hydrobiidae, the Haliplidae, one genus of Dytiscidae and the Gyrinidae, the larvae have tracheal gills. Beetles are found in a very wide range of aquatic habitats. Aquatic beetles are classified as clingers, climbers, sprawlers, swimmers, divers and burrowers.

Water beetles display a wide array of respiratory adaptations. Many larvae are able to breathe via the integument; and many of them are equipped with various kinds of gills (tracheal gills, spiracular gills), which may be even retractable, as in many Dryopidae. In contrast to the larvae, adults have no gills. Most species carry a smaller or larger air bubble with them, which is in contact with the tracheal system. This air supply may be stored in the subelytral space (e.g. Dytiscidae, Gyrinidae), underneath the coxal plates (Haliplidae), on the ventral surface (Hydrophilidae) or on any part of the body, where it is usually held by hydrofuge pubescence or scales; in Elmidae, for instance, the air bubble can replace oxygen through diffusion of dissolved oxygen from the surrounding water while the beetle is fully submerged. In such a case the air bubble is called gas gill (or plastron) because it functions as a physical gill. Two kinds of plastron can be distinguished microplastron and macroplastron. The Gyrinidae, or whirligig beetles, occur on the surface of ponds in aggregations of up to thousands of individuals. Water beetles can be used to control water plants that have become pests.

The major studies on aquatic Coleoptera also include the works from Andhra Pradesh (Mukhopadhyay and Ghosh 2003), West Bengal (Biswas and Mukhopadhyay 1995) and Sikkim (Mukhopadhyay and Ghosh 2003). More than 223 species of aquatic coleopterans are known from India. Only 31 species of beetles are reported from the present study. More intensive survey spread over different seasons would be required to provide a complete picture of the aquatic beetle diversity of this area.

Key to Five Families of Adult Coleoptera, from Hyderabad

01. Each eye divided into two, usually shiny black elytra, often seen swimming on the water surface in groups – **Gyrinidae**

    Eyes normal, not divided into two – 2

02. Plates covering almost the entire first leg segment and first few abdominal segments. Hind coxa, hind femur and basal abdominal ventrites concealed under conspicuous "hindcoxal plates" – **Haliplidae**

    No plates on ventral surface covering legs or abdominal segments – 3

03. First segment of hind legs dividing the first abdominal segment. Overall body shape streamlined. Metasternum with characteristic lateral "wings". Metacoxae large, posteriorly with a paired posterior metacoxal process. Size: 1–50 mm, often streamlined – **Dytiscidae**

    First abdominal segment not divided by hind coxae – 04

04. Maxillary palps long, visible dorsally. Antennae with last four segments in the form of a club starting with a "cuplike" segment, pubescent antennal club with 3 segments, abdomen usually with 4–5 clearly visible sternites – **Hydrophilidae**

Maxillary palps short, not extending beyond the head so no seen in dorsal view. Antennae may be clubbed or not but not as above. Antenna long or short, 7–11 segments, second segment never greatly enlarged. Frontoclypeal suture usually present. Size: 0.8–11 mm. Usually found in association with running water – **Elmidae**

A checklist of Gerromorpha (Hemiptera) from India (Thirumalai 2002) and a synoptic list of Nepomorpha (Hemiptera: Heteroptera) from India (Thirumalai 2007) are also given in ZSI website www.zsi.gov.in. An attempt has been made to update the checklist of aquatic Coleoptera. Of the 18 families of aquatic Coleoptera known from the world representative of five families namely Dytiscidae, Gyrinidae, Hydrophilidae, Haliplidae, Elmidae, Dryopidae and Notoridae are chiefly represented in India. The checklist of aquatic Coleoptera from India presented here includes five families and lists a total of 396 species under five families. The earlier knowledge and scientific contribution on aquatic beetles (Vazirani 1968, 1970 and 1984) are noteworthy to understand the present fauna. The major studies on aquatic Coleoptera also include the works of Jach and Balke (2008), Mukhopadhyay and Ghosh (2003) and Biswas and Mukhopadhyay (1995). The members of the family Dytiscidae (predacious diving beetles) feed vigorously upon almost all invertebrates and fish eggs and fry. These beetles generally occupy clean and fresh macrophytic leaves near the bottom along the littoral zone. They are active swimmers and swift divers. Adult dytiscids range from 1.4 to 3.8 mm in length. Although most species are small to medium sized, some adults can attain a length of 35 mm. The hind coxae are very large and the second and third legs are widely separated. The antennae are very long and threadlike with 11 segments. The members of the family Gyrinidae (whirligig beetles) are found in freshwater ponds, lakes, open flowing streams, etc. The first abdominal sternite is divided by hind coxae (suborder Adephaga); short, clubbed antennae; and seemingly 2 pairs of eyes. The forelegs are long and thin; the middle and hind legs are short and paddle-like, not extending beyond the margin of the abdomen (only front legs visible in dorsal view); the body is elongate oval and flattened, usually 3 to 15 mm in length. The members of Haliplidae (crawling water beetles) live among aquatic vegetation along the edges of ponds, lakes, streams or creeks. They are best identified by the large coxal plates covering the base of the hind legs and abdomen. Their tarsi have two claws. They are omnivores found in the vegetation of pools. They are small beetles with their size at maturity of about 2–6 mm. Regimbart (1882) recorded the first Indian species *Haliplus angustifrons* from Bihar. So far five species are recorded under the genus *Haliplus* from India.

The hydrophilids (water scavenger beetles) are predominant in rivers and streams. They are characterized by their short-clubbed antennae that generally remain concealed beneath the head and long maxillary palps resembling antennae like Dytiscidae; they also make contact with the surface water film with the anterior edge of their body, but unlike the former, their hind legs move alternately while swimming and they are not very good swimmers. Beetles belonging to the family Elmidae (riffle beetles) live in running water. Some breathe underwater using an air film trapped by hairs as a physical gill, mostly aquatic in both adult and larval stages. This is a family of small beetles 2–5 mm long. They have punctured elytra and raised lines on the thorax. The riffle beetles usually have filiform antennae that are much longer than the head. Their tarsi are distinctly five segmented and have 5–6 abdominal segments. They are underwater crawlers and do not swim; therefore, they have no swimming hairs on their hind legs.

The inventory comprises of 31 species accommodated under 20 genera and four families. Under each species, citation for original description and other accompanying work necessary to undertake the taxon is given.

1. Family: Dytiscidae

The members of this family have adapted perfectly well to aquatic life. All adults and larvae are aquatic. These beetles are commonly known as “predacious diving beetles” as they feed vigorously upon almost all invertebrates and fish eggs and fry. Both adults and larvae are predaceous and attack a wide variety of small aquatic organisms. These beetles generally occupy clean and fresh macrophytic leaves near the bottom along the littoral zone. They are active swimmers and swift divers. Adult dytiscids range from 1.4 to 3.8 mm in length. Although most species are small to medium sized, some adults can attain a length of 35 mm. The body is covered with an adherent layer of grease which holds dust particles or detritus. They are usually black or brownish in colour, sometimes marked with dull yellow, orange or brown shades. The hind coxae are very large and the second and third legs are widely separated. The hind legs of dytiscid beetles are very important and contribute mainly to swimming movements. The antennae are very long and threadlike with 11 segments. Ten pairs of spiracles are present, the first two on the thorax, three to nine on the abdominal segments and the tenth on the tip of the abdomen. The spiracles open in subelytral chambers and help in oxygen supply. During submergence these beetles utilize the oxygen from the tracheae and subelytral chambers. Dey and Sengupta (1993) have recorded 16 species from a few wetlands of Kolkata and surrounding districts. More than 3,700 species are known (Nilsson and Persson 1990), of which 223 have been recorded from India.

Adults are 1/4 to 1-3/16 in. long, ovate and smooth and have shining black bodies. There is a yellow margin around the front of the head and sides of the thorax and wing covers. The antennae are threadlike and prominent, with the hind legs longest and flattened to serve as oars in swimming. They are attracted to light, often migrate from one pond to another and are strong fliers. Unlike other water beetles which move their legs alternately when swimming, these beetles stroke them together like oars as the backswimmer bugs do. They can be collected by sweeping submerged vegetation in streams and ponds with a dip net. Both adults and larvae are predaceous. Sharp hollow mandibles (jaws) are used to inject paralyzing and digestive fluids into their prey and to draw out the liquid contents. They attack aquatic insects and fish and have the ability to regenerate lost parts to some extent. Larvae crawl to shore to pupate in the soil, and hibernation occurs in the water as an adult or larvae. There is one generation per year, and adults can live several years.

2. Family: Gyrinidae

The members of family Gyrinidae are commonly known as whirligig beetles. They are found in freshwater ponds, lakes, open flowing streams, etc. When the gyrinid beetles are swimming on the surface of the water, the dorsal portion of the eye is in the air and the ventral portion in the water. The first abdominal sternite is divided by hind coxae (suborder Adephaga); short, clubbed antennae; and seemingly two pairs of eyes, one above and one below the water level. The forelegs are long and thin; the middle and hind legs are short and paddle-like, not extending beyond the margin of the abdomen (only front legs visible in dorsal view); the body is elongate oval and flattened, usually 3 to 15 mm in length, and the tarsi are 5-5-5. Vazirani has recorded 46 species under the family Gyrinidae from India. Adults are 3/8 in. long or slightly longer, oval, flat and hard bodied with a shiny black bronze sheen. The legs are brownish yellow. Eyes are divided into two widely separated parts; the upper one is oval and remains above the water, and the lower one is somewhat smaller and remains below the water. These fast-moving beetles are often seen swimming in groups in endless gyrations or circular "skating" movements, in a spot on the water surface. The outer margins of the wing covers are curved inward near the tip. The legs are flattened and fitted for swimming, and the antennae are quite short with the last segment enlarged. They are found in lakes, ponds and streams. The adult scavengers and the larvae are predaceous and aquatic. The larvae leave the water to pupate on bordering plants and overwinter as adults. There is one generation per year.

3. Family: Hydrophilidae

This is another major family of aquatic Coleoptera. There are more than 2,500 known species, and many new ones are being added every year. Currently 171 genera are known. The family is diverse not only in number of species but also with respect to variety of form, size and ecological strategies (Hansen 1991). Hydrophilids occur in all biogeographic regions. The hydrophilids commonly termed as "water scavenger beetles" are characterized by their short-clubbed antennae that generally remain concealed beneath the head and long maxillary palps resembling antennae like Dytiscidae; they also make contact with the surface water film with the anterior edge of their body, but unlike the former, their hind legs move alternately while swimming, and they are not very good swimmers. Adults are good fliers and some leave the water and crawl on land. The air supply is through the tracheal system and spiracles from subelytral chamber and from silvery film of air retained on ventral side of the body by hydrofuge hairs. For the renewal of oxygen supply, the beetles come to the surface with body slightly inclined to one side so as to keep the cleft between head and thorax in contact with surface film. The surface film is broken by antennal tip. They feed mainly on detritus, algae and decaying vegetative matter. Biswas and Mukhopadhyay (1995) provided the latest account of Hydrophilidae from West Bengal, wherein 40 species belonging to 19 genera are dealt. Adults are large about 1-1/2 in. long, hard bodied and elliptical with triangular yellowish markings on the abdomen sides. The body top is smooth and shiny black with a greenish tinge. A long spinelike keel on the thorax underside between the legs can be jabbed into the fingers when the beetle is handled carelessly. The antennae are club shaped and the legs are flattened for swimming. They are good fliers and are very much attracted to lights in large numbers in the spring. Beetles are commonly seen swimming or crawling among the water plants or on the bottom of shallow pools, feeding mostly on dead or decaying vegetation. The hind legs move alternately when swimming. The larvae are predaceous and cannibalistic. There are one to two generations per year.

4. Family: Haliplidae

The Haliplidae or crawling water beetles are a comparatively small group of inconspicuous, small water-dwelling insects. The family contains five genera and about 200 species are known worldwide. Adults live among aquatic vegetation along the edges of ponds, lakes, streams or creeks. The crawling water beetles are best identified by the large coxal plates covering the base of the hind legs and abdomen. Although they are mainly crawlers, they do have swimming hairs on their legs and do sometimes swim. Their tarsi have two claws. They are omnivores found in the vegetation of pools. They are small beetles with their size at maturity of about 2–6 mm. Regimbart (1882) recorded the first Indian species *Haliplus angustifrons* from Bihar. So far seven species are recorded under the genus *Haliplus* from India.

5. Family: Elmidae

This is a family of small beetles 2–5 mm long. They have punctured elytra and raised lines on the thorax. They live in running water. Some breathe underwater using an air film trapped by hairs as a physical gill. About 300 species are known worldwide. Elmids are small beetles, usually less than 3 mm long, and most are aquatic in both adult and larval stages. The adults breathe by means of a hydrofuge ventral plastron and the larvae with retractile cloacal gills. Adults and larvae inhabit the substratum of creeks and rivers, feeding on diatoms, encrusting algae detritus or submerged decaying wood, and they are good water quality indicators. The riffle beetles usually have filiform antennae that are much longer than the head. Their tarsi are distinctly five segmented. They are underwater crawlers and do not swim; therefore, they have no swimming hairs on their hind legs. They have 5–6 abdominal segments. Beetles belonging to the family Elmidae (riffle beetles) live in running water. Some breathe underwater using an air film trapped by hairs as a physical gill, mostly aquatic in both adult and larval stages. Water beetles, especially Elmidae, are gaining increasing recognition as indicators of water quality, water types and endangered habitats (Jach and Matsui 1994).

Order: Coleoptera

I. Family: Dytiscidae

Subfamily: Hydroporinae

1. *Hydrovatus confertus* (Sharp)
2. *Guignotus flammulatus* (Sharp)
3. *Guignotus inconstans* (Reg)

Subfamily: Notorinae

4. *Canthydrus laetabilis* (Walker)
5. *Canthydrus morsbachi* (Wehncke)
6. *Hydrocoptus subvittulus* (Mots)

Subfamily: Laccophilinae

7. *Laccophilus clarki* (Sharp)
8. *Laccophilus ellipticus* (Regimbart)
9. *Laccophilus uniformis* (Motsch)

Subfamily: Dytiscinae

10. *Cybister (Melanectes) tripunctatus asiaticus* Sharp
11. *Cybister (Melanectes) convexus* (Sharp)
12. *Eretes sticticus* (Linnaeus)
13. *Hydaticus (Guignotites) vittatus* (F.)
14. *Rhantaticus congestus* (Klug)
15. *Sandracottus dejeani* (Aube)

II. Family: Gyrinidae

Subfamily: Enhydrinae

16. *Dineutus (Protodineutus) indicus* (Aube)

Subfamily: Gyrininae

17. *Gyrinus convexiusculus* (Macleay)

Subfamily: Orechtochilinae

18. *Orectochilus (Patrus) semivestitus* (Guerin)
19. *Orectochilus (Patrus) discifer* (Walker)

III. Family: Hydrophilidae

Subfamily: Hydrophilinae

20. *Hydrophilus olivaceous* (F.)
21. *Regimbartia attenuate* (Fabricius)
22. *Helochares anchoralis* (Sharp)
23. *Berosus indicus* (Mots.)
24. *Berosus pulchellus* (Macleay)

Subfamily: Hydrochinae

25. *Hydrochus bindosus* (Mots)

Subfamily: Sphaeridiinae

26. *Dactylosternum abdominale* (F.)
27. *Sphaeridium dimidiatum* (Gory)

IV. Family: Haliplidae

28. *Haliplus angustifrons* (Regimbart)
29. *Haliplus* (*Liaphlus*) *pulchellus indicus* (Regimbart)

V. Family: Elmidae

30. *Stenelmis* ssp., (Dufour)

Conclusion

Although all species of Plecoptera, Ephemeroptera, Odonata and Trichoptera have aquatic stages, these are relatively small and have little numerical significance when compared to the large orders Coleoptera and Hemiptera. Insect collections were made from various surveys to the different lakes in and around Hyderabad, during April, 2008, to December, 2012. The study reports the presence of 14 species of aquatic Hemiptera belonging to 5 families and 31 species of aquatic Coleoptera under five families. Many aquatic species are included in aquatic Hemiptera, but only species from five families, Belostomatidae, Nepidae, Corixidae, Notonectidae and Gerridae, are reported from the lakes of Hyderabad. Aquatic Coleoptera are highly diverse and distributed, but only five families, namely, Dytiscidae, Gyrinidae, Hydrophilidae, Haliplidae and Elmidae, are chiefly represented in the present report from the lakes of Hyderabad. The diversity of insect fauna in the different wetland types varied widely which was dependent on the availability of macrophytes and general physico-chemical conditions of water. It is presumed that further intensive seasonal surveys to many more wetlands belonging to different types and detailed taxonomic studies may reveal some species which may be significant both ecologically and taxonomically. Further studies aiming to improve our knowledge on water bugs and beetles should focus on collecting in little known areas, revision of the still unstudied material from additional families and filling the large gaps in our knowledge regarding the diversity of water beetles in some specific habitats.

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References

Bal A, Basu RC (1994a) Insecta: Hemiptera: Mesoveliidae, Hydrometridae, Veliidae and Gerridae. In: State fauna series 5: Fauna of West Bengal, Part 5. Zoological Survey of India, Kolkata, pp 511–534

Bal A, Basu RC (1994b). Insecta: Hemiptera: Mesoveliidae, Hydrometridae, Veliidae and Gerridae. In: State fauna series 5: Fauna of West Bengal, Part 5. Zoological Survey of India, Kolkata, pp 535–558

Bhattacharya DK (2000) Insect fauna associated with large water hyacinth in freshwater wetlands of west Bengal. In: Aditya AK, Haldar P (eds) Diversity and environment. Proceedings of national seminar on environment biology. Daya Publishing House, Delhi, pp 165–169

Biswas B, Mukhopadhyay P (1995) Insecta: Coleoptera: State Fauna series. 3: Fauna of West Bengal, 3 pt. 6 A: 1–51. Zoological Survey of India, Kolkata

Deepa J (2010) Aquatic insects of Wyra lake, Khammam A.P., Wetland ecosystem series. Records of the Zoological Survey of India, Kolkata

Deepa J, Rao CAN (2007) Aquatic Hemiptera of Pocharam Lake, Andhra Pradesh. Zoos Print J 22(12):2937–2939

Deepa J, Rao CAN (2010). Aquatic Entomofauna of Pocharam Lake, Andhra Pradesh (Hemiptera & Coleoptera, Wetland ecosystem series, 13:37–49, Records of the Zoological Survey of India, Kolkata

Deepa J, Rao CAN (2011) On Collections of aquatic and semiaquatic bugs and beetles of KBR National Park, Hyderabad, Andhra Pradesh. In: Bugs R (ed) All, newsletter of the invertebrate conservation & information network of South Asia, no. 17, March, 2011, pp 13–15

Deepa J, Chandra K, Rao CAN (2010) Insecta: Aquatic Coleoptera, State Fauna series, Fauna of Madhya Pradesh. Zoological Survey of India, Kolkata

Dey M, Sengupta T (1993) Beetles (Coleoptera: Insecta) of wetlands of Calcutta & its surroundings. Rec Zool Surv India 93(1–2):103–138

Fabricius JC (1775) Systema Entomologica. Flensburgi et Lipsiae

Ghosh AK (1996) Insect biodiversity in India. Orient Insects 30:1–10

Hansen M (1991) The hydrophilid beetles: phylogeny, classification and a revision of the genera (Coleoptera, Hydrophilidae). Biol Skrift 40:367

Jach MA, Balke M (2008) Developments in hydrobiology, fresh water animal diversity, vol 198. Springer, Dordretch, pp 419–442

Jach MA, Matsui E (1994) The Japanese species of the genus Limnebius (Coleoptera, Hydraenidae). Jpn J Entomol 62(2):267–274

Junk WJ (1977) The invertebrate fauna of floating vegetation of Bong Barapet, a reservoir in Central Thailand. Hydrobiologia 53:229–238

Lawrence JF (1982) Coleptera. In: Parker SP (ed) Synopsis and classification of living organisms, vol 2. McGraw Hill, New York, pp 482–553

Mukhopadhyay P, Gosh SK (2003) Insecta: Coleoptera. Fauna of Sikkim. State Fauna Series 9(Part:3):19–33. Zoological Survey of India, Kolkata

Nilsson AN, Persson S (1990) Dimorphism of the metasternal wing in *Agabus raffrayi* and *A. labiatus* (Coleoptera: Dytiscidae) questioned. Aquat Insects 12:135–144

Ramakrishna (2000) Limnological investigation and distribution of micro and macro invertebrates and vertebrates of Fox Sagar Lake, Hyderabad. Rec Zool Surv India 98(1):169–196

Regimbart M (1882) New species of Gyrinidae in the Leyden museum. Notes Leyden Mus 4:59–71

Thirumalai G (1989) Aquatic and semiaquatic Hemiptera (Insecta) of Javadi Hills, Tamil Nadu. Zool Surv India 118:1–64

Thirumalai G (1999) Aquatic and semiaquatic heteroptera of India. Indian Association of Aquatic Biologist (IAAB) Publication No. 7:1–74

Thirumalai G (2002) A check list of Gerromorpha (Hemiptera) from India. Rec Zool Surv India 100(1–2):55–97

Thirumalai G (2007) A synoptic list of Nepomorpha (Hemiptera: Heteroptera) from India. Rec Zool Surv India Occ Pap 273:1–84

Tonapi GT (1959) Studies on the aquatic insect fauna of Poona (Aquatic Heteroptera). Proc Nat Inst Sci India 25:321–332

Vazirani TG (1968) Contribution to the study of aquatic beetles(coleopteran) I. On a collection of Dytiscidae from Western ghats with description of two new species. Orient Insects 1:99–112

Vazirani TG (1969a) Contribution to the study of aquatic beetles (Coleoptera). 2. A review of the subfamilies Noterinae, Laccophilinae, Dytiscinae and Hydroporinae (in part) from India. Orient Insects 2(3 & 4):221–341

Vazirani TG (1969b) Contribution to the study of aquatic beetles. IV. A review of Pleurodytes Regimbart (Col., Dytiscidae). Ann Soc Ent Fr 5(1):137–141

Vazirani TG (1969c) Contribution to the study of aquatic beetles (Coleoptera). VI. A review of Hydroporinae: Dytiscidae, in part, from India. Bull Mus Nat Hist Nat Paris (2) 41(1):203–225

Vazirani TG (1970) Fauna of Rajasthan, India pt. 5. Aquatic beetles (Insecta: Coleoptera: Dytiscidae). Rec Zool Surv Calcutta 62(1–2):29–50 (1964)

Vazirani TG (1984) The fauna of India. Coleoptera, Family Gyrinidae and Family Haliplidae. Zoological Survey of India, Calcutta

9 Odonate Fauna of Rajasthan, India with Links to Arabia and Himalaya

Akhlaq Husain*

Abstract

The present paper deals with the update on odonate fauna of Rajasthan, based on earlier records. All together, there are 53 species belonging 34 genera, 8 families under 2 suborders with 15 species common to Arabia and 51 to Himalaya which confirms the linkage of Rajasthan and Thar Desert to Sahara Desert and Palaearctic Region. A list of 20 more species, recently recorded from southern part of the state, has also been added.

Keywords

Odonate • Rajasthan • Distribution • Checklist

Introduction

The odonate fauna of Rajasthan has attracted the attention of various workers (Agarwal 1957; Bose and Mitra 1976; Prasad and Thakur 1981; Thakur 1985; Tyagi and Miller 1991; Prasad and Varshney 1995; Prasad 1996a, b, 2004a, b; Chandra and Sharma 2010; Sharma 2010a, b, c, 2011a, b, 2012; Sharma and Dhadeech 2010, 2011; Sharma and Sewak 2010a,b; Sharma and Kankane 2012; Husain 2011; Husain and Sharma 2012; Palot and Soniya 2000) during the past but no consolidated and update account of the total species is available and hence an attempt in this regard has been made. The old records are generally limited to mere lists. In all there are 53 species belonging 34 genera, 8 families under 2 suborders with 15 (28.30 %) species common to Arabia and 51 (96.23 %) to Himalaya which is interesting from zoogeographical point of view and confirms the theory of the linkage of 'Indian Desert' to Sahara Desert and Palaearctic Region. Colouration/measurements of species are followed after Fraser (1933, 1934, 1936), Prasad (1996b, 2004a, b, 2007) and Subramanian (2009).

Rajasthan

Rajasthan is the largest state of India by area (10.4 %, covering 342,239 km^2), located between 23° 30′ and 30° 11′ N and 69° 29′ and 78° 17′ E in north-west, which parallels the Sutlej-Indus river valley along its border with Pakistan to the west. It is also bordered by Gujarat to the south-west, Madhya Pradesh to the south-east, Uttar Pradesh and Haryana to the north-east and Punjab

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to the north. At the eastern side lies the famous Keoladeo National Park near Bharatpur, a World Heritage Site. It also has two national tiger reserves, Ranthambore (Sawai Madhopur dist.) and Sariska Tiger Reserve (Alwar dist.) and a small Tal Chhapar Sanctuary (Sujangarh, Churu dist.). The Desert National Park (Jaisalmer dist.), in Thar, is an excellent example of the ecosystem of the desert and its diverse fauna.

Geographically, it includes the major part of Thar Desert along north-western side, the Aravalli Range running from south-west peak Guru Shikhar at 1,722 m (Mount Abu) to Khetri in the north-east and the termination of river Ghaggar (originating in Haryana) into the sands of Thar in the northern corner of the state. About three-fifth of the state lies north-west of the Aravallis, leaving two-fifth on the east and south direction. The hill station Mount Abu is separated from the main ranges by the River West Banas. The Thar extends into the Indian states of Gujarat, Haryana and Punjab. The north-western part of the state is generally sandy and dry with thorn scrub forests in a band around the Thar between the desert and the Aravallis. With the exception of Mount Abu, the hilly Vagad region in southern most part on border with Gujarat is the wettest region in Rajasthan and the most heavily forested. The south-eastern area, higher in elevation (100 to 350 m) and more fertile, has very diversified topography. In the south lies the hilly tract of Mewar. In the south-east, a large area (in districts of Kota and Bundi) forms a tableland. To the north-east of this is a rugged region (bad-lands) following the line of the Chambal River. Farther north the state levels out; the flat plains of the north-eastern (Bharatpur district) are part of an alluvial basin.

This region receives less than 400 mm of rain in an average year. The western deserts accumulate about 100 mm annually, while the south-eastern part of the state receives 650 mm annually, most of which falls from July through September during the monsoon season. Temperatures can exceed 45 °C in the summer months and drop below freezing in the winter. On average winter temperatures range from 8 to 28 °C and summer temperatures range from 25 to 46 °C. Average rainfall also varies; the western deserts accumulate about 100 mm (about 4 in.) annually, while the south-eastern part of the state receives 650 mm annually, most of which falls from July through September during the monsoon season. The Luni River and its tributaries are the major river system of Godwar and Marwar regions, draining the western slopes of the Aravallis and emptying south-west into the Great Rann of Kutch wetland in neighbouring Gujarat. Eastern and south-eastern region is drained by the Banas and Chambal rivers, the tributaries of Ganga. As regards insects, the species richness as per 'Shannon's Diversity Index' is the highest in the order Lepidoptera (5.98) and lowest in Odonata (0.41), probably due to scanty water resources (Ramakrishna et al. 2010).

Systematic Account, Distribution, Habitat, Conservation Status and Threats

Order: Odonata Fabricius, 1793
(Dragonflies and Damselflies)
Suborder: Anisoptera Selys, 1840
(Dragonflies)
Family: Aeshnidae Rambur, 1842
(Darners, Hawkers)
Genus: *Anax* Leach, 1815
(Subfamily: Aeshninae Rambur, 1842)

1. *Anax guttatus* (Burmeister, 1839)

Aeschna guttata Burmeister, 1839. *Handb. Ent.*, 2: 840.

Anax mangus Rambur, 1842. *Ins. Nevrop.*: 188.

Anax guttata Brauer, 1866. *Reise d. Novara Neur.*: 62.

Anax guttatus Hagen, 1867. *Verh. zool.-bot. Ges. Wien*, 16: 39; Fraser, 1936. *Faun. Brit. India, Odo.*, 3: 140-142; Prasad, 2004. *Fauna of Desert National Park, Conservation Area Series* 19: 51-58 (Girab, Barmer dist.); Subramanian, 2009. *Dragonflies of India, A Field Guide*: 37, 2 figs. (throughout Oriental region); Sharma & Sewak, 2010. *Proceedings: Impact of Climate Change on Biodiversity and Challenges in Thar Desert*: 321-324 (Rajasthan).

Anax goliathus Fraser, 1922. *J. Bombay nat. Hist. Soc.*, 28: 906.

English Name
Blue-Tailed Green Darner.

Description
Male: Face golden-yellow/greenish-yellow, eyes bluish-yellow/black, thorax greenish, abdomen pale green/turquoise-blue/green with turquoise-blue spots above, wings transparent, hindwing with amber-yellow patch, pterostigma reddish and legs black.

Abdomen 56.0–62.0, hindwing 50.0–54.0 mm (Fraser 1936; Subramanian 2009), abdomen 57.0, fwing. 52.0, hwing. 51.0 mm (Prasad 1996a, b).

Female: Hindwing often without amber patch, turquoise-blue of 2nd segment divided into four patches and orange spots on abdomen more confluent.

Abdomen 56.0–58.0, hindwing 52.0–54.0 mm (Fraser 1936; Subramanian 2009), abdn. 52.5, fwing. 50.0, hwing. 50.0 (Prasad 2004a).

Distribution
Mostly plains, occurring up to an altitude of 1,800 m in Western Ghats (India).

Rajasthan
Girab, Barmer dist., and Desert National Park.

India
Andhra Pradesh (Waltair, Visakhapatnam dist.), Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Eastern Himalaya, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Karnataka (Kodagu dist./Coorg), Kerala (Anaimalai hills; Malabar), Punjab, Tamil Nadu (Anaimalai, Coimbatore dist., Chennai; Nilgiri), Uttarakhand (Dehra Dun dist.) and Uttar Pradesh.

Elsewhere
Australia (Northern Territory, Queensland), Bangladesh, Brunei Darussalam, China (Guangdong, Guangxi, Hainan, Taiwan), Cook Islands, Hong Kong, Indonesia (Bali, Irian Jaya, Jawa, Kalimantan, Lesser Sunda Island, Maluku, Sulawesi, Sumatera), Japan (Nansei-shoto), Kiribati, Laos, Malaysia, Marshall Islands, Micronesia FS, Myanmar, Nepal, Papua New Guinea, Philippines, Seychelles to Samoa in Pacific, Singapore, Sri Lanka, Thailand, Timor Leste, United States Minor Outlying Islands and Viet Nam.

Habitat
Inhabits open weedy ponds, marshes, big wells and lakes and is tolerant of disturbance. Breeds in marshes.

Conservation Status
IUCN Red List: Least Concern.

2. *Anax immaculifrons* Rambur, 1842

English Name
Magnificent Emperor.

Description
Male: Face greenish, eyes sapphire-blue, thorax bluish-green/turquoise-blue above with two black streaks on sides, abdomen black/turquoise-blue with a black mark, transparent wings tinted with amber-yellow, pterostigma reddish-brown and legs black.

Abdomen 52.0–55.0, anal appendage 6.0, hindwing 55.0 mm (Fraser 1936), abdomen 52.0–55, hwing 55.0 mm (Subramanian 2009).

Female: Turquoise-blue replaced by greenish-yellow and black by reddish-brown.

Abdomen 56.0, hindwing 58.0–60.0 mm (Fraser 1936; Subramanian 2009).

Distribution
At altitude varying from 457.2–2,286.0 m/1,500 to 7,500 ft altitude.

Rajasthan
Mount Abu Wildlife Sanctuary, Sirohi district.

India
Bihar, Chandigarh, Eastern Ghats, Himalaya, Maharashtra (Mumbai, Nagpur, Pench National

Park, Pune and Sanjay Gandhi National Park), Nilgiri plateau, Punjab (Gurdaspur dist.), Sikkim, Uttarakhand (Dehra Dun and Pauri dists.), Western Ghats and Western Himalaya.

Habitat
Found in streams, especially in hilly and mountainous areas. Breeds in marshes, sluggish brooks, pools and very slow-running marshy streams where larvae may be seen on muddy substratum. The eggs are inserted into the submerged reeds by the female.

Conservation Status
IUCN Red List: Least Concern.

Threats
Potential localised threats could be excessive development for tourism, urbanisation and possibly pollution.

3. *Anax parthenope* Selys, 1839

English Name
Lesser Emperor.

Description
Eyes green, a blue saddle at 2nd and 3rd segment, a yellow rim at base of 2nd, abdomen and thorax brown, prominent blue collar on greenish body and holds abdomen almost straight.

Male: Green eyes and waisted abdomen.

Abdomen 47.0–49.0, anal appendage 5.0, hindwing 46.0–50.0 mm (Fraser 1936).

Female: Abdomen 46.0–48.0, hindwing 48.0–50.0 mm (Fraser 1936).

Distribution

Rajasthan
Thar Desert; in and around Mount Abu Wildlife Sanctuary, Sirohi dist.; and Pichola Lake, Udaipur.

India
Delhi, Jammu and Kashmir, Tamil Nadu (Coimbatore dist., Coorg at an altitude over 914.4 m/3,000 ft), Uttarakhand (Nainital dist.), West Coast and Deccan.

Habitat
It occurs at standing, often large and sometimes brackish water bodies, more rarely at slowly running waters.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Hemianax* Selys, 1883
(Subfamily: Aeshninae Rambur, 1842)

4. *Hemianax ephippiger* (Burmeister, 1839)

English Name
Vagrant Emperor.

Description
Eyes brown, blue saddle extending over top half of abdomen; 61.0–66.0 mm in length.

Male: Abdomen 42.0, anal appendage 5.0, hindwing 44.0 mm (Fraser 1936).

Female: Abdomen 40.0, hindwing 46.0 mm (Fraser 1936).

Distribution

Rajasthan
Thar Desert; Pali district.

India
Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Chandigarh, Chattisgarh, Dadra and Nagar Haveli, Daman and Diu, Delhi, Goa, Gujarat (Kathiawar coast), Haryana, Himachal Pradesh (Kangra dist.), Jharkhand, Karaikal, Karnataka, Kerala, Maharashtra (Mumbai, Pune), Odisha, Puducherry (Mahe), Punjab, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh (Afzalgarh, Dist. Bijnor) and West Bengal (Darjeeling).

Habitat
It occurs at standing, often large and sometimes brackish water bodies, more rarely at slowly running waters.

Conservation Status
IUCN Red List: Least Concern.
Family: Gomphidae

(Club-Tails)
Genus: *Ictinogomphus* Cowley, 1934
(Subfamily: Lindeniinae Selys, 1854)

5. *Ictinogomphus rapax* (Rambur, 1842)

English Name
Common Club-Tail.

Description
Male: Eyes bluish-grey, thorax black with yellow markings, abdomen black with yellow and stripes/spots, wings transparent, pterostigma black and legs black.

Abdomen (including appendage) 52.0, hindwing 40.0 mm (Fraser 1934), abdomen 52.0, hwing. 40.0 (Subramanian 2009).

Female: Yellow markings more extensive, abdomen stout and compressed.

Abdomen 50.0, hindwing 42.0–44.0 mm (Fraser 1934; Subramanian 2009).

Distribution

Rajasthan
Thar Desert at Osian and Lake Kailana, Jodhpur; Mandor Gardens, Jodhpur; Pichola Lake, Udaipur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Throughout – Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Haryana, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Jammu and Kashmir, Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Pune; Sanjay Gandhi National Park and Ujani Wetland, Solapur dist.) Manipur, Meghalaya, Mizoram, Odisha, Puducherry, Punjab, Sikkim, Tamil Nadu, Uttarakhand (Dehra Dun dist.), Uttar Pradesh, West Bengal (Darjeeling).

Elsewhere
Bangladesh, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand and Viet Nam.

Habitat
Breeds in perennial ponds, reservoirs and rivers.

Conservation Status
IUCN Red List: Least Concern.

Threats
Presently it does not have any threats across its whole range, but deforestation in hill areas may affect.
Genus: *Onychogomphus* Selys, 1854
(Subfamily: Onycogomphinae Chao, 1984)

6. *Onychogomphus grammicus* (Rambur, 1842)

English Name
Claw-Tail

Description
Male: Face sandy-yellow, eyes bottle-green, thorax yellow with black markings, abdomen yellow and black, anal appendage yellow, wings hyaline with saffron and yellow, pterostigma yellow and legs yellow with black and brownish-black markings.

Abdomen 33.0–39.0, hindwing 29.0–30.0 mm (Fraser 1934).

Female: Abdomen with reddish-yellow.

Abdomen 37.0, hindwing 30.0 mm (Fraser 1934).

Distribution

Rajasthan
Chittorgarh.

India
Northern and central parts of India. Bihar, Delhi and Uttar Pradesh.

Habitat
No information appears to have been recorded on its habitat requirements, but it is reasonable to assume that it is a stream species and very likely a forest stream species.

Conservation Status
IUCN Red List: Data Deficient.

Threats

Habitat loss through human development of the area is a known threat to this species.

Genus: *Paragomphus* Cowley, 1934

(Subfamily: Onychogomphinae Chao, 1984)

7. *Paragomphus lineatus* (Selys, 1850)

English Name

Lined Hook-Tail.

Description

Yellow dragonfly with bluish-grey eyes and black and brown markings.

Male: Abdomen (including appendage) 32.0–37.0, hindwing 24–27 mm (Fraser 1934), abdn. 35.0, fwing. 26.5, hwing. 26.0 (Prasad, 1996), abdn. 34.0, fwing. 27.0, hwing. 26.0 (Prasad 2004b).

Female: Abdomen 31.0–36.0, hindwing 24.0–27.0 mm (Fraser 1934).

Distribution

Rajasthan

Thar Desert; in and around Mount Abu Wildlife Sanctuary, Sirohi dist.

India

Throughout. Chhattisgarh (Bastar dist.), Delhi, Kerala (Birds Lagoon), Gujarat (Kheda dist.), Himachal Pradesh (Kangra dist.), Karnataka (Bangalore, Kodagu/Coorg), Kerala (Palakkad/Palghat), Maharashtra (Pune), Tamil Nadu (Chennai, Nilgiris, Trichinopoly), Punjab (Hoshiarpur dist.), Uttarakhand (as *Mesogomphus lineatus*: Dehra Dun and Nainital dists. and Rajaji National Park) and West Bengal (Raniganj, Burdwan).

Habitat

The habitat is poorly known although it does include open, sluggish and often seasonal streams.

Conservation Status

IUCN Red List: Least Concern.

Threats

One of the ongoing threats affecting the habitat of this species is the production of crops and the associated water pollution is also having a direct effect on the quality of the habitat of this species.

Family: Libellulidae Rambur, 1842

(Skimmers)

Genus: *Brachydiplax* Brauer, 1868

(Subfamily: Brachydiplactinae Tillyard, 1917)

8. *Brachydiplax sobrina* (Rambur, 1842)

English Name

Little Blue Marsh Hawk.

Description

Small black dragonfly with dense bluish-white pruinescence on thorax and abdomen.

Male: Abdomen 20.0–24.0, hindwing 25.0–28.0 mm (Fraser 1936; Subramanian 2009).

Female: Abdomen 16.0–22.0, hindwing 22.0–26.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan

Thar Desert; Keoladeo National Park, Bharatpur; Lake Kailana, Jodhpur.

India

Assam, Jharkhand (Dhanbad), Karnataka (Hebbal tank, Bangalore), Kerala (Malabar, Travancore), Maharashtra (Mumbai); Punjab (Hoshiarpur dist.), Tamil Nadu (Kodagu/Coorg, Fraserpet), Uttarakhand (Dehra Dun dist.), Uttar Pradesh, West Bengal (Kolkata), West Coast from Mumbai to Travancore.

Habitat

It breeds in ponds, water-filled ditches and marshes, including man-made structures.

Conservation Status

IUCN Red List: Least Concern.

Threats

There do not appear to be any obvious major threats to this species at present, although some parts of its range are undergoing urbanisation.

Genus: *Orthetrum* Newman, 1833

(Subfamily: Libellulinae Rambur, 1842)

9. *Orthetrum glaucum* (Brauer, 1865)

English Name
Blue Marsh Hawk.

Description
Medium-sized dragonfly with bluish-black thorax and blue abdomen.

Male: Abdomen 29.0–35.0, hindwing 33.0–40.0 mm (Fraser 1936; Subramanian 2009), abdn. 33.5, fwing. 37.0, hwing. 36.0 (Prasad 1996a, b), abdn. 33.0, fwing. 36.5, hwing. 36.0 (Prasad 2004b).

Female: Abdomen 28.0–32.0, hindwing 32.0–37.0 mm (Fraser 1936; Subramanian 2009), abdn. 30.0, fwing. 36.0, hwing. 35.5 (Prasad 1996a, b).

Distribution

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian, Jodhpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Throughout India (plains and above altitude of 1,219.2 m/4,000 ft). Andhra Pradesh, Arunachal Pradesh, Chhattisgarh (Bastar dist.), Gujarat (Amreli dist.), Himachal Pradesh (Kangra and Solan dists., Renuka Wetland, Sirmour dist.), Karnataka, Kerala, Maharashtra (Sanjay Gandhi National Park), Manipur, Meghalaya, Mizoram, Odisha, Punjab, Sikkim, Tamil Nadu (in Nilgiris: Kallar and Buliar), Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh and Tehri dists. and Rajaji National Park), Uttar Pradesh, West Bengal and West Coast.

Habitat
Breeds in ponds, drains, ditches and other open lentic habitats.

Conservation Status
IUCN Red List: Least Concern.

10. *Orthetrum luzonicum* (Brauer, 1868)

English Name
Tricoloured Marsh Hawk.

Description
Medium-sized dragonfly with blue, yellow and brown markings.

Male: Abdomen 28.0–30.0, hindwing 30.0–32.0 mm (Fraser 1936; Subramanian 2009), abdn. 27.0, fwing. 28.5, hwing. 27.5 mm (Prasad 1996a, b).

Female: Abdomen 28.0–32.0, hindwing 30.0–32.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan
Thar Desert.

India
Widely distributed – Andhra Pradesh, Assam, Chhattisgarh (Bastar dist.), Delhi, Eastern Ghats, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Tamil Nadu (Coimbatore; Kundah, Nilgiris), Uttarakhand (Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists.), West Bengal and West Coast.

Habitat
Breeds in habitats such as marshes, boggy areas and wet abandoned ricefields.

Conservation Status
IUCN Red List: Least Concern.

11. *Orthetrum pruinosum neglectum* (Rambur, 1842)

English Name
Crimson-Tailed Marsh Hawk.

Description
Male: Face ochreous/reddish-brown, eyes blue-black/bluish-grey, thorax with hairs and reddish-brown/purple, abdomen red/purplish in old,

wings transparent/brownish towards tip in old, pterostigma reddish-brown and legs black/reddish-brown.

Abdomen 28.0–31.0, hindwing 32.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 28.5–30.0, fwing. 34.5–36.0, hwing. 34.0–35.5 mm (Prasad 1996a, b), abdn. 26.5, fwing. 32.5, hwing. 32.0 mm (Prasad 2004b).

Female: Face olivaceous, eyes yellowish with brown, thorax reddish-brown/ochreous with brown stripe, abdomen red/purplish in old and wings with indistinct basal markings.

Abdomen 30.0, hindwing 37.0 mm (Fraser 1936; Subramanian 2009), abdn. 27.0, fwing. 32.0, hwing. 32.0 mm (Prasad 2004b).

Distribution

Rajasthan

Raghunath, Sikar dist.; Pichola Lake, Udaipur; Thar Desert at Osian, Jodhpur; in and around Mount Abu Wildlife Sanctuary and Nikki lake in Mt. Abu, Sirohi district.

India

Bihar, Chhattisgarh (Bastar dist.), Delhi, Eastern Himalaya, Gujarat (Ahmedabad, Pipri and Valsad dists.), Himachal Pradesh (Bilaspur, Hamirpur, Kangra, Kinnaur, Mandi, Sirmour, Solan and Una dists. and Renuka Wetland), Jharkhand (Dhanbad), Punjab (Hoshiarpur dist.), Maharashtra (Sanjay Gandhi National Park and Tadoba Tiger Reserve), Sikkim, Tamil Nadu (Ooty, Nilgiris), Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists. and Rajaji National Park), and West Bengal (Kolkata).

Habitat

Breeds in small tanks and also pools in river beds.

Conservation Status

IUCN Red List: Least Concern.

Remarks

Aside from the nominate subspecies, three other subspecies are recognised. *Orthetrum pruinosum neglectum* is widespread in mainland Asia, *O. pruinosum schneideri* occurs in the Malay peninsular and Borneo and *O. pruinosum clelia* occurs in the Philippines and Taiwan (where *O. p. neglectum* occurs also).

12. *Orthetrum sabina sabina* (Drury, 1770)

English Names

Green Marsh Hawk, Oasis Skimmer, Slender Skimmer.

Description

Slender-bodied pale green or yellowish dragonfly. Easily identified with greenish-yellow and black segmented body. Sexes almost alike.

Male: Face yellowish green; eyes green mottled with black; thorax greenish-yellow with black tiger-like stripes; legs black; inner side of anterior femora yellow; wings transparent, inner edge of hindwing tinted with yellow; wing-spot black with reddish-brown spot; abdomen segments 1–3 green with broad black rings and distinctly swollen at base.

Abdomen 30.0–36.0, hindwing 30.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 33.0–34.5, fwing. 32.0–33.0, hwing. 30.5–32.0 (Prasad 1996a, b), abdn. 32.0–33.0, fwing. 31.0–32.0, hwing. 31.0–31.5 mm (Prasad 2004a), abdn. 30.0–33.0, fwing 30.0, hwing. 29.5–30.0 mm (Prasad 2004b).

Female: Very similar to male.

Abdomen 32.0–35.0 mm, hindwing 31.0–35.0 mm (Fraser 1936; Subramanian 2009), abdn. 32.5–33.5, fwing. 31.0–34.0, hwing. 30.0–35.5 mm (Prasad 1996a, b), abdn. 30.0–34.0, fwing. 30.0–34.5, hwing. 30.0–35.0 mm (Prasad 2004b).

Distribution

Rajasthan

Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Hemawas Dam, Pali dist.; Balsamand, Kuri village and Agolai, Jodhpur dist.; Girab, Barmer dist., Desert National Park; Keoladeo National Park and Noah village, Bharatpur dist.; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India

Throughout Indian subcontinent up to an altitude of 2,000 m/6,562 ft.

Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar (Singhbhum), Chhattisgarh (Bastar dist.), Delhi, Goa, Gujarat (Ahmedabad, Bhuj, Junagadh, Kachchh, Pipri, Surat and Valsad dists.), Haryana, Himachal Pradesh (Bilaspur, Kangra, Sirmour, Solan and Una dists. and Renuka Wetland), Jharkhand (Dhanbad and Singhbhum dists.), Karnataka (Kodagu dist./Coorg) Kerala (Malabar, Thiruvananthapuram), Madhya Pradesh, Maharashtra (Melghat Tiger Reserve, Sanjay Gandhi National Park and Tadoba Tiger Reserve), Manipur, Meghalaya, Nilgiris (2,133.6 m/7,000 ft), Odisha, Punjab (Ferozepur, Hoshiarpur, Ropar and Sangrur dists.), Sikkim, Tamil Nadu (Nilgiris), Tripura, Uttarakhand (Dehra Dun, Nainital and Pauri dists. and Rajaji National Park), Uttar Pradesh (Varanasi) and West Bengal (Kolkata).

Habitat

It occupies a broad range of slow-flowing and still-water habitats, from ponds to wet ricefields and marshes. It is very tolerant of disturbance.

Conservation Status

IUCN Red List: Least Concern.

13. *Orthetrum taeniolatum* (Schneider, 1845)

English Names

Azure Blue Skimmer, Azure Skimmer, Little Skimmer, Small Skimmer.

Description

Abdomen tapers evenly without a 'waist'; length about 35.0 mm.

Male: Covered in a light-blue pruinescence, combining black, brown and beige with two whitish bands on side of thorax. Another useful feature to identify the species is brown colour of top of the eyes.

Abdomen 22.0–25.0, hindwing 25.0–27.0 mm (Fraser 1936), abdn. 23.0–24.0, fwing. 25.0–27.0, hwing. 25.0–26.0 mm (Prasad 2004b).

Female: Without dusty look.

Abdomen 24.0, hindwing 28.0 mm (Fraser 1936), abdn. 20.0, fwing. 26.0, hwing. 25.0 mm (Prasad 1996a, b), abdn. 23.0–24.0, fwing. 25.0–26.5, hwing. 25.5–27.0 mm (Prasad 2004b).

Distribution

Rajasthan

Thar Desert at Osian and Lake Kailana; Mandore, Jodhpur district; in and around Mount Abu Wildlife Sanctuary and Nikki lake in Mt. Abu, Sirohi district; Raghunath, Sikar district; Jawavadam, Ramgarh; Udaipur.

India

Andhra Pradesh, Arunachal Pradesh, Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahwa, Amreli, Pipri, Saputara, Vadodara and Valsad dists.), Himachal Pradesh (Bilaspur, Kangra, Kinnaur and Una dists.), Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Nagaland, Punjab (Gurdaspur and Hoshiarpur dists.), Sikkim, Tamil Nadu, Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists. and Rajaji National Park), West Bengal.

Habitat

Found in medium to slow-moving marshy streams, commonly around open rocky and sandy-bed streams. Breeds side pools of streams during monsoon. Larvae are found in slow-flowing marshy streams.

Conservation Status

IUCN Red List: Least Concern.

14. *Orthetrum triangulare triangulare* (Selys, 1878)

English Name

Blue-Tailed Forest Hawk.

Description

Medium-sized dragonfly with black thorax, black-brown patch at wing base and blue abdomen.

Male: Abdomen 29.0–33.0, hindwing 37.0–41.0 mm (Fraser 1936; Subramanian 2009).

Female: Abdomen 29.0–32.0, hindwing 37.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Up to elevations of 1,200 m/3,937 ft in South Africa and between 800 and 1,890 m. (2,625 and 6,201 ft) in Malawi.

Rajasthan

Thar Desert; in and around Mount Abu Wildlife Sanctuary and Nikki lake in Mt. Abu, Sirohi district.

India

Arunachal Pradesh, Bihar, Haryana, Himachal Pradesh (Bilaspur, Kangra. Kinnaur, Sirmour and Solan dists. and Renuka Wetland), Jammu and Kashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, South India (1,524–2,286 m/5,000–7,500 ft altitude), Tamil Nadu, Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists. and Rajaji National Park), Uttar Pradesh and West Bengal.

Habitat

Usually found in pools, pans, marshes and quite reaches of rivers where it can perch on reeds or tall grass in hilly areas and is tolerant of disturbance. Breeds in small ponds and marshy areas with dense reed vegetation.

Conservation Status

IUCN Red List: Least Concern.

Remarks

Two subspecies are currently recognised, the nominate subspecies and *Orthetrum triangulare malaccense*.

Genus: *Palpopleura* Rambur, 1842

(Subfamily: Palpopleurinae – Widows)

15. *Palpopleura sexmaculata sexmaculata* (Fabricius, 1787)

Popular English Name

Blue-Tailed Yellow Skimmer.

Description

Small-sized dragonfly with greenish-yellow thorax and blue abdomen.

Male: Abdomen 14–16, hindwing 15–21 mm (Fraser 1936; Subramanian 2009).

Female: Abdomen 13–14, hindwing 18–21 mm (Fraser 1936; Subramanian 2009), abdn. 14.0, fwing. 18.5, hwing. 18.0 mm (Prasad 1996a, b).

Distribution

Rajasthan

In and around Mount Abu Wildlife Sanctuary, Sirohi district.

India

Andhra Pradesh, Assam, Bihar, Delhi, Eastern Ghats, Himachal Pradesh (Bilaspur, Hamirpur and Kangra dists.), Karnataka, Punjab (Hoshiarpur dist.), Tamil Nadu (Anaimalai, Shevaroy and Nilgiri hills; Kodagu/Coorg), Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists. and Rajaji National Park) and West Bengal.

Habitat

Breeds in marshy areas and small pools.

Conservation Status

IUCN Red List: Least Concern.

Genus: *Acisoma* Rambur, 1842

(Subfamily: Sympetrinae Tillyard, 1917)

(Darters)

16. *Acisoma panorpoides panorpoides* Rambur, 1842

English Name

Trumpet Tail.

Description

Small-sized blue dragonfly with pale blue face, eyes blue/glossy brown spotted with black, thorax azure-blue, bulged abdomen azure-blue with black stripe above, wings transparent, pterostigma pale yellow and legs black with yellow.

Male: Abdomen 15.0–18.0, hindwing 16.0–21.0 mm (Fraser 1936; Subramanian 2009), abdn. 17.5, fwing. 21.0, hwing. 20.0 mm (Prasad 2004b).

Female: Very similar to male.

Abdomen 15.0–18.0, hindwing 17.0–22.0 mm (Fraser 1936; Subramanian 2009), abdn. 18.0, fwing. 20.5, hwing. 20.0 mm (Prasad 1996a, b), abdn. 18.0, fwing. 21.0, hwing. 20.0 mm (Prasad 2004a), abdn. 16.5, fwing. 20.5, hwing. 20.0 mm (Prasad 2004b).

Distribution

Rajasthan

Pichola Lake, Udaipur; Lake Kailana, Jodhpur; Girab, Barmer dist., Desert National Park; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district; Jaisamand, Alwar dist.

India

Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Chandigarh, Delhi, Gujarat (Ahmedabad dist.), Himachal Pradesh (Kangra and Sirmour dists. and Renuka Wetland), Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab (Hoshiarpur dist.), Sikkim, South India, Uttarakhand (Dehra Dun, Nainital, Pauri and Uttarkashi dists.), Uttar Pradesh and West Bengal (Darjeeling, Jalpaiguri, Kolkata).

Habitat

Swampy and well-vegetated open habitats.

Conservation Status

IUCN Red List: Least Concern.

Threats

Drainage and destruction of swampy habitats may be a potential threat in some parts of its range.

Genus: *Brachythemis* Brauer, 1868
(Subfamily: Sympetrinae Tillyard, 1917)

17. *Brachythemis contaminata* (Fabricius, 1793)

English Name

Ditch Jewel.

Description

Male: Face olivaceous, eyes olivaceous-brown/bluish-grey, thorax olivaceous-brown or reddish-brown with two reddish-brown stripes, abdomen red, wings transparent with reddish venation and a broad orange patch extending from base to rusty pterostigma and legs brown.

Abdomen 18.0–21.0, hindwing 20.0–23.0 mm (Fraser 1936; Subramanian 2009), abdn. 18.0, fwing. 25.0, hwing. 24.0 mm (Prasad 2004b), abdn. 19.0, fwing. 23.5, hwing. 23.0 mm (Prasad 2007).

Female: Face creamy, eyes brown/bluish-grey, thorax greenish-yellow with brown stripe above, abdomen olivaceous-brown with black stripe above and wings transparent without orange patch. Abdomen 18.0–20.0, hindwing 22.0–25.0 mm (Fraser 1936; Subramanian 2009), abdn. 16.0, fwing. 25.0, hwing. 24.5 mm (Prasad 1996a, b), abdn. 15.5, fwing. 24.0, hwing. 23.0 (Prasad 2004b), abdn. 18.0–19.0, fwing 25.0–26.0, 23.0–25.0 (Prasad 2007).

Distribution

Rajasthan

Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Keoladeo National Park, Bharatpur; Jhapog, Sardar Samand and Bhilwara; in and around Mount Abu Wildlife Sanctuary and Nikki lake in Mt. Abu, Sirohi district.

India

Andaman and Nicobar Islands, Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Chhattisgarh (Bastar dist.), Eastern Himalaya, Delhi, Goa, Gujarat (Baruch, Kheda, Surat and Surendranagar dists.), Himachal Pradesh (Bilaspur, Kangra, Sirmour and Una dists. and Renuka Wetland), Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Chandrapur dist., Melghat Tiger Reserve, Osmanabad dist., Sanjay Gandhi National Park, Khandala, Khed and Lonavala, Pune dist. and Tadoba Tiger Reserve), Manipur, Meghalaya, Odisha, Punjab (Hoshiarpur and Ropar dists,), Tamil Nadu (Coomb river, Chennai), Tripura, Uttarakhand (Dehra Dun, Nainital and Pauri dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Kolkata).

Habitat

It inhabits weedy ponds, lakes and slowly moving streams. It is very tolerant of disturbance.

Conservation Status

IUCN Red List: Least Concern.
Genus: *Bradinopyga* Kirby, 1893
(Subfamily: Sympetrinae Tillyard, 1917)

18. *Bradinopyga geminata* (Rambur, 1842)

English Name

Granite Ghost.

Description

Medium-sized grey dragonfly with black and white markings.

Male: Abdomen 26.0–29.0, hindwing 33.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 29.5, fwing. 33.0, hwing. 32.0 mm (Prasad 1996a, b), abdn. 28.0, fwing. 34.0, hwing. 33.0 mm (Prasad 2004a), abdn. 29.0–30.0, fwing. 33.0–34.0, hwing. 33.0 mm (Prasad 2004b), abdn. 27.50, forewing 35.00, hindwing 34.00 mm (Prasad 2007).

Female: Abdomen 26.0–29.0, hindwing 32.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 28.0, fwing. 34.5, hwing. 34.0 mm (Prasad 2004b).

Distribution

At around 457.2 m/1,500 ft altitude in Peninsular India.

Rajasthan

Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana and Pataudi House, Paota, Jodhpur dist.; Barna, Jaisalmer dist., Desert National Park; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India

Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Chhattisgarh (Bastar dist.), Delhi, Eastern Himalaya, Gujarat (Bhuj, Kachchh and Kheda dists.), Haryana, Himachal Pradesh, Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Ambenali, Satara dist., Chandrapur dist., Melghat Tiger Reserve, Sanjay Gandhi National Park and Tadoba Tiger Reserve), Odisha, Peninsular India, Tamil Nadu, Tripura, Uttarakhand (Dehra Dun and Nainital dists.), Uttar Pradesh and West Bengal (Kolkata).

Habitat

Adults are common along small pools of water or small stagnant water bodies nearby agricultural fields. They also breed in wells, tanks, drums, rainy hollows in the rocks and invariably settling with wings flattened on the granite face, with which their marbled grey-coloured body harmonies to such an extent that they become practically invisible.

Conservation Status

IUCN Red List: Least Concern.

Threats

No information is available.
Genus: *Crocothemis* Brauer, 1868
(Subfamily: Sympetrinae Tillyard, 1917)

19. *Crocothemis servilia servilia* (Drury, 1773)

English Names

Oriental Scarlet, Ruddy Marsh Skimmer.

Description

Medium-sized blood red or reddish-yellow dragonfly with amber-coloured patch at base of wings.

Male: Face blood red, eyes blood red above purple on sides, thorax blood red to orange, abdomen blood red with mid-dorsa carina blackish on last few segments, anal appendage blood red, wings transparent with base marked rich amber-yellow, pterostigma brown and legs reddish. Whitish lines on thorax, whitish surround to face and dusky tips on wings in subadult.

Abdomen 24.0–35.0, hindwing 27.0–38.0 mm (Fraser 1936), abdn. 21.0–22.0, fwing. 26.0–27.0, hwing. 25.0–26.0 mm (Prasad 1996a, b), abdn. 24.0–27.0, fwing. 29.0–31.0, hwing. 28.0–30.5 mm (Prasad 2004a), abdn. 28.0–28.5, fwing. 33.5–34.0, hwing. 32.0 mm (Prasad 2004b), abdn. 24.0–25.0, hwing. 27.0–38.0 (Subramanian 2009).

Female: Face pale yellow, eyes brown/olivaceous, thorax brown, abdomen yellowish-brown with black stripe above, wings transparent with basal amber marking paler, pterostigma pale yellow and legs brown.

Abdomen 25.0–32.0, hindwing 31.0–37.0 mm (Fraser 1936; Subramanian 2009), abdn. 21.0–22.0, fwing. 26.5–27.7, hwing. 25.0–25.5 mm (Prasad 1996a, b), abdn. 22.0–26.0, fwing. 27.0–29.5, hwing. 26.0–29.0 mm (Prasad 2004a), abdn. 22.0–23.0, fwing. 29.0, hwing. 28.5–29.5 mm (Prasad 2004b).

Distribution

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Ajmer, Gudha-Bhilwara dist. and Jodhpur; Girab, Barmer dist., Sam area and Sudasari, Jaisalmer dist., Desert National Park; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Throughout India – Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahmedabad, Ahwa, Baruch, Bhuj, Jamnagar, Junagadh, Kachchh, Pipri, Saputara and Valsad dists.), Haryana (Hissar), Eastern Himalaya, Himachal Pradesh (Kangra dist. and Renuka Wetland), Western Himalaya, Goa, Jharkhand (Dhanbad and Singhbhum dists.), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Colaba, Mumbai; Gondhonkher, Buldhana dist., Khed and Lone, Pune dist., Matheran, Raigad dist., Upla, Melghat Tiger Reserve, Osmanabad dist., Sanjay Gandhi National Park and Tadoba Tiger Reserve), Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Punjab (Amritsar, Ferozepur, Gurdaspur, Hoshiarpur, Ropar and Sangrur dists.), Sikkim, South India, Tamil Nadu, Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri and Pithoragarh dists. and Rajaji National Park), Uttar Pradesh (Varanasi) and West Bengal (Kolkata).

Habitat
Occurs in natural and man-made habitats, breeds in ponds, ditches, marshes and open swamps.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Diplacodes* Kirby, 1889
(Subfamily: Sympetrinae Tillyard, 1917)

20. *Diplacodes lefebvrii* (Rambur, 1842)

English Names
Black Ground Percher, Black Percher, Purple Darter.

Description
Small-sized black dragonfly with smoky-brown wing tips.

Male: Abdomen 17.0–25.0, hindwing 21.0–29.0 mm (Fraser 1936; Subramanian 2009), fwing. 22.0, hwing. 21.0 (Prasad 1996a, b).

Female: Abdomen 14.0–18.0, hindwing 18.0–23.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan
Thar Desert; Keoladeo National Park, Bharatpur; Lake Kailana, Akhairaj ji ka Talao, Kuri village, Agolgi and Agolai, Jodhpur dist.; Bara Talab and Hemawas dam, Pali dist.

India
Chandigarh, Chhattisgarh (Bastar dist.), Delhi, Kerala, Gujarat, Madhya Pradesh, Maharashtra, Uttarakhand and West Coast (Fraserpet, Coorg).

Habitat
Almost all kinds of well-vegetated freshwater habitats, including seasonal.

Conservation Status
IUCN Red List: Least Concern.

Threats
Drainage and destruction of swampy habitats.

21. *Diplacodes nebulosa* (Fabricius, 1793)

English Name
Black-Tipped Ground Skimmer.

Description
Small-sized greenish-yellow and black dragonfly with black-tipped transparent wings.

Male: Abdomen 15.0–17.0, hindwing 17.0–19.0 mm (Fraser 1936; Subramanian 2009), abdn. 16.0, fwing. 20.0, hwing. 19.0 mm (Prasad 1996a, b).

Female: Abdomen 14.0–15.0, hindwing 18.0 mm (Fraser 1936; Subramanian 2009), abdn. 12.0, fwing. 16.0, hwing. 15.0 mm (Prasad 1996a, b).

Distribution

Rajasthan
Thar Desert; Lake Kailana and Balsamand, Jodhpur dist.

India
Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Haryana, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Punjab (Amritsar dist.), Sikkim, Tamil Nadu, Uttarakhand (Dehra Dun and Nainital dists.), Uttar Pradesh and West Bengal (Kolkata).

Habitat
It is found at marshes, well-vegetated ponds and lake shores.

Conservation Status
IUCN Red List: Least Concern.

22. *Diplacodes trivialis* (Rambur, 1842)

English Name
Ground Skimmer.

Description
Small-sized greenish-yellow or blue dragonfly with black markings.

Male: Abdomen 19.0–22.0, hindwing 22.0–23.0 mm (Fraser 1936; Subramanian 2009), abdn. 19.0–20.5, fwing. 23.0–24.0, hwing. 21.0–22.0 mm (Prasad 1996a, b), abdn. 20.0, fwing. 23.0–24.0, hwing. 22.0 mm (Prasad 2004b).

Female: Abdomen 18.0–20.0, hindwing 22.0–24.0 mm (Fraser 1936; Subramanian 2009), abdn. 18.0–19.5, fwing. 23.0–24.0, hwing. 20.5–21.0 mm (Prasad 1996a, b), abdn. 19.0–19.5, fwing. 23.5–24.0, hwing. 21.0–21.5 mm (Prasad 2004b).

Distribution

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian, Jodhpur; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Andaman and Nicobar Islands, Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahwa, Jamnagar and Junagadh dists.), Eastern Himalaya, Goa, Himachal Pradesh (Kangra dist.), Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Punjab (Hoshiarpur dist.), Sikkim, Tamil Nadu, Tripura, Uttarakhand (Dehra Dun and Nainital dists.), Uttar Pradesh and West Bengal (Kolkata).

Habitat
It breeds in ponds, wet ricefields, shallow lakes, drainage ditches and similar habitats.

Conservation Status
IUCN Red List: Least Concern.

Threats
There are likely to be local threats arising from the loss of wetlands due to agriculture and developmental activities. Not threatened at present.
Genus: *Neurothemis* Brauer, 1867
(Subfamily: Sympetrinae Tillyard, 1917)

23. *Neurothemis fulvia* (Drury, 1773)

English Name
Fulvous Forest Skimmer

Description
Medium-sized rusty (reddish-brown)-coloured dragonfly with transparent wing tips.

Male: Face reddish-brown, eyes dark reddish-brown/golden-brown, thorax and abdomen reddish-brown, wings opaque with dark reddish-brown with transparent tips, pterostigma dark reddish-brown, legs dark reddish-brown.

Abdomen 21.0–26.0, hindwing 27.0–32.0 mm (Fraser 1936; Subramanian 2009), abdn. 24.5, fwing. 31.0, hwing. 30.0 mm (Prasad 1996a, b).

Female: Head, thorax and abdomen paler than that of male or rusty brown, wings clear amber-yellow with a dark stripe extending to tip in forewing.

Abdomen 20.0–24.0, hindwing 26.0–32.0 mm (Fraser 1936; Subramanian 2009), abdn. 24.0, fwing. 30.5, hwing. 30.0 mm (Prasad 1996a, b).

Distribution
Up to altitude of 914.4 m/3,000 ft.

Rajasthan
Thar Desert.

India
Arunachal Pradesh, Assam, Chhattisgarh (Bastar dist.), Deccan plateau, Delhi, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Jharkhand, Karnataka, Kerala (Malabar), Madhya Pradesh, Maharashtra (Moolah Canal/pools in the neighbouring Bhairoba Nala, Pune), Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Punjab, Tamil Nadu, Tripura, Uttarakhand (Dehra Dun and Nainital dists. and Rajaji National Park) and West Bengal (Darjeeling).

Habitat
Breeds in weedy ponds, reservoirs and marshes and in agricultural or open fields and occupies a broad altitudinal range.

Conservation Status
IUCN Red List: Least Concern.

24. *Neurothemis intermedia intermedia* (Rambur, 1842)

English Name
Ruddy Meadow Skimmer.

Description
Medium-sized red dragonfly with a broad amber patch at base of wings.

Male: Abdomen 22–24, hindwing 24–27 mm (Fraser 1936; Subramanian 2009), abdn. 23.0–24.0, fwing. 25.0–27.5, hwing. 24.5–27.0 mm (Prasad 1996a, b), abdn. 23.5, fwing. 26.0, hwing. 26.0 mm (Prasad 2004b).

Female: Abdomen 21–24, hindwing 25–28 mm (Fraser 1936; Subramanian 2009), abdn. 22.0–24.0, fwing. 25.0–28.0, hwing. 24.0–27.5 mm (Prasad 1996a, b), abdn. 23.0, fwing. 25.5, hwing. 25.0 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert.

India
Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Deccan, Eastern Himalaya, Himachal Pradesh (Kangra dist.), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Pune, Mahabaleshwar and Mumbai), Manipur, Meghalaya, Mizoram, Odisha, Punjab (Hoshiarpur dist.), Sikkim, Tamil Nadu, Tripura, Uttarakhand (Dehra Dun dist. and Rajaji National Park), Uttar Pradesh and West Bengal.

Habitat
It breeds in a variety of standing water habitats.

Conservation Status
IUCN Red List: Least Concern.

25. *Neurothemis tullia tullia* (Drury, 1773)

English Name
Pied Paddy Skimmer.

Description
Both sexes differ significantly in colouration as under:

Male: Face black, eyes blackish/brown, thorax black with creamy stripe, wing bases opaque blue-black bordered by milky-white patch with transparent tips, pterostigma brownish, abdomen black with creamy stripe above, legs black.

Abdomen 16.0–20.0, hindwing 19.0–23.0 mm (Fraser 1936; Subramanian 2009), abdn. 19.5, fwing. 24.0, hwing. 23.0 mm (Prasad 1996a, b), abdn. 19.0, fwing. 24.0, hwing. 24.0 mm (Prasad 2004b).

Female: Face olivaceous-yellow, eyes brownish/olivaceous, thorax greenish-yellow with yellowish stripe (bordered with black) above, wing bases amber-yellow, pterostigma brownish, legs yellow/black.

Abdomen 16.0–19.0, hindwing 20.0–23.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan
Thar Desert; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Bihar, Chhattisgarh (Bastar dist.), Deccan, Delhi, Eastern Himalaya, Gujarat (Surat dist.), Himachal Pradesh (Kangra, Sirmour and Una dists. and Renuka Wetland), Karnataka, Kerala (Malabar), Madhya Pradesh, Maharashtra (Mumbai), Peninsular India, Punjab (Hoshiarpur dist.), Uttarakhand (Dehra Dun dist.), Tamil Nadu (Chennai; Kodagu/Coorg), West Bengal and West Coast.

Habitat
It breeds in marshes, well-vegetated ponds and lake margins and ricefields.

Conservation Status
IUCN Red List: Least Concern.

Threats
There do not appear to be any global threats to this very widespread and common species at present.
Genus: *Tetrathemis* Brauer, 1868
(Subfamily: Tetrathemistinae Tillyard, 1917)

26. *Tetrathemis platyptera* Selys, 1878

Popular English Name
Pigmy Skimmer.

Description
Small-sized, large-headed black and yellow dragonfly with amber-coloured patch on hindwing.

Male: Distinct in yellow and black markings and vivid turquoise eyes, yellow base on hindwings. Abdomen 15.0–18.0, hindwing 18.0–21.0 mm (Fraser 1936; Subramanian 2009), fwing. 20.5, hwing. 20.0 mm (Prasad 2004b).

Female: Abdomen 14.0–16.0, hindwing 19.0–24.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan
Thar Desert.

India
Andhra Pradesh, Gujarat (Pipri dist.), Karnataka (Chandagal, Mysore), Kerala (Malabar, Thiruvithamcoor/Travancore, Thiruvananthapuram), Uttarakhand and Tamil Nadu (Anaimalai, Kodagu/Coorg, Nilgiris), Uttarakhand (Dehra Dun and Nainital dists.).

Habitat
It breeds in pools in forest, including secondary forest.

Conservation Status
IUCN Red List: Least Concern.

Threats
Habitat loss through forest clearance for agricultural and timber crops is a potential threat to viable habitat of this species.
Genus: *Hydrobasileus* Kirby, 1889
(Subfamily: Trameinae Tillyard, 1917)

27. *Hydrobasileus croceus* (Brauer, 1867)

English Name

Amber-Winged Marsh Glider.

Description

Large dragonfly with transparent rusty wings.

Male: Abdomen 29–33, hindwing 40–42 (Fraser 1936; Subramanian 2009).

Female: Abdomen 28–34, hindwing 42–48 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan

Thar Desert.

India

Eastern India, Andhra Pradesh, Assam, Karnataka (Kodagu/Coorg), Kerala (Malabar), Maharashtra (Khandala; Mumbai), Meghalaya, Odisha and Western Ghats.

Habitat

It breeds in weedy ponds and lakes.

Conservation Status

IUCN Red List: Least Concern.

Genus: *Pantala* Hagen, 1861

(Subfamily: Trameinae Tillyard, 1917)

28. *Pantala flavescens* (Fabricius, 1798)

English Names

Globe Skimmer, Globe Wanderer, Wandering Glider.

Description

Medium-sized dragonfly with rusty thorax and yellow abdomen.

Male: Face bright golden-yellow or orange, eyes reddish-brown/bluish-grey, thorax olivaceous or rusty and is coated thickly with fine yellowish hair, pale green or bluish-green on sides, wings transparent and base of hindwing amber-yellow, pterostigma reddish-brown, abdomen reddish-brown and tinted with brick red above with black spots above last few segments, legs black. Abdomen 29.0–35.0, hindwing 38.0–40.0 mm (Fraser 1936; Subramanian 2009), abdn. 32.05, fwing. 42.0, hwing. 41.5 mm (Prasad 1996a, b), abdn. 30.0–31.5, fwing. 38.0–39.0, hwing. 38.0 mm (Prasad 2004a), abdn. 30.0–33.0, fwing. 41.0–42.5, hwing. 40.0–41.5 mm (Prasad 2004b).

Female: Very similar to the male, eyes olivaceous-brown above and wings smoky, abdomen without red colouration as found in males.

Abdomen 30.0–33.0, hindwing 39.0–41.0 mm (Fraser 1936; Subramanian 2009), abdn. 32.0, fwing. 42.0, hwing. 41.0 mm (Prasad 1996a, b), abdn. 30.0–32.0, fwing. 39.0–40.0, hwing. 38.5–40.0 mm (Prasad 2004a), abdn. 32.0, fwing. 42.0, hwing. 41.0 mm (Prasad 2004b).

Distribution

Circumtropical and subtropical, found up to 5,486.4 m/18,000 ft.

Rajasthan

Thar Desert; Girab, Barmer dist., Desert National Park; Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Pataudi House, Paota and Kuchaman road, Jodhpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India

Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahwa, Baruch, Jamnagar and Mehsana, Pipri, Surat and Valsad dists.), Goa, Himachal Pradesh, Jammu and Kashmir, Jharkhand (Dhanbad), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Meghalaya, Odisha, Punjab (Hoshiarpur dist.), Tamil Nadu (south-east), Uttarakhand (Dehra Dun, Nainital, Pauri and Pithoragarh dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Kolkata).

Habitat

It occurs in a variety of habitats, especially temporary pools, also found deep into arid areas. It is an obligatory seasonal migrant that follows the rain-fronts of the Intertropical Convergence Zone. It can complete its life cycle in two months, from a newly laid egg to an emerging adult.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Rhyothemis* Hagen, 1867
(Subfamily: Trameinae Tillyard, 1917)

29. *Rhyothemis variegata variegata* (Linnaeus, 1763)

English Name
Common Picture Wing.

Description
Medium-sized dragonfly with butterfly-like yellow and brown wing.

Male: Abdomen 23.0–25.0, hindwing 33.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 24.0, fwing. 52.0, hwing. 32.0 mm (Prasad 1996a, b).

Female: Abdomen 20.0–22.0, hindwing 28.0–37.0 mm (Fraser 1936; Subramanian 2009).

Distribution

Rajasthan
Pichola Lake, Udaipur; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district; Thar Desert.

India
Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Dadra and Nagar Haveli, Daman and Diu, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karaikal, Karnataka (Bangalore), Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Puducherry (Mahe, Yanam), Punjab, Sikkim, Tamil Nadu, Tripura, Uttarakhand (Dehra Dun dist.), Uttar Pradesh, West Bengal (Darjeeling).

Elsewhere
Bangladesh, Cambodia, Hong Kong, Laos, Malaysia, Myanmar (main), Nepal, Sri Lanka and Thailand.

Habitat
It is found in ponds, lakes, reservoirs, marshes, paddy fields, irrigation canals etc.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Tholymis* Hagen, 1867
(Subfamily: Trameinae Tillyard, 1917)

30. *Tholymis tillarga* (Fabricius, 1798)

English Names
Coral-Tailed Cloud Wing, Crepuscular Darter, Evening Skimmer, Foggy-Winged Twister, Old World Twister, Twister.

Description
Medium-sized red dragonfly with brown and white patch on hindwing.

Male: Abdomen 28.0–33.0, hindwing 33.0–37.0 mm (Fraser 1936; Subramanian 2009), abdn. 30.0, fwing. 34.5, hwing. 34.0 mm (Prasad 1996a, b).

Female: Abdomen 27.0–31.0, hindwing 31.0–37.0 mm (Fraser 1936; Subramanian 2009), abdn. 26.0, fwing. 31.5, hwing. 31.0 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert; in and around Mount Abu Wildlife Sanctuary, Sirohi district; Jodhpur; Kumbhalgarh Wildlife Sanctuary.

India
Chhattisgarh (Bastar dist.), Delhi, Gujarat (Surat dist.), Himachal Pradesh, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Punjab (Hoshiarpur dist.), Uttarakhand (Dehra Dun dist.), Uttar Pradesh and West Bengal.

Habitat
It is very common across much of south-east Asia and locally very common in southern Africa; moreover it is under-recorded due to its crepuscular behaviour.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Tramea* Hagen, 1861
(Subfamily: Trameinae Tillyard, 1917)

31. ***Tramea basilaris burmeisteri*** **(Palisot de Beauvois, 1805)**

English Names
Keyhole Glider, Red Marsh Trotter, Wheeling Glider.

Description
Medium-sized red or yellow dragonfly with brown and yellow patches on hindwings.

Male: Abdomen 30.0–35.0, hindwing 40.0–44.0 mm (Fraser 1936; Subramanian 2009).

Female: Abdomen 32.0–36.0, hindwing 38.0–45.0 mm (Fraser 1936; Subramanian 2009), abdn. 32.0–33.0, fwing. 42.0–43.0, hwing. 41.0–42.0 mm (Prasad 1996a, b).

Distribution
Seen up to altitude over 2,133.6 m/7,000 ft (in Nilgiris).

Rajasthan
Thar Desert; Keoladeo National Park, Bharatpur; Mandore gardens nr. Jodhpur.

India
Andhra Pradesh (Kolleru Lake), Bihar, Chhattisgarh (Bastar dist.), Deccan, Delhi, Haryana (Hissar), Jharkhand (Dhanbad), Kerala (Kollam, Marayur), Madhya Pradesh (Sagar dist.), Maharashtra (Karnala Bird Sanctuary, Panvel, nr Mumbai), Meghalaya, Odisha, Punjab (Hoshiarpur dist.), Tamil Nadu (Nilgiris), Uttarakhand, Uttar Pradesh and West Bengal (Kolkata).

Habitat
It is known to breed in ponds and marshes.

Conservation Status
IUCN Red List: Least Concern.

Threats
Presently no significant global threats although it may be under threat from habitat loss in the future.

Remarks
An extremely widespread species, occurring throughout Africa and extending into Iran, India and Sri Lanka, Nepal, Myanmar and Thailand. Also recognised as two subspecies, *T. basilaris basilaris* (Beauvais, 1817) and *T. basilaris burmeisteri* Kirby, 1889 (from India, Malaysia, Myanmar, Nepal, Oriental region and Sri Lanka).

32. ***Tramea virginia*** **(Rambur, 1842)**

English Name
Olive Marsh Trotter.

Description
Male: Face olivaceous, eyes reddish-brown/lilaceous, thorax olivaceous-green, abdomen brick red and marked with black/reddish spot, anal appendage black/red, wings hyaline with reddish reticulation at basal half and tinted with amber-yellow, base of forewing tinted with golden amber, base of hindwing with a brunt-brown or reddish-brown mark, pterostigma blackish-brown and legs black or reddish-brown.

Abdomen 34.0–37.5, hindwing 43.0–49.0 mm (Fraser 1936), abdn. 34.0, fwing. 43.0, hwing. 42.5 mm (Prasad 1996a, b).

Female: Differs only basal marking on hindwing in a large indentation on basal side cutting into two spots, anal appendage black, straight and very narrow.

Abdomen 35.0, hindwing 49.0 mm (Fraser 1936), abdn. 34.0, fwing 49.5, hwing. 48.5 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Bihar, Chhattisgarh (Bastar dist.), Gujarat (Ahmedabad dist.), Himachal Pradesh (Kangra dist.), Jammu and Kashmir, Tamil Nadu, Uttarakhand (Dehra Dun dist.), Uttar Pradesh and West Bengal.

Habitat
It breeds in ponds and lakes.

Conservation Status
IUCN Red List: Least Concern.

Threats
There appear to be no significant threats to this species at present.
Genus: *Zyxomma* Rambur, 1842
(Subfamily: Trameinae Tillyard, 1917, Gliders)

33. *Zyxomma petiolatum* Rambur, 1842

English Name
Brown Dusk Hawk, Long-Tailed Dusk Darter.

Description
Large-sized brown dragonfly with long and thin abdomen and brown-tipped wings.

Male: Abdomen 37.0–42.0, hindwing 32.0–35.0 mm (Fraser 1936), abdn. 37.0–42.0, hwing. 32.0–35.0 mm (Subramanian 2009).

Female: Abdomen 37.0–42.0, hindwing 32.0–38.0 mm (Fraser 1936; Subramanian 2009).

Distribution
Found above 914.4 m/3,000 ft.

Rajasthan
Thar Desert.

India
Throughout. Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Goa, Karnataka, Kerala, Laccadive Islands, Maharashtra (Pune, Mumbai), Puducherry (Mahe), Tamil Nadu (Chennai, Kodagu/Coorg, Kallar-Nilgiris), Uttarakhand (Dehra Dun dist.) and West Bengal.

Habitat
It breeds in small stagnant pools, ponds, swamp forest and slow-flowing rivers.

Conservation Status
IUCN Red List: Least Concern.

Genus: *Trithemis* Brauer, 1868
(Subfamily: Trithemistinae Tillyard, 1917)

34. *Trithemis aurora* (Burmeister, 1839)

English Name
Crimson Marsh Glider.

Description
Male: Head reddish-brown/reddish, eyes crimson/brown, thorax red with purple, abdomen crimson with a tinge of violet, wing base with a broad patch of amber, pterostigma reddish-brown and legs black.

Abdomen 21.0–29.0, hindwing 24.0–34.0 mm (Fraser 1036; Subramanian 2009), abdn. 23.0–24.0, fwing. 24.0–25.5, hwing. 24.0 mm (Prasad 1996a, b), abdn. 23.0–28.0, fwing. 25.0–26.5, hwing. 25.0–26.0 mm (Prasad 2004b), abdn. 23.0, fwing. 28.0, hwing. 27.0 mm (Prasad 2007).

Female: Head olivaceous/reddish-brown, eyes purplish-brown/grey, thorax olivaceous with brown and black stripes, abdomen reddish-brown with black markings, pterostigma brown and legs grey with yellow stripes.

Abdomen 19.0–27.0, hindwing 24.0–31.0 mm (Fraser 1936), abdn. 23.0–27.0, fwing. 25.0–27.0, hwing. 25.0–27.0 mm (Prasad 2007), abdn. 19.0–27.0, hwing. 24.0 mm (Subramanian 2009).

Distribution
Up to about 1,219.2 m/4,000 ft altitude.

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Jodhpur, and Mandore Jodhpur district; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Dadra and Nagar Haveli, Daman and Diu, Delhi, Goa, Gujarat (Jamnagar and Junagadh, Pipri, Surat and Vasad

dists.), Haryana, Himachal Pradesh (Bilaspur, Hamirpur and Kangra dists. and Renuka Wetland, Sirmour dist.), Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Manipur, Meghalaya, Mizoram, Odisha, Puducherry (Karaikal, Mahe), Punjab (Hoshiarpur dist.), Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh (Dehra Dun, Nainital, Pauri, Pithoragarh and Tehri dists. and Rajaji National Park), West Bengal (Darjeeling) and Western Ghats.

Habitat
It uses diverse wetland habitats such as ponds, lakes, marshes, wet paddy fields, streams, rivers and irrigation canals.

Conservation Status
IUCN Red List: Least Concern.

Remarks
Trithemis adelpha Selys, 1878, known from the Philippines, is sometimes considered to be a junior synonym of *T. aurora*, which also occurs in the Philippines.

35. *Trithemis festiva* (Rambur, 1842)

English Name
Black Stream Glider, Indigo Dropwing.

Description
Dark blue, orange streaks on abdomen, without dark wing tips (distinguishing from *Indothemis limbata* Selys, 1891).

Male: Abdomen 22.0–28.0, hindwing 26.0–32.0 mm (Fraser 1936; Subramanian 2009), abdn. 24.5, fwing. 28.0, hwing. 28.0 mm (Prasad 1996a, b), abdn. 24.0–25.0, fwing. 28.0, hwing. 27.0–27.5 mm (Prasad 2004b).

Female: Abdomen 21.0–24.0, hindwing 24, 0–29.0 mm (Fraser 1936), abdn. 22.0, fwing. 27.0, hwing. 26.0 mm (Prasad 1996a, b), abdn. 21.5–23.5, fwing. 26.0, hwing. 25.0–25.5 mm (Prasad 2004b), abdn. 21.0–24.0, hwing. 29.0 mm (Subramanian 2009),

Distribution
Common in plains.

Rajasthan
Thar Desert; Fateh Sagar and Pichola Lakes, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India
Andhra Pradesh (Waltair), Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Eastern Himalaya, Gujarat (Pipri, Saputara and Valsad dists.), Himachal Pradesh (Bilaspur, Hamirpur, Kangra, Sirmour and Solan dists. and Renuka Wetland), Karnataka, Kerala (Idamalayar, near Edamalayar Dam; Malabar), Madhya Pradesh, Maharashtra (Bordharan and Wanarvira, Wardha dist., Buldhana dist., Chandrapur dist., Colaba, Mumbai; Khandala and Khed, Pune; Lingmala falls, Mahabaleshwar; Matheran and Poladpur, Raigad dist., Melghat Tiger Reserve; Rajapur, Ratnagiri dist., Sanjay Gandhi National Park and Tadoba Tiger Reserve), Manipur, Meghalaya, Mizoram, Odisha, Punjab (Gurdaspur dist.), Tripura, Tamil Nadu (East Coast of Chennai, Waltair), Uttarakhand (Chamoli, Dehra Dun, Nainital, Pauri, Pithoragarh, Tehri and Uttarkashi dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Kolkata).

Habitat
It breeds in still waters or more commonly in streams with sluggish current.

Conservation Status
IUCN Red List: Least Concern.

Remarks
It is sometimes confused with *Indothemis limbata* Selys, 1891 (a Cambodian and Malaysian sp.) but can be distinguished from it in having dark wing tips. In size and behaviour it is quite similar to more widely distributed *Trithemis annulata*, the Violet Dropwing, but its habitat preference and looks are very different.

36. *Trithemis kirbyi kirbyi* Selys, 1891

English Names

Kirby's Dropwing, Orange Darter, Orange-Winged Dropwing, Scarlet Rock Glider, Rock Dropwing.

Description

Medium-sized bright red dragonfly with amber or reddish-yellow wing base, thorax and abdomen bright vermilion red, a broad basal bright reddish-yellow marking on all wings, pterostigma black with a narrow red stripe at its middle, venation yellow.

Male: Bright red.

Abdomen 21.0–24.0, hindwing 24.0–27.0 mm (Fraser 1936,; Subramanian 2009), abdn. 24.0, fwing. 27.5, hwing. 27.0 mm (Prasad 1996a, b), abdn. 24.0–25.0, fwing. 28.0, hwing. 27.0–27.5 mm (Prasad 2004b).

Female: Yellowish-brown.

Abdomen 23.0, hindwing 26.0–30.0 mm (Fraser 1936; Subramanian 2009), abdn. 21.5–23.5, fwing. 26.0, hwing. 25.0–25.5 mm (Prasad 2004b).

Distribution

Rajasthan

Thar Desert at Osian, Jodhpur; Pichola lake, Udaipur; in and around Mount Abu Wildlife Sanctuary, Sirohi district.

India

Chhattisgarh (Bastar dist.), Delhi, Gujarat (Amreli dist.), Himachal Pradesh (Kangra dist.), Karnataka, Maharashtra, Peninsular India, Punjab (Hoshiarpur dist.), Tamil Nadu and Uttarakhand (Dehra Dun dist.).

Habitat

Streams, rivers and pools in savanna, woodland or bushes.

Conservation Status

IUCN Red List: Least Concern.

Remarks

In Arabia they are intermediate between those of the type locality of India and the South African subspecies *T. kirbyi ardens* (Gerstaecker, 1891), the Rock Downwing.

37. *Trithemis pallidinervis* (Kirby, 1889)

English Name

Dancing Dropwing, Long-Legged Marsh Skimmer.

Description

Yellowish-brown medium sized with long, spiderlike legs, thorax with three black stripes on each side and black underside of abdomen. Male and female having similar markings.

Male: Metallic purple.

Abdomen 28.0–32.0, hindwing 30.0–36.0 mm (Fraser 1936; Subramanian 2009), abdn. 27.0–32.5, fwing. 30.0–35.0, hwing. 30.0–34.0 mm (Prasad 1996a, b).

Female: Yellowish-white.

Abdomen 26.0–28.0, hindwing 30.0–32.0 mm (Fraser 1936; Subramanian 2009), abdn. 26.0–29.0, fwing. 30.0–34.0, hwing. 30.0–34.0 mm (Prasad 1996a, b), abdn. 26.5, fwing. 33.5, hwing. 32.5–33.0 mm (Prasad 2004b).

Distribution

Rajasthan

Thar Desert at Osian, Lake Kailana, Takhat Sagar and Bijolai, Jodhpur; Pichola Lake, and Fateh Sagar, Udaipur; Keoladeo National Park, Bharatpur; in and around Mount Abu Wildlife Sanctuary, Sirohi district; Hemawas Dam, Pali dist.; Chittorgarh; Gape Sagar, Dungarpur; Noah village, Bharatpur dist.

India

Andaman and Nicobar Islands. Andhra Pradesh (Himayat Sagar Lake, Hyderabad), Assam, Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Dadra and Nagar Haveli, Daman and Diu, Delhi, Eastern Himalaya, Goa, Gujarat (Kheda dist.), Haryana (Hissar), Himachal Pradesh (Kangra dist. and Renuka Wetland, Sirmour dist.), Jammu and Kashmir, Jharkhand, Karaikal, Karnataka (Kodagu/Coorg), Kerala (Malabar), Madhya Pradesh, Maharashtra (Pune, Mahabaleshwar, Mumbai and Khandala), Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Puducherry (Mahe and Yanam dist.), Punjab (Hoshiarpur and Ropar dists.), Sikkim, Tamil Nadu (Chennai), Tripura, Uttarakhand (Dehra Dun, Nainital, and Pauri dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Darjeeling).

Habitat

It breeds in marshes, ponds, lakes etc. In parts of its range, it appears to be a pioneer species, colonising new created ponds and wetlands. It is tolerant of disturbance.

Conservation Status

IUCN Red List: Least Concern.
Genus: *Selysiothemis* Ris, 1897
(Subfamily: Urothemistinae Lieftinck, 1954)

38. *Selysiothemis nigra* (Vander Linden, 1825)

English Names

Black Pennant, Desert Darter.

Description

Big body and head, whitish pale, clear and shiny wings (veins difficult to locate). As flutter its wings in breeze and hence the name 'Pannant'. The species' most distinguishing features are the size of the wings (they're very large and broad for such a small dragonfly) and the shape of the pterostigma, which resembles an equals sign.

Male: Uniformly black, although they do develop a whitish pruinescence on their thorax and abdomen.

Abdomen 21.0–23.0, hindwing 25.0–29.0 mm (Fraser 1936).

Females and immature males have a yellowish-brown or sandy-brown thorax and abdomen with extensive black markings.

Abdomen 11.0–20.0, hindwing 22.0–26.0 mm (Fraser 1936), abdn. 18.0, fwing. 22.0–25.0, hwing. 21.5–24.0 mm (Prasad 2004a).

Distribution

Rajasthan

Thar Desert; Sam area, Jaisalmer dist., Desert National Park; Jodhpur; Kaylana lake.

India

Jammu and Kashmir.

Habitat

It is mostly confined to shallow standing waters that are unshaded. It is a strong migrant and probably has a short larval phase which allows it to reproduce in ephemeral (short-lived) water bodies.

Conservation Status

IUCN Red List: Least Concern.

Threats

Developmental activities could be a threat to the species, but being adapted to reproduce in ephemeral water conditions will therefore be less impacted by climate change than other species.

Remarks

The most distinguishing features of the species are the size of the wings (very large and broad for such a small dragonfly) and the shape of the pterostigma, which resembles an equals (=) sign.
Suborder: Zygoptera
Family: Chlorocyphidae Cowley, 1937
Genus: *Libellago* Selys, 1840

39. *Libellago lineata lineata* (Burmeister, 1839)

English Name

River Heliodor.

Description

Small-sized black and yellow damselfly with black-tipped transparent wings.

Male: Beautifully marked with yellow-orange and black with white-stockinged leg.

Abdomen 15.0, hindwing 17.0 mm (Fraser 1934), abdn. 15.0, fwing. 16.5, hwing. 16.5 mm (Prasad 1996a, b), abdn. 13.0–17.0, hwing. 17.0–20.0 mm (Subramanian 2009).

Female: Paler and more greenish in colour.

Abdomen 13.0–16.0, hindwing 18.0–22.0 mm (Fraser 1934), abdn. 14.5–15.0, fwing. 16.0, hwing. 15.5–16.0 mm (Prasad 1996a, b), abdn. 13.0–17.0, hwing. 17.0–20.0 mm (Subramanian 2009).

Distribution

Rajasthan
Dandi River, Dungarpur; vide 'the IUCN Red List of Threatened Species 2012.2'.

India
Arunachal Pradesh, Assam (Cachar), Chhattisgarh (Bastar dist.), Himachal Pradesh, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Tripura, Uttarakhand (Dehra Dun, Nainital and Pauri dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Darjeeling and Jalpaiguri).

Habitat
It is found in lowland streams and rivers, comparatively open habitats in vicinity of clear streams or rivers. In Thailand at least it occurs on streams in agricultural land.

Conservation Status
IUCN Red List: Least Concern.

Remarks
In peninsular and southern India, *L. lineata indica* replaces the typical form.
Family: Coenagrionidae Kirby, 1890
Genus: *Agriocnemis* Selys, 1877
(Subfamily: Agriocnemidinae Fraser, 1957)

40. *Agriocnemis pygmaea* (Rambur, 1842)

English Names
Pygmy Dartlet, Pygmy Wisp, Wandering Midget, Wandering Wisp.

Description
Small-sized apple-green damselfly with black thoracic stripes and orange-coloured terminal abdominal segments.

Male: Eyes black and apple green, thorax black with apple-green stripes, abdomen black and apple green with terminal segments brick red, wings transparent, pterostigma yellowish in forewings and black in hindwings, legs yellow and black.

Abdomen 16.0–17.0 mm, hindwing 9.5–10.0 mm (Fraser 1933; Subramanian 2009), abdn. 16.5–17.5, fwing. 9.5–11.0, hwing. 9.0–10.0 mm (Prasad 1996a, b), abdn. 16.0, fwing. 10.5, hwing. 10.0 mm (Prasad 2004a), abdn. 16.5–17.5, fwing. 9.5–10.0, hwing. 9.5–10.0 mm (Prasad 2004b).

Female: Little larger and more robust in three forms viz. red, sub-dull and isochrome.

Abdomen 18.0 mm, hindwing 11.0–12.0 mm (Fraser 1933; Subramanian 2009), abdn. 17.0–18.5, fwing. 11.0–12.5, hwing. 11.0–12.0, mm (Prasad 1996a, b), abdn. 16.0, fwing. 10.0, hwing. 10.0 mm (Prasad 2004a), abdn. 16.5–17.5, fwing. 9.5–10.0, hwing. 9.5–11.0 mm (Prasad 2004b).

Distribution
West, central, south and south-east Asia (Oriental region), N. Australia and Pacific Islands.

Rajasthan
Pichola Lake, Udaipur; Girab, Barmer dist., Desert National Park; Keoladeo National Park, Bharatpur; Lake Kailana, Jodhpur.

India
Andaman and Nicobar Islands (Nicobar), Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Dadra and Nagar Haveli, Daman and Diu, Delhi, Goa, Gujarat (Ahmedabad, Bhavnagar, Gandhinagar, Jamnagar, Kheda, Surendranagar and Valsad), Haryana, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Jammu and Kashmir, Jharkhand (Dhanbad), Karnataka, Kerala, Laccadive Islands, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Puducherry (Karaikal, Mahe, Yanam), Punjab (Hoshiarpur dist.), Sikkim, Tamil Nadu (Chennai), Tripura, Uttarakhand (Dehra Dun, Pauri and Tehri dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Kolkata).

Habitat
Found in diverse natural and man-made habitats. Larvae commonly occur among the aquatic weeds and algae.

Conservation Status
IUCN Red List: Least Concern.

Remarks
Agriocnemis sania Nielsen, 1959, was made a subspecies of *A. pygmaea* (Rambur 1942) by Pinhey (1974). Dumont (1974) redescribed the taxon and elaborated on the differences between *A. sania* and *A. pygmaea*, the latter being very abundant and widespread in Asia. Though more taxonomic work is needed, both species are currently considered as good species, with *A. sania* occurring in north-eastern Africa and *A. pygmaea* being widespread in southern Asia (vide IUCN Red List of Threatened Species).
Genus: *Cercion* Navas, 1907
(Subfamily: Coenagrioninae Kirby, 1890)

41. *Cercion malayanum* (Selys, 1876)

English Name
Malay Lily Squatter.

Description
Male: Eyes olivaceous, thorax bronzed-black above and marked with greenish-yellow stripe, abdomen pale blue/creamy and marked with black, anal appendage short and slightly notched at tip, wings hyaline, pterostigma creamy and legs bluish-white and marked with black.

Abdomen 22.0, hindwing 15.0 mm (Fraser 1933).

Female: Mostly like male ground colour greenish-yellow instead of blue with different markings. Abdomen 20.0, hindwing 15.0 mm (Fraser 1933).

Distribution

Rajasthan
Phulera, Jaipur district.

India
Assam, Maharashtra (Nagpur, 304.8 m/1,000 ft) and West Bengal (from tidal mangrove forest).

Habitat
Shallow lakes and ponds, where it keeps away from the water's edge and perches on floating vegetation.

Conservation Status
IUCN Red List: Least Concern.

Threats
Habitat loss through human development of the area.

Remarks
The placement of this species in *Cercion* is highly doubtful. It has been treated both under *Coenagrion* and *Enallagma* (original name); however, there is little support for placing it in either of these genera.
Genus: *Amphiallagma* Kennedy, 1920
(Subfamily: Ischnurinae Fraser, 1957)

42. *Amphiallagma parvum* (Selys. 1876)

English Name
Little Blue.

Description
Very small species.

Male: Eyes deep sky blue, thorax black above with very broad azure-blue stripes with black border, abdomen pale sky blue and marked with broad quadrate dorsal spot and other marks, anal appendage short and truncate, wings hyaline, pterostigma small blackish/yellow in young and legs white with a black line.

Abdomen 17.0, hindwing 11.0 mm (Fraser 1933), abdn. 17.0–18.0, fwing. 11.0–11.5, hwing. 10.0–11.5 mm (Prasad 1996a, b), abdn. 16.5–17.5, fwing. 11.5–12.0, hwing. 10.5–11.0 mm (Prasad 2004b).

Female: Isochrome form mostly like male but with greenish-yellow or yellow thorax (stripes unenclosed with black in heterochrome form), abdomen with broader dorsal stripes and anal appendage very small and bluish.

Abdomen 17.0, hindwing 11.0 mm (Fraser 1933), abdn. 16.5–17.0, fwing. 11.0, hwing. 10.0 mm (Prasad 1996a, b), abdn. 17.0, fwing. 11.5, hwing. 10.5–11.0 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert.

India
Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahmedabad and Mehsana dists.), Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Orissa, Puducherry (Mahe), Punjab (Hoshiarpur dist.), Sikkim, Tamil Nadu, Uttarakhand (Dehra Dun and Nainital dist. and Rajaji National Park), Uttar Pradesh and West Bengal.

Elsewhere
Myanmar, Nepal, Sri Lanka and Thailand.

Habitat
Found throughout the year in wetlands. Breeds in stagnant water bodies covered with aquatic plants or weedy tanks.

Conservation Status
IUCN Red List: Lest Concern.

Remarks
It is often placed in the genus *Enallagma* Charpentier, 1840
Genus: *Ischnura* Charpentier, 1840
(Subfamily: Ischnurinae Fraser, 1957)

43. *Ischnura aurora aurora* (Brauer, 1865)

English Name
Aurora Blue-Tail, Gossamer Damselfly, Wandering Blue-Tail.

Description
Small apple-green damselfly with black thoracic stripes and blue-tipped yellow tail.

Male: Abdomen 16.0–20.0, hindwing 10.0–12.0 mm (Fraser 1933), abdn. 19.0–20.0, fwing. 11.0–11.5, hwing. 10.0–11.0 (Prasad 1996a, b), abdn. 20.0, fwing. 13.5, hwing. 13.0 mm (Prasad 2004a), abdn. 16.0–17.0, fwing. 11.0–12.0, hwing. 10.0–12.0 mm (Prasad 2004b) abdn. 16.0–20.0, hwing. 10.0–20.0 mm (Subramanian, 2009).

Female: Abdomen 18.0–20.0, hindwing 14.0–15.0 mm (Fraser 1933; Subramanian, 2009), abdn. 19.0–19.5, fwing. 15.5–16.5, hwing. 14.5–16.0 mm (Prasad 1996a, b), abdn. 21.0–23.0, fwing. 16.5–19.0, hwing. 10.0–11.0 mm (Prasad 2004b).

Distribution

Rajasthan
Girab, Barmer dist., Desert National Park; Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Keoladeo National Park, Bharatpur; Mount Abu Wildlife Sanctuary and Nikki lake in Mt. Abu, Sirohi district; Gape Sagar, Dungarpur.

India
Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar), Delhi, Gujarat (Ahmedabad, Gandhinagar, Kheda, Mehsana and Surendranagar, Valsad dists.), Haryana (Hissar dist.), Himachal Pradesh (Bilaspur, Kangra, Hamirpur, Solan and Una dists. and Renuka Wetland, Sirmour dist. as *Ischnura delicata*), Jharkhand (Dhanbad), Kerala, Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Manipur, Meghalaya, Nagaland, Odisha, Punjab (as *I. Delicate* from Amritsar, Gurdaspur, Hoshiarpur, Jalandhar and Kapurthala dists.), Sikkim, Tamil Nadu (Ootacamund, Nilgiris, 2,286 m/7,500 ft), Uttarakhand (Dehra Dun, Nainital, Pithoragarh and Tehri dists. and Rajaji National Park), Uttar Pradesh and West Bengal (Darjeeling, Jalpaiguri).

Habitat
It breeds in a variety of habitats, from marshes and tidal mangrove swamps, to ponds and lakes and wet ricefields. It occurs from the lowlands to high altitudes.

Conservation Status
IUCN Red List: Least Concern.

44. *Ischnura rufostigma* Selys, 1876

English Name
Reddish Darlet.

Description
Male: Eyes dark olivaceous/pale below, thorax steel black and marked with narrow bluish stripes, abdomen reddish-orange with quadrate black spot on 1st segment, anal appendage ochreous with black tip, wings hyaline, pterostigma of forewing very narrow, elongate and diamond shaped and legs yellowish with a minute black spot.

Abdomen 23.0, hindwing 14.0–15.0 mm (Fraser 1933), abdn. 22.0, fwing. 15.0, hwing. 14.5 mm (Prasad 1996a, b).

Female: Mostly like male except the isochromatic form.

Abdomen 22.0, hindwing 16.0–17.0 mm (Fraser 1933).

Distribution

Rajasthan
As per Bose and Mitra (1976).

India
Assam (Tezpur), Bihar (Pusa), Chhattisgarh (Bastar dist.), Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh (Mhow), Manipur, Meghalaya, Nagaland, Uttarakhand (Nainital dist.) and West Bengal (Kolkata).

Habitat
Inhabits a variety of standing water habitats.

Conservation Status
IUCN Red List: Least Concern.

Remarks
Ischnura annandalei Laidlaw, 1919 is a species from N Shan States, Myanmar.

45. *Ischnura senegalensis* (Rambur, 1842)

English Names
African Blue-Tail, Common Blue-Tail, Marsh Blue-Tail, Senegal Blue-Tail, Senegal Golden Dartlet, Ubiquitous Blue-Tail.

Description
Small pale green damselfly with black and yellow thoracic stripes; abdomen yellowish with basal and terminal blue spots.

Male: Head and thorax bright orange, eyes green, abdomen with segments 1–2, 7 and 8–10 bright orange, 3–6 pale blue while partly 7 and 8–10 orange. Distinctive segment 2 in that black top half creeps right down the side of abdomen as a 'saddle mark'.

Abdomen 21.0–23.0, hindwing 13.0–15.0 mm (Fraser 1933; Subramanian, 2009), abdn. 22.0, fwing. 12.5, hwing. 13.0 mm (Prasad 1996a, b), abdn. 20.0–21.0, fwing. 14.5–15.5, hwing. 14.0–15.0 mm (Prasad 2004a), abdn. 22.0–24.0, fwing. 17.0–19.0, hwing. 16.5–18.00 mm (Prasad 2004b).

Female: Abdomen 20.0–24.0, hindwing 14.0–16.0 mm (Fraser 1933; Subramanian, 2009), abdn. 24.0, fwing. 17.0, hwing. 16.0 mm (Prasad 2004a), abdn. 21.0–23.0, fwing. 16.5–19.0, hwing. 16.0–18.0 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert; Girab, Barmer dist., Desert National Park; Keoladeo National Park, Bharatpur; Phulera, Jaipur dist.; Mount Abu Wildlife Sanctuary, Sirohi district.

India
Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahmedabad, Bhuj, Gandhinagar, Jamnagar, Kachchh, Kheda, Mehsana, Saputara dists.), Himachal Pradesh (Bilaspur dist. and Renuka Wetland, Sirmour dist.), Jharkhand (Dhanbad), Madhya Pradesh, Maharashtra (Sanjay Gandhi National Park), Manipur, Punjab (Hoshiarpur dist.), South India, Tamil Nadu (Ootacamund Lake, 2,209.8 m/7,250 ft), Uttarakhand (Dehra Dun and Tehri dists.), Uttar Pradesh and West Bengal.

Habitat
It occupies a variety of stagnant and slowly flowing water bodies. It is salt, pollution and disturbance-tolerant species.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Rhodischnura* Laidlaw, 1919
(Subfamily: Ischnurinae Fraser, 1957)

46. *Rhodischnura nursei* (Morton, 1907)

English Name
Reddish Dartlet.

Description
Male: Eyes green/greenish-yellow, thorax black above with narrow green stripes, abdomen crimson/citron-yellow/black, anal appendage reddish or ochreous, wings hyaline, pterostigma of forewing diamond shaped and of hindwing much smaller, hyaline with borders similar to forewing and legs pale yellow with fine black spines.

Abdomen 14.0, hindwing 9.5 mm (Fraser 1933), abdn. 15.5, fwing. 9.5, hwing. 9.0 mm (Prasad 1996a, b), abdn. 16.0, fwing. 10.0, hwing. 9.0 mm (Prasad 2004a), abdn. 15.0–16.0, fwing. 9.5–10.0, hwing. 9.5–10.0 mm (Prasad 2004b).

Female: Variable as per different forms.

Abdomen 15.0–17.0, hindwing 11.0 mm (Fraser 1933), abdn. 15.0, fwing. 12.0, hwing. 11.5 mm (Prasad 2004b).

Distribution

Rajasthan
Girab, Barmer district; Desert National Park; Pichola Lake, Udaipur; Mount Abu Wildlife Sanctuary, Sirohi dist., Jodhpur; Bhagowani (Bose and Mitra 1976). Mansarovar Resort, Jaipur (vide Query Results, Asia Dragonfly); Kaylana lake.

India
N W India. Andhra Pradesh (Hyderabad), Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahmedabad, Kheda and Surendranagar dists.), Haryana (Hissar), Madhya Pradesh, Maharashtra (Ghorpad Dam and Mohurli lake, Tadoba-Andhari National Park/Tiger Reserve, Nagpur), Orissa, Punjab (Ferozepur dist.), Tamil Nadu, Uttarakhand (Dehra Dun, Nainital and Pauri dists.), Uttar Pradesh (Agra, Varanasi) and West Bengal.

Habitat
It is commonly found among aquatic vegetation in ponds and lakes. They are also found in riparian zones (area bordering a river) of stagnant wetlands.

Conservation Status
IUCN Red List: Least Concern.
Genus: *Ceriagrion* Selys, 1876
(Subfamily: Pseudagrioninae Tillyard, 1917)

47. *Ceriagrion cerinorubellum* (Brauer, 1865)

English Name
Orange-Tailed Marsh Dart, Ornate Coral-Tail.

Description
Medium-sized pale green damselfly with orange-coloured segments at base and end of abdomen.

Male: Abdomen 31.0–33.0, hindwing 20.0–21.0 mm (Fraser 1933; Subramanian, 2009).

Female: Abdomen 31.0–35.0, hindwing 20.0–21.0 mm (Fraser 1933), abdn. 31.0–35.0, hwing. 20.0–21.0 mm (Subramanian, 2009).

Distribution

Rajasthan
Thar Desert; Mount Abu Wildlife Sanctuary, Sirohi district.

India
Assam (Guwahati and Sibsagar), Delhi, Himachal Pradesh (Renuka Wetland, Sirmour dist.), Uttarakhand (Dehra Dun dist.) and Tamil Nadu (North Kodagu/Coorg).

Habitat
It breeds in a wide variety of standing water habitats, from drains in town and cities to marshes and swamp forest, and even the landward margins of mangrove swamp.

Conservation Status
IUCN Red List: Least Concern.

48. *Ceriagrion coromandelianum* (Fabricius, 1798)

English Name
Coromandel Marsh Dart.

Description
Medium-sized pale green damselfly with bright yellow (in male) and pale green tail (in female).

Male: Abdomen 28.0–30.0, hindwing 18.0–20.0 mm (Fraser 1933; Subramanian, 2009), abdn. 30.0–31.0, fwing. 20.0–21.5, hwing. 19.5–20.0 mm (Prasad 1996a, b), abdn. 29.5, fwing. 20.5, hwing. 20.0 mm (Prasad 2004b).

Female: Abdomen 29.0–32.0, hindwing 20.0 mm (Fraser 1933; Subramanian, 2009), abdn. 29.0–30.0, fwing. 21.0–22.5, hwing. 20.0–21.5 mm (Prasad 1996a, b), abdn. 28.0, fwing. 21.0, hwing. 20.5 mm (Prasad 2004b).

Distribution

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian, Jodhpur; Keoladeo National Park, Bharatpur; Mount Abu Wildlife Sanctuary, Sirohi district.

India
Throughout. Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Goa, Gujarat (Jamnagar and Kheda dists.), Himachal Pradesh (Bilaspur, Kangra, Hamirpur, Shimla and Una dists. and Renuka Wetland, Sirmour dist.), Jharkhand (Dhanbad), Kerala, Maharashtra (Chandrapur dist., Khandala, Pune dist., Sanjay Gandhi National Park and Tadoba Tiger Reserve), Meghalaya, Punjab (Hoshiarpur dist.), Tamil Nadu, Tripura, Uttarakhand (Chamoli, Dehra Dun, Nainital and Uttarkashi dists. and Rajaji National Park), Uttar Pradesh and West Bengal (mangrove forests).

Habitat
Ponds, ditches, ricefields and other open standing waters.

Conservation Status
IUCN Red List: Least Concern.

Genus: *Pseudagrion* Selys, 1976
(Subfamily: Pseudagrioninae Tillyard, 1917)

49. *Pseudagrion decorum* (Rambur, 1842)

English Name
Elegant Sprite.

Description
Light blue all through with legs blackish and wings darkish.

Male: Abdomen 28.0–30.0, hindwing 18.0–20.0 mm (Fraser 1933), abdn. 28.0–28.5, fwing. 19.5–20.5, hwing. 19.0–19.5 mm (Prasad 1996a, b), abdn. 28.5–29.0, fwing. 20.0, hwing. 19.0–19.5 mm (Prasad 2004b).

Female: Abdomen 31.0, hindwing 20.0 mm (Fraser 1933), abdn. 28.5, fwing. 20.0–20.5, hwing. 19.5–20.0 mm (Prasad 1996a, b), abdn. 28.0–29.0, fwing. 20.0–21.0, hwing. 20.0 mm (Prasad 2004b).

Distribution

Rajasthan
Thar Desert; Keoladeo National Park, Bharatpur.

India
Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Ahmedabad, Jamnagar, Kheda and Surat dists.), Himachal Pradesh (Bilaspur and Una dists. and Renuka Wetland, Sirmour dist.), Karnataka, Kerala, Madhya Pradesh, Maharashtra (Nagpur dist. and Sanjay Gandhi National Park), Odisha, Punjab (Hoshiarpur dist.), Tamil Nadu (Ootacamund, Nilgiris at 2,209.8 m/7,250 ft, Coorg at 1,219.2 m/4,000 ft), Uttarakhand (Dehra Dun and Nainital dists. and Rajaji National Park), Uttar Pradesh and West Bengal.

Habitat
Its larvae are common in slow-flowing marshy streams and reservoirs.

Conservation Status
IUCN Red List: Least Concern.

50. *Pseudagrion rubriceps rubriceps* (Selys, 1876)

English Name
Saffron-Faced Blue Dart.

Description
Medium-sized blue damselfly with characteristic bright orange face.

Male: Abdomen 29.0, hindwing 18.0–20.0 mm (Fraser 1933; Subramanian, 2009), abdn. 32.0, fwing. 20.5, hwing. 20.0 mm (Prasad 1996a, b), abdn. 29.0, fwing. 19.0, hwing. 18.5 mm (Prasad 2004b).

Female: Abdomen 29.0, hindwing 21.0 mm (Fraser 1933; Subramanian, 2009).

Distribution

Rajasthan
Pichola Lake, Udaipur; Thar Desert at Osian and Lake Kailana, Jodhpur; Mount Abu Wildlife Sanctuary, Sirohi district; Surpur ki nadi, Dungarpur.

India
Assam, Bihar, Chhattisgarh (Bastar dist.), Delhi, Gujarat (Gandhinagar dist.), Himachal Pradesh (Bilaspur. Hamirpur and Sirmour dists. and Renuka Wetland, Sirmour dist.), Jharkhand (Dhanbad), Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Punjab (Hoshiarpur dist.), Tamil Nadu, Uttarakhand (Dehra Dun, Nainital, Pauri and Tehri dists. and Rajaji National Park), Uttar Pradesh and West Bengal.

Habitat
Found in open streams and ponds.

Conservation Status
IUCN Red List: Least Concern.
Family: Lestidae Calvert, 1901
(Spread-Wings)
Genus: *Lestes* Leach, 1815
(Subfamily: Lestinae Calvert, 1901)

51. *Lestes viridulus* Rambur, 1842

English Name
Spread-Wing

Description
Male: Face brown, eyes pale yellow, thorax khaki-brown or fawn, abdomen pale yellow, anal appendage yellow with black tip, wings hyaline, pterostigma khaki-brown and legs pale yellow with black spines.

Abdomen 34.0–35.0, hindwing 23.0–24.0 mm (Fraser 1933), abdn. 31.0–32.5, fwing. 22.0–23.5, hwing. 21.5–22.0 mm (Prasad 1996a, b), abdn. 32.0–34.5, fwing. 21.5–23.5, hwing. 20.5–23.0 mm (Prasad 2004b).

Female: Like male except in abdominal colouration, pterostigma longer and narrow, anal appendage palest brown and legs with longitudinal dark brown stripe.

Abdomen 34.0, hindwing 24.0 mm (Fraser 1933), abdn. 30.0–33.0, fwing. 21.5–23.0, hwing. 21.0–23.0 (Prasad 1996a, b), abdn. 29.0–34.0, fwing. 21.0–23.5, hwing. 21.0–23.5 mm (Prasad 2004b).

Distribution

Rajasthan
Agolai and Umaidpur, Jodhpur.

India
Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Deccan, Gujarat (Kheda, Saputara and Surendranagar dists.), Haryana (Hissar), Himachal Pradesh (Bilaspur and Kangra dists.), Karnataka (south Kodagu/Coorg), Madhya Pradesh, Maharashtra (type from Mumbai), Punjab (Bhatinda, Ferozepur and Hoshiarpur dists.), Uttarakhand (Dehra Dun, Nainital and Pauri dists. and Rajaji National Park), Uttar Pradesh and Western India.

Elsewhere
Bangladesh and Thailand. Myanmar (possibly).

Habitat and Ecology
Commonly found in dry season and is to be sought for among long grass. Aestivating adults commonly found in thick forest from October to April amidst dry vegetation. Nothing known about its breeding habitat, presumably ponds and similar habitats, including intermittent ones.

Conservation Status
IUCN Red List: Least Concern.
Family: Platycnemididae Tillyard, 1917
(White-Legged Damselflies)
Genus: *Copera* Kirby, 1890
(Subfamily: Platycnemidinae Tillyard, 1917)

52. *Copera marginipes* (Rambur, 1842)

English Name
Yellow Bush Dart.

Description
With a black band extending from eye to eye.

Male: Abdomen 28.0–31.0, hindwing 16.0–18.0 mm (Fraser 1933; Subramanian, 2009), abdn. 31.0, fwing. 19.0, hwing. 18.0 mm (Prasad 1996a, b).

Female: Abdomen 29.0–30.0, hindwing 20.0 mm (Fraser 1933; Subramanian, 2009), abdn. 26.5, fwing. 17.5, hwing. 17.0 mm (Prasad 1996a, b).

Distribution

Rajasthan
Thar Desert; Lake Kailana, Jodhpur; Udai Sagar, Udaipur.

India
Andaman and Nicobar Islands (south Andaman Islands), Assam (Margherita), Bihar, Chandigarh, Chhattisgarh (Bastar dist.), Deccan, Delhi, Goa, Himachal Pradesh (Kangra and Sirmour dists. and Renuka Wetland, Sirmour dist.,), Karnataka (Kodagu/Coorg), Kerala, Madhya Pradesh (Mhow), Maharashtra (Buldhana dist., Gondhonkher; Hingoli dist., Khandala and Lone, Pune dist., Mahabaleshwar, Melghat Tiger Reserve, Amravati dist., Mumbai, Sanjay Gandhi Tiger Reserve and Wardha dist.), Meghalaya, Tamil Nadu, Uttarakhand (Dehra Dun, Nainital and Pauri dist.), Uttar Pradesh, West Bengal (Jalpaiguri), Western Ghats and Western Himalaya.

Habitat
Found in ponds, puddles, canals and streams.

Conservation Status
IUCN Red List: Lest Concern.

Remarks
The body measurements (abdomen and hind-wings) have been found variable.
Genus: *Disparoneura* Selys, 1860
(Subfamily: Disparoneurinae Fraser, 1957)

53. *Disparoneura quadrimaculata* (Rambur, 1842)

English Name
Black-Winged Bamboo-Tail.

Description
Medium-sized brick-red damselfly with black-banded wings.

Male: Abdomen 32.0, hindwing 22.0 mm (Fraser 1933; Subramanian, 2009), abdn. 31.0, fwing. 23.5, hwing. 23.0 mm (Prasad 1996a, b), abdn. 31.5, fwing. 23.0, hwing. 22.5 mm (Prasad 2004b).

Female: Abdomen 29.0–30.0, hindwing 22.0 mm (Fraser 1933; Subramanian, 2009).

Distribution

Rajasthan
Thar Desert; Gyan Sarovar and around Mount Abu Wildlife Sanctuary and Nakki lake in Mt Abu, Sirohi district.

India
Bihar, Central India, Chhattisgarh (Bastar dist.), Deccan (western side), Delhi, Gujarat (Sasan Gir; Gir Forest National Park; Amreli, Junagadh and Valsad dists.), Himachal Pradesh as *Rhinocypha quadrimaculata quadrimaculata*, Karnataka (Kodagu/Coorg, Mysore), Madhya Pradesh (Kanha National/Tiger Reserve, Mandla and Balaghat

dists.), Maharashtra (Mahabaleshwar, Mumbai, Panch Mahal, Pune, Satara; Melghat Tiger Reserve, Amravati dist., Tadoba Tiger Reserve, Chandrapur dist., Sanjay Gandhi National Park, nr. Mumbai and Bhimashankar Wildlife Sanctuary, Pune dist.), Tamil Nadu (Pykara riverside, Ooty; Mudumalai Wildlife National Park/Tiger Reserve and Wildlife Sanctuary), Uttar Pradesh, West Bengal and Western Ghats.

Habitat

Confined to hill streams and rivers of forested areas, found frequently perching on emergent aquatic plants and overhanging vegetation and breeds in hill streams, generally above 457.2 m/1,500 ft.

Conservation Status

IUCN Red List: Least Concern.

Zoogeography

Since the Thar Desert part of the state is the extension of Sahara Desert through Persian and Arabian Deserts and is located at a meeting point of Palaearctic and Oriental regions and due to this fact Rajasthan and its desert part has an admixture of Saharan, Palaearctic and Oriental elements but more of Palaearctic origin as under:

Arabian Deserts

15 species (out of 53):

Anisoptera: 12 species – *Anax parthenope* (Kuwait, Oman, Qatar and UAE), *Hemianax ephippiger* (UAE and Yemen), *Orthetrum sabina sabina* (Bahrain, Kuwait, Oman, Qatar Saudi Arabia and Yemen), *O. taeniolatum* (Oman, Saudi Arabia, UAE and Yemen), *Crocothemis servilia servilia* (Qatar), *Diplacodes lefebvrii* (Qatar, UAE and Yemen), *Pantala flavescens* (Oman, Qatar, Saudi Arabia, UAE and Yemen), *Tramea basilaris* (Oman and UAE), *Trithemis festiva* (Kuwait), *T. kirbyi kirbyi* (Oman, Qatar and UAE), *T. pallidinervis* (Oman, Saudi Arabia and Yemen) and *Selysiothemis nigra* (Kuwait, Qatar, Saudi Arabia and UAE).

Zygoptera: 3 species – *Agriocnemis pygmaea* (Oman), *Ischnura senegalensis* (Oman, Qatar, UAE and Yemen) and *Pseudagrion decorum* (Oman and UAE).

Himalayan Region

51 species (out of 53):

Anisoptera: 37 species – *Anax guttatus* (Himachal Pradesh, north-east and Uttarakhand), *A. maculifrons* (Himalaya), *A. parthenope* (Jammu and Kashmir and UK), *Hemianax ephippiger* (HP, NE and UK), *Ictinogomphus rapax* (HP, J and K, NE and UK), *Paragomphus lineatus* (HP and UK), *Brachydiplax sobrina* (NE and UK), *Orthetrum glaucum* (HP, NE and UK), *O. luzonicum* (HP, NE and UK), *O. pruinosum neglectum* (HP, Sikkim and UK), *O. sabina sabina* (HP, NE, Sik and UK), *O. taeniolatum* (HP, NE and UK), *O. triangulare triangulare* (HP, J and K, NE and UK), *Palpopleura sexmaculata sexmaculata* (HP, NE and UK), *Acisoma panorpoides panorpoides* (HP, NE and UK), *Brachythemis contaminate* (HP, NE and UK), *Bradinopyga geminate* (HP, NE and UK), *Crocothemis servilia servilia* (HP, NE, Sik and UK), *Diplacodes lefevrii* (UK), *D. nebulosa* (HP, NE, Sik and UK), *D. trivialis* (HP, NE, Sik and UK), *Neurothemis fulvia* (HP, NE and UK), *N. intermedia intermedia* (HP, NE, Sik and UK), *N. tullia tullia* (HP, Ne and UK), *Tetrathemis platyptera* (UK), *Hydrobasileus croceus* (NE), *Pantala flavescens* (HP, J and K, NE and UK), *Rhyothemis variegata variegata* (HP, NE, Sik and UK), *Tholymis tillarga* (UK), *Tramea basilaris burmeisteri* (UK), *T. virginia* (HP, J and K and UK), *Zyxomma petiolatum* (NE and UK), *Trithemis aurora* (HP, J and K, NE, Sik and UK), *T. festiva* (HP, NE and UK), *T. kirbyi kirbyi* (HP and UK), *T. pallidinervis* (HP, NE, Sik and UK) and *Selysiothemis nigra* (J and K).

Zygoptera: 14 species – *Libellago lineata lineata* (Himachal Pradesh, Uttarakhand and north-east), *Agriocnemis pygmaea* (HP, J and K, NE, Sikkim and UK), *Cercion malayanum* (NE), *Amphiallagma parvum* (NE and UK), *Ischnura aurora aurora* (HP, NE, Sik and UK), *I. rufostigma* (HP, J and K, NE and UK), *I. senegalensis* (HP and UK), *Rhodischnura nursei* (UK), *Ceriagrion cerinorubellum* (NE and UK), *C. cor-*

omandelianum (HP, NE and UK), *Pseudagrion decorum* (HP and UK), *P. rubriceps rubriceps* (HP and UK), *Lestes viridulus* (HP and UK) and *Copera marginipes* (HP, NE and UK).

Conclusion

1. *Fauna*: 53 species belonging to 34 genera 8 families under 2 suborders are found in Rajasthan (including Thar Desert part).
2. *Systematic Account*: Besides update on nomenclature, English names, description (general colouration with sexual differences), male and female measurements, habitat, conservation status of each species have been provided.
3. *Distribution*: Distribution in Rajasthan (including desert part), rest of India and elsewhere has been given.
4. *Zoogeography*: The state with its desert part has an admixture of Saharan, Palaearctic and Oriental elements. Out of 53 species, 15 (28.30 %, 12 anisopterans and 3 zygopterans) are common to Arabian Deserts and 51 (96.23 %, 37 anisopterans and 14 zygopterans) to the Himalayan region in India. *Onychogomphus grammicus* (anisopteran) and *Disparoneura quadrimaculata* (zygopteran) both are not found in Arabia and Himalayan regions.
5. *Habitat*: Occurrence of each species as per preference and breeding are given.
6. *Conservation Status Under IUCN Red List*: All the species fall under 'Least Concern' category, except for *Onychogomphus grammicus* whose data is deficient.
7. *Threats*: Presently no serious threats are seen but destruction of their habitats (seasonal or permanent) may certainly be harming their existence.

Addendum

Additional list of species from Southern Rajasthan (Bhilwara, Chittorgarh, Pratapgarh, Rajsamand and Udaipur districts): Koli et al. (2014) listed 54 species from Southern Rajasthan and out of which the following 20 species (updated) are additional records, making a total of 73 species from the state, with their Common English Names, localities and IUCN (International Union for Conservation of Nature) Red List Categories (*DD* Data deficient, *LC* Least concern, *NT* Near threatened).

Suborder: Anisoptera
Family: Libellulidae

1. *Crocothemis erythraea* (Brulle, 1832); Scarlet Dragonfly; Pichola Lake, Udaipur; LC/DD (Koli et al. 2014).
2. *Indothemis carnatica* (Fabricius, 1798); Blue-tailed Green Darner; Udai Sagar Lake, Udaipur; NT.
3. *Orthetrum brunneum* (Fonscolombe, 1837); Southern Skimmer; Menar, Pichola, Rup Sagar and Udaisagar Lakes, Udaipur; LC.
4. *O. chrysis* (Selys, 1891); Brown-backed Red Marsh; Pichola Lake, Udaipur; LC.
5. *Sympetrum meridionale* (Selys, 1841); Southern Darter; Ghasa and Menar Lakes, Udaipur; Karmoi River Stream, Pratapgarh; LC/DD (Koli et al. 2014).
6. *Tramea limbata* (Desjardins, 1832); Black Marsh Trotter, Ferrugineus or Voyaging Glider; Rup Sagar and Udai Sagar Lakes, Udaipur; LC.

Family: Macromiidae

7. *Epophthalmia frontalis* (Selys, 1871); Ghasa Lake, Udaipur; LC.
8. *Macromia ellisoni* Fraser, 1824; Coorg Torrent Hawk; Pichola Lake, Udaipur; LC.

Suborder: Zygoptera
Family: Chlorocyphidae

9. *Rhinocypha bisignata* (Hagen in Selys, 1853); Stream Ruby; Karmoi River Stream, Pratapgarh; LC.

Family: Coenagrionidae

10. *Aciagrion occidentale* Laidlaw, 1919; Asian Slim Damselfly; Ghasa, Menar and Pichola Lakes, Udaipur; LC.

11. *Agriocnemis femina* (Brauer, 1868); Variable Wisp; Badwai, Pichola and Udai Sagar Lakes, Udaipur and Meja Dam, Bhilwara; LC.
12. *Ceriagrion olivaceum* Laidlaw, 1914; Rusty Marsh Dart; Ghasa, Pichola and Udai Sagar Lakes; LC.
13. *C. rubiae* Laidlaw, 1916; Orange Marsh Dart; Badwai, Ghasa, Pichola, Udai Sagar Lakes, Udaipur; LC.
14. *Ischnura forcipata* Morton, 1907; Ghasa, Rup Sagar and Udai Sagar Lakes, Udaipur and Sitamata Wildlife Sanctuary, Pratapgarh; LC.
15. *Pseudagrion australasiae* (Selys, 1876); Blue-headed Sprite; Udai Sagar Lake, Udaipur and Rajsamand Lake, Rajsamand; LC.
16. *P. hypermelas* Selys, 1876; Violet-striped Blue Dart; Rajsamand Lake, Rajsamand; LC.
17. *P. microcephalum* (Rambur, 1842); Blue Grass Dartlet or Blue Sprite; Ghasa and Udai Sagar Lakes, Udaipur; LC.

Family: Lestidae

18. *Lestes* sp.; Badwai Lake, Udaipur

Family: Platycnemididae

19. *Calicnemia imitans* Lieftinck, 1948; Rajsamand Lake, Rajsamand; LC.
20. *Prodasineura verticalis* (Selys, 1860); Black Bamboo-tail; Karmoi River Stream, Pratapgarh; LC.

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References

Agarwal JP (1957) Contribution towards the Odonata fauna of Pilani. In: Proceedings of the 44th Indian science congress, Kolkata, p 309

Bose B, Mitra TR (1976) The Odonata of Rajasthan. Rec Zool Surv India Kolkata, 71:1–11

Chandra K, Sharma G (2010) New records and addition to Odonata (Insecta: Arthropoda) fauna of Pichhola lake, Udaipur, Rajasthan, India. In: National seminar on impact of climate change on biodiversity and challenges in the Thar Desert. Abstracts. Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 91–92

Dumont HJ (1974) *Ischnura intermedia* sp.n. from Turkey, and its relations to *I. forcipata* Morton, 1907, and *I. pumilio* (Charpentier, 1825) (Anisoptera, Conagrionidae). Odontologica 33(3):153–165

Fraser FC (1933) The fauna of British India, including Ceylon and Burma, vol 1, Odonata. Taylor & Francis, London, xi +423 pp

Fraser FC (1934) The fauna of British India, including Ceylon and Burma, vol 2, Odonata. Taylor & Francis, London, xxi +398 pp

Fraser FC (1936) The fauna of British India, including Ceylon and Burma, vol 3, Odonata. Taylor & Francis, London, ix +461 pp

Husain A (2011) Odonate species common to Indian, Qatar and UAE Deserts. In: National seminar on biodiversity and intangible natural heritage, Desert Regional Centre, Zoological Survey of India, Jodhpur. Abstracts, no. 92, 28 September, p 66

Husain A, Sharma G (2012) Odonates of Arabian and Indian deserts and their conservation status. Biol Forum Int J Spl Iss 4(1):74–91

Koli VK, Bhatnagar C, Shekhawat DS (2014) Diversity and species composition of Odonates in Southern Rajasthan, India. Proc Zool Soc, Springer (Published online on 22 March 2014). doi:10.1007/s12595-014-0103-x

Palot MJ, Soniya VP (2000) Odonata of Keoladeo National Park, Bharatpur, Rajasthan, India. Zoos Print J 15(8):317–320

Pinhey E (1974) Three undescribed Odonata taxa from Africa. Arnoldia Rhod 7(2):1–6, *Gomphidia quarrei confinii, Eleuthemis buettikoferi quadrigutta*

Prasad M (1996a) Studies on Odonata fauna of Bastar, Madhya Pradesh. India Rec Zool Surv India 95(3–4):165–213

Prasad M (1996b) Odonata in the Thar Desert. In: Ghosh AK, Baqri QH, Prakash I (eds) Faunal diversity in the Thar Desert: gaps in research. Scientific Publishers, Jodhpur, pp 145–149

Prasad M (2004a) Insecta: Odonata of Desert National Park. In: Fauna of Desert National Park, Rajasthan, Conservation area series 19. Zoological Survey of India, Kolkata, pp 51–58

Prasad M (2004b) Insecta: Odonata. In: Fauna of Gujarat, state fauna series 8. Zoological Survey of India, Kolkata, pp 19–40

Prasad M (2007) Insecta: Odonata. In: Fauna of Pichhola lake, Wetland ecosystem series 8. Zoological Survey of India, Kolkata, pp 79–83

Prasad M, Thakur RK (1981) Further additions to the Odonata (Insecta). In: Fauna of Rajasthan. Jantu 1:26–28

Prasad M, Varshney RK (1995) A checklist of the Odonata of India including data on larval studies. Orient Insects 29:385–428

Ramakrishna, Baqri QH, Shivaperuman C (2010) Faunal ecology and conservation of the Great Indian Desert. In: National seminar on impact of climate change on biodiversity and challenges in Thar Desert. Abstracts. Zoological Survey of India, Desert Regional Centre, Jodhpur, Rajasthan, pp 3–41

Sharma G (2010a) Studies on the reproductive behaviour of Disparoneura quadrimaculata (Rambur) (Odonata: Insecta) at Gyan Sarover, Mount Abu, Rajasthan, India. National seminar on impact of climate change on biodiversity and challenges in the Thar Desert. Abstracts. Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 113–114

Sharma G (2010b) Studies on the reproductive behaviour of Disparoneura quadrimaculata (Rambur) (Odonata: Insecta) at Gyan Sarover, Mount Abu, Rajasthan, India. In: Proceedings: impact of climate change on biodiversity and challenges in Thar Desert, Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 198–202

Sharma G (2010c) Studies on the diversity of Damselflies and Dragonflies (Odonata: Insecta: Arthropoda) in and around Mount Abu Wildlife Sanctuary and on the reproductive behaviour of selected species. In: Proceedings: impact of climate change on biodiversity and challenges in Thar Desert, Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 339–341

Sharma G (2011a) Diversity analysis studies of Odonata (Insecta: Arthropoda) fauna of selected four lakes of Udaipur, Rajasthan. National seminar on biodiversity and intangible natural heritage, Desert Regional Centre, Zoological Survey of India, Jodhpur. Abstracts, 28th September, p 18

Sharma G (2011b) Studies on the reproductive behaviour of Trithemis festiva (Rambur) at Fateh Sagar Lake, Udaipur, Rajasthan. National seminar on biodiversity and intangible natural heritage, Desert Regional Centre, Zoological Survey of India, Jodhpur. Abstracts, 28 September, pp 26–27

Sharma G (2012) Studies on the faunal diversity and government efforts for conservation of tigers at Sariska Tiger Reserve, Rajasthan. In: Proceedings of the national conference on prospects and challenges in field of Applied Zoology, 12–13 January 2012. Lachoo Memorial College of Sciences & Technology, Jodhpur, pp 43–48

Sharma G, Dhadeech SN (2010) Studies on Damselflies and Dragonflies (Odonata: Insecta) in and around Thar Desert at Osian, Jodhpur, Rajasthan, India. In: Proceedings: impact of climate change on biodiversity and challenges in Thar Desert. Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 195–202

Sharma G, Dhadeech SN (2011) Comparative studies on the reproductive behaviour of Dragonfly, Neurobasis chinensis chinensis (Linnaeus) at Ravi river, Chamba (H. P.) and Dragonfly, Orthetrum Sabina Sabina (Drury) at Kailana lake, Jodhpur (Rajasthan). National seminar on biodiversity and intangible natural heritage, Desert Regional Centre, Zoological Survey of India, Jodhpur. Abstracts, 28th September, pp 64–65

Sharma G, Kankane PL (2012) Fauna of ecosystems of India. Thar Desert 1–18, Published by Zoological Survey of India, Kolkata

Sharma G, Sewak R (2010a) Status, diversity and conservation of Damselflies and Dragonflies (Odonata: Insecta) of Rajasthan and their role as biological control agent. National seminar on impact of climate change on biodiversity and challenges in the Thar Desert. Abstracts. Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 105–106

Sharma G, Sewak R (2010b) Status, diversity and conservation of Damselflies and Dragonflies (Odonata: Insecta) of Rajasthan and their role as biological control agent. In: Proceedings: impact of climate change on biodiversity and challenges in Thar Desert, Zoological Survey of India, Kolkata; Evergreen Printers, Jodhpur, pp 319–324

Subramanian KA (2009) India –a lifescape: dragonflies of India, a field guide. Vigyan Prasar, Noida, 168 pp

Thakur RK (1985) Field notes on the Odonata around lake Kailana, Jodhpur (Rajasthan). Bull Zool Surv India 7(1–2):21–25

Tyagi BK, Miller PL (1991) A note on Odonata collected in South-Western Rajasthan, India. Notul Odonatol 3:134–135

Odonata of Andaman and Nicobar Islands, India

10

C. Sivaperuman

Abstract

This study was conducted in Andaman and Nicobar Islands from 2008 through 2013 to assess the status and distribution of odonate fauna. The Andaman and Nicobar archipelago consist of 572 islands, extending over 800 km. These islands can be broadly divided into two groups, namely, the Andamans and the Nicobars. The following areas were covered during the study period, namely, Great Nicobar Island, Ritchie's archipelago and North Andaman. The Andaman and Nicobar Islands support unique assemblages of dragonflies and damselflies comprising many species. Further studies are required to better understand the population ecology, habitat destruction and other anthropogenic disturbances to conserve the unique population.

Keywords

Checklist • Conservation • Damselflies • Dragonflies • Diversity

Introduction

The Andaman and Nicobar archipelago consist of 572 islands, extending over 800 km. These islands were once a part of the Asian mainland but got detached some 100 Ma ago during the Upper Mesozoic period due to geological upheaval. The existing groups of islands constitute the physiographic continuation of the mountainous ranges of Naga and Lushai Hills and Arakan Yoma of Burma through Cape Negrais to the Andaman and Nicobar Islands and southeast of Sumatra. The chains of these islands are in fact the camel backs of the submerged mountain ranges projecting above the sea level running north to south between 6° 45′ and 13° 30′ N latitudes and 90° 20′ and 93° 56′ E longitudes with an extent of 8,249 km^2.

The Andaman and Nicobar Islands can be broadly divided into two groups, namely, the Andamans and the Nicobars. These two groups

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are separated by the Ten Degree Channel which is about 150 km wide and 400 fathoms deep. Average annual temperature varies from 24 to 28 °C. The elevations range from 0 to 732 m at Saddle Peak in North Andaman and 642 m at Mount Thuillier in Great Nicobar Island. The rainfall is slightly higher in Nicobar with an annual average of 3,000–3,500 mm.

Dragonflies (Anisoptera) and damselflies (Zygoptera) are one of the most easily recognizable insect taxa, due to their large size, bright colours and behaviour. They include the largest insect that ever lived, the griffenfly *Meganeuropsis permiana* Carpenter, with a wingspan of c. 70 cm (Kalkman et al. 2008). Dragonflies are a well-studied group of invertebrates with their increasing recognition in conservation worldwide (Cordoda-Aguilar 2008; Samways 2008). Dragonflies are key organisms of the food web as predators both as larvae and as imagoes (Benke 1976). They usually have definite habitat preference and territorial behaviour (Corbet 1999).

A total of 5,680 species of Odonata are known from all over the world, of these 2,739 species belonging to the suborder Zygoptera (19 families) and 2,941 species to the suborder Anisoptera (12 families) (Kalkman et al. 2008). India has a wide variety of suitable habitats that support large populations of Odonata and 470 species belong to 139 genera and 19 families occur in India (Subramanian 2009). In Andaman and Nicobar Islands, a total of 72 species belong to 11 families and 38 genera were reported by various workers (Selys 1853, 1863, 1871; Fraser 1933, 1934, 1936; Lahiri 1975, 1998; Chhotani et al. 1983; Lahiri and Mitra 1993; Mitra and Maiti 1992; Mitra 1995, 2002; Ram et al. 2000; Yeh and Veenakumari 2000; Nandy and Babu 2009).

Methods

Field studies were conducted from 2008 through 2013 to assess the status and distribution of odonate fauna, and also consulted with available literature to prepare the updated checklist of this paper. Odonates were identified based on standard systematic keys (Fraser 1924, 1933, 1934, 1936; Subramanian 2009; Mitra 2006).

Species Richness and Abundance of Odonates Total number of odonates and number of individuals seen in each location were calculated using the census data and field observations.

Diversity Indices Diversity indices were calculated using the programme SPDIVERS. BAS developed by Ludwig and Reynolds (1998).

Results and Discussion

A total of 72 taxa of Odonata were recorded in Andaman and Nicobar Islands, these belong to 9 families and 38 genera (Table 10.1). Of these, the Libellulidae were the most common with

Table 10.1 List of dragonflies and damselflies of Andaman and Nicobar Islands, India

Sl. No.	Species name	Common name	IUCN status	Distribution Andaman	Distribution Nicobar
	Order Odonata				
	Suborder Anisoptera				
	Family Aeshnidae				
1.	*Anaciaeschna jaspidea* (Burmeister, 1839)	Rusty darner	LC		√
2.	*Anax guttatus* (Burmeister, 1839)	Blue-tailed green darner	LC	√	√
3.	*Gynacantha andamanae* (Yeh & Veenakumari, 2000)	Dingy Duskhawker	–	√	

(continued)

Table 10.1 (continued)

Sl. No.	Species name	Common name	IUCN status	Distribution	
				Andaman	Nicobar
4.	*Gynacantha hyalina* (Selys)		–	√	
5.	*Gynacantha bayadera* (Selys, 1891)	Parakeet darner	LC	√	√
6.	*Gynacantha dravida* (Lieftinck, 1960)	Brown darner	DD	√	√
7.	*Gynacantha subinterrupta* (Rambur)		–		√
8.	*Oligoaeschna andamani* (Chhotani, Lahiri & Mitra, 1983)		–	√	
	Family Macromiidae				
9.	*Epophthalmia vittata vittata* (Burmeister, 1839)	Common Torrent Hawk	–	√	
	Family Gomphidae				
10.	*Gomphidia ganeshi* (Chotani, Lahiri & Mitra, 1983)		–	√	
11.	*Gomphidia t-nigrum* (Selys, 1854)		LC	√	
	Family Libellulidae				
12.	*Acisoma panorpoides panorpoides* (Rambur, 1842)	Trumpet tail	LC		√
13.	*Agrionoptera insignis* (Rambur, 1842)	Red Swamp Dragon	LC		√
14.	*Agrionoptera insignis nicobarica* (Brauer)	Red Swamp Dragon	LC		√
15.	*Brachydiplax chalybea chalybea* (Brauer, 1868)	Blue Dasher	LC	√	√
16.	*Brachythemis contaminata* (Fabricius, 1793)	Ditch Jewel	LC	√	√
17.	*Camacinia gigantea* (Brauer, 1867)	Scarlet Skimmer	LC		√
18.	*Cratilla lineata* (Forerster, 1903)	Emerald-banded Skimmer	–	√	
19.	*Cratilla metallica* (Brauer)	Dark-tipped Forest Skimmer	–	√	
20.	*Crocothemis servilia servilia* (Drury, 1770)	Ruddy Marsh Skimmer	LC	√	
21.	*Diplacodes trivialis* (Rambur, 1842)	Ground Skimmer	LC	√	√
22.	*Diplacodes nebulosa* (Fabricius, 1793)	Black-tipped Ground Skimmer	LC	√	
23.	*Indothemis carnatica* (Fabricius, 1798)	Light-tipped Demon	NT	√	
24.	*Lathrecista asiatica asiatica* (Fabricius, 1798)	Asiatic Blood Tail	LC	√	√
25.	*Lyriothemis cleis* (Brauer, 1868)	Yellow Forest Chaser	LC	√	
26.	*Nesoxenia lineata* (Selys, 1879)	Striped Grenadier	LC	√	√
27.	*Neurothemis fluctuans* (Fabricius, 1793)	Grasshawk Skimmer	LC	√	√

(continued)

Table 10.1 (continued)

Sl. No.	Species name	Common name	IUCN status	Distribution	
				Andaman	Nicobar
28.	*Neurothemis fulvia* (Drury, 1773)	Fulvous Forest Skimmer	LC	√	√
29.	*Neurothemis intermedia intermedia* (Rambur, 1842)	Amber-winged Marsh Skimmer	LC	√	√
30.	*Neurothemis intermedia atalanta* (Ris, 1919)	Paddyfield Parasol	LC	√	
31.	*Neurothemis ramburii ramburii* (Brauer)	Ramburi Red Parasol	LC	√	
32.	*Orthetrum chrysis* (Selys, 1891)	Brown-backed Red Marsh Hawk	LC	√	
33.	*Orthetrum pruinosum pruinosum* (Burmeister, 1839)	Crimson-tailed Marsh Hawk	LC	√	√
34.	*Orthetrum pruinosum neglectum* (Rambur, 1842)	Crimson-tailed Marsh Hawk	LC	√	√
35.	*Orthetrum sabina sabina* (Drury, 1770)	Green Marsh Hawk	LC	√	√
36.	*Pantala flavescens* (Fabricius, 1798)	Wandering Glider	LC	√	√
37.	*Potamarcha congener* (Rambur, 1842)	Yellow-tailed Ashy Skimmer	LC	√	
38.	*Rhyothemis variegata variegata* (Linnaeus, 1763)	Common Picture Wing	LC	√	√
39.	*Rhyothemis phyllis phyllis* (Sulzer)	Common Plain Skimmer	LC		√
40.	*Tholymis tillarga* (Fabricius, 1798)	Coral-tailed Cloud Wing	LC	√	√
41.	*Tramea basilaris burmeisteri* (Kirby, 1889)	Red Marsh Trotter	LC	√	
42.	*Tramea limbata similiata* (Rambur, 1842)	Black Marsh Trotter	LC	√	√
43.	*Tramea virginia* (Rambur, 1842)	Saddlebag Glider	LC	√	√
44.	*Tramea transmarina euryale* (Selys)	Saddlebag Glider	LC		√
45.	*Trithemis aurora* (Burmeister, 1839)	Crimson Marsh Glider	LC	√	√
46.	*Trithemis festiva* (Rambur, 1842)	Black Stream Glider	LC	√	
47.	*Trithemis pallidinervis* (Kirby, 1889)	Long-legged Marsh Glider	LC	√	√
48.	*Zyxomma obtusum* (Albarda, 1881)	Dingy Duskflyer	-		√
49.	*Zyxomma petiolatum* (Rambur, 1842)	Brown Dusk Hawk	LC	√	
	Suborder Zygoptera				
	Family Calopterygidae				
50.	*Vestalis gracilis gracilis* (Rambur, 1842)	Clear-winged Forest Glory	–	√	√

(continued)

Table 10.1 (continued)

Sl. No.	Species name	Common name	IUCN status	Distribution	
				Andaman	Nicobar
	Family Chlorocyphidae				
51.	*Libellago andamanensis* (Fraser, 1924)		VU	√	
52.	*Libellago aurantiaca* (Selys, 1959)	Fiery Gem	LC		√
53.	*Libellago balus* (Hamalainen, 2002)	Clearwing Gem	EN		√
54.	*Libellago blanda* (Hagen in Selys, 1853)		–		√
	Family Coenagrionidae				
55.	*Aciagrion pallidum* (Selys, 1891)	Pale Slender Dartlet	LC	√	
56.	*Agriocnemis femina oryzae* (Lieftinck)	Variable Wisp	LC	√	√
57.	*Agriocnemis pygmaea* (Rambur, 1842)	Pygmy Dartlet	LC		√
58.	*Agriocnemis rubescens* (Selys)	Red-tipped Shadefly	–	√	
59.	*Ceriagrion auranticum auranticum* (Fraser)	Orange-tailed Sprite	LC		√
60.	*Ceriagrion cerinorubellum* (Brauer, 1865)	Orange-tailed Marsh Dart	LC	√	
61.	*Ceriagrion olivaceum* (Laidlaw, 1914)	Rusty Marsh Dart	LC	√	√
62.	*Ischnura senegalensis* (Rambur, 1842)	Senegal Golden Dartlet	LC	√	√
63.	*Pseudagrion williamsoni* (Fraser)		LC		√
64.	*Pseudagrion andamanicum* (Fraser, 1924)		–	√	√
65.	*Pseudagrion microcephalum* (Rambur, 1842)	Blue Grass Dartlet	LC		√
66.	*Pseudagrion pruinosum pruinosum* (Burmeister)	Grey Sprite	LC		√
	Family Lestidae				
67.	*Lestes malabarica* (Fraser, 1929)	Malabar Spreadwing	DD	√	
68.	*Lestes praemorsus praemorsus* (Selys)	Scalloped Spreadwing	LC	√	
	Family Platycnemididae				
69.	*Copera marginipes* (Rambur, 1842)	Yellow Bush Dart	LC	√	
70.	*Copera vittata serpica* (Selys, 1863)	Blue Bush Dart	LC		√
	Family Platystictidae				
71.	*Drepanosticta annandalei* (Fraser, 1924)		–	√	
	Family Protoneuridae				
72.	*Prodasineura verticalis andamanensis* (Fraser, 1924)	Black Bambootail	LC	√	

38 species, followed by Coenagrionidae (12 species) and Aeshnidae (8 species). The family Libellulidae was the dominant in terms of species richness (52.77 %) followed by Coenagrionidae (16.66 %) and Aeshnidae (11.11 %). According to the IUCN status, the *Libellago balus* listed as endangered, *Libellago andamanensis* as vulnerable and *Indothemis carnatica* as near threatened.

Distribution of Odonates in Great Nicobar Island

Species of odonates recorded in different location during the period of study is given in Table 10.2. Out of 20 species, *Orthetrum sabina sabina, Lathercista asiatica asiatica, Agriocnemis pygmaea* and *Diplocodes trivialis* were recorded in all the sites.

Diversity Indices in Different Locations

Species diversity index (H') was highest in Gingen Basti (2.66) and lowest at B-quarry (1.67). Simpson Index (λ) was highest at Indira Point and Lakshman Beach (0.18) followed by Kopen heat (0.17) and B-quarry (0.16) (Table 10.3).

Distribution of Odonates in Ritchie's Archipelago

Species of odonates recorded in different location during the period of study is given in Table 10.4.

Species Diversity Indices of Odonates in Ritchie's Archipelago

Species diversity index (H') was highest in Havelock (3.08) and lowest at Middle Button (0.69) (Table 10.5).

A total of 72 species of odonates under nine families and 38 genera were recorded in Andaman and Nicobar Islands. The occurrence of at least 72 species of odonates on the Andaman and Nicobar Islands suggests an excellent species richness, which likely reflects the wide variety of aquatic and terrestrial habitats on the forests. Many streams and ponds, often found to be with abundant shoreline vegetation, provide the

Table 10.2 Distribution of the odonates in different locations in Great Nicobar Island

Sl. No.	Species name	1	2	3	4	5	6	7	8	9	10	11
1.	*Gycantha dravida* (Lieftinck)	√			√	√					√	
2.	*Orthetrum sabina sabina* (Drury)	√	√	√	√	√	√	√	√	√	√	√
3.	*Rhyothemis variegate variegate* (Linnaeus)	√		√	√	√	√		√			
4.	*Brachythemis* sp.	√		√		√				√		√
5.	*Lathrecista asiatica asiatica* (Fabricius)	√	√	√	√	√	√	√	√	√	√	√
6.	*Trithemis pallidinervis* (Kirby)	√	√		√				√	√		
7.	*Pantala flavescens* (Fabricius)			√	√					√		
8.	*Ischnura senegalensis* (Rambur)	√		√			√	√				√
9.	*Neurothemis fluctuans* (Fabricius)	√		√	√	√				√		
10.	*Neurothemis intermedia intermedia* (Rambur)			√	√	√			√		√	
11.	*Neurothemis fulvia* (Drury)	√				√				√		
12.	*Vestalis gracilis* (Rambur)			√		√						
13.	*Agriocnemis femina oryzae* (Lieftinck)	√	√		√			√				√
14.	*Diplocodes trivialis* (Rambur)	√	√	√	√	√	√	√	√	√	√	√
15.	*Brachythemis contaminata* (Fabricius)	√		√		√						
16.	*Orthetrum pruinosum neglectum* (Rambur)	√		√	√	√			√			
17.	*Trithemis festiva* (Rambur)	√		√	√	√						
18.	*Rhyothemis phyllis phyllis* (Sulzer)	√		√		√						
19.	*Agriocnemis pygmaea* (Rambur)	√	√	√	√	√	√	√	√	√	√	√
20.	*Acisoma panorpoides panorpoides* (Rambur)			√	√		√					

1 Amphibian road, *2* B-quarry, *3* Gingen Basti, *4* Gandhi Nagar, *5* East-west road, *6* Indira Point, *7* Lakshman Beach, *8* Mahar Nala, *9* Navidera, *10* Kopen heat, *11* Kondul

Table 10.3 Diversity indices of odonates in GNBR

	Richness indices		Diversity indices		Hill's number		Evenness indices	
Location	*R*1	*R*2	*λ*	*H′*	*N*1	*N*2	*E*1	*E*2
Amphibian road	3.83	2.26	0.08	2.58	13.16	12.62	0.93	0.82
B-quarry	1.62	1.28	0.16	1.67	5.31	6.36	0.93	0.88
Gingen Basti	3.90	2.33	0.05	2.66	14.29	18.40	0.96	0.89
Gandhi Nagar	3.34	2.00	0.07	2.53	12.49	15.00	0.96	0.89
East-west road	3.53	2.06	0.05	2.65	14.17	18.23	0.98	0.94
Indira Point	1.66	1.15	0.18	1.75	5.77	5.65	0.90	0.82
Lakshman Beach	1.73	1.41	0.18	1.59	4.88	5.57	0.89	0.81
Mahar Nala	1.92	1.30	0.15	1.92	6.85	6.81	0.93	0.86
Navidera	2.23	1.50	0.10	2.10	8.19	9.66	0.96	0.91
Kopen heat	1.53	1.18	0.17	1.68	5.35	5.82	0.94	0.89
Kondul	1.75	1.26	0.13	1.88	6.55	7.74	0.97	0.94

Table 10.4 Distribution of the odonates in Ritchie's archipelago

		Islands of Ritchie's archipelago								
Sl. No.	Species name	Havelock	John Lawrence	Henry Lawrence	Inglis	South Button	North Button	Middle Button	Outram	Neil
1.	*Vestalis gracilis gracilis* (Rambur)	√	√		√		√			√
2.	*Lestes praemorsa praemorsa* (Selys)	√	√	√						√
3.	*Prodasineura verticalis andamanensis* (Fraser)	√								√
4.	*Copera marginipes* (Rambur)	√	√	√						√
5.	*Drepanosticta annandalei* (Fraser)	√	√							
6.	*Aciagrion pallidum* (Selys)		√			√				
7.	*Agriocnemis femina oryzae* (Lieftinck)	√	√		√	√				√
8.	*Agriocnemis rubescens* (Selys)	√					√			√
9.	*Pseudagrion andamanicum* (Fraser)	√	√					√	√	√
10.	*Anax guttatus* (Burmeister)	√		√	√					√
11.	*Gynacantha hyalina* (Selys)								√	√
12.	*Brachydiplax chalybea chalybea* (Brauer)	√								√
13.	*Crocothemis servilia servilia* (Drury)	√	√		√				√	√
14.	*Diplocodes trivialis* (Rambur)	√	√	√			√			√

(continued)

Table 10.4 (continued)

		Islands of Ritchie's archipelago								
Sl. No.	Species name	Havelock	John Lawrence	Henry Lawrence	Inglis	South Button	North Button	Middle Button	Outram	Neil
15.	*Diplacodes nebulosa* (Fabricius)	√	√							√
16.	*Lathrecista asiatica asiatica* (Fabricius)	√								
17.	*Neurothemis fluctuans* (Fabricius)	√	√	√						√
18.	*Neurothemis intermedia intermedia* (Rambur)			√						√
19.	*Orthetrum chrysis* (Selys)	√								
20.	*Orthetrum pruinosum neglectum* (Rambur)	√				√				
21.	*Orthetrum sabina sabina* (Drury)	√	√	√				√	√	√
22.	*Pantala flavescens* (Fabricius)	√								√
23.	*Tremea limbata similiata* (Rambur)	√			√					√
24.	*Trithemis aurora* (Burmeister)			√						√
25.	*Trithemis festiva* (Rambur)	√	√	√						
26.	*Acisoma panorpoides panorpoides* (Rambur)	√	√							√
27.	*Potamarcha congener* (Rambur)	√		√						√
28.	*Cratilla lineata* (Brauer)	√								√
29.	*Rhyothemis variegata variegata* (Linnaeus)	√	√	√			√			√
30.	*Tholymis tillarga* (Fabricius)	√		√						√
31.	*Zyxomma petiolatum* (Rambur)	√	√				√			√

Table 10.5 Diversity indices of odonates in Ritchie's archipelago

Islands	$R1$	$R2$	λ	H'	$N1$	$N2$	$E1$	$E2$
Havelock	5.58	2.77	0.04	3.08	21.69	23.75	0.94	0.83
John Lawrence	3.58	2.12	0.06	2.59	13.32	15.82	0.96	0.89
Henry Lawrence	2.81	1.86	0.09	2.26	9.61	11.55	0.94	0.87
Inglis	1.21	0.96	0.25	1.41	4.11	4.00	0.88	0.82
South Button	0.87	0.95	0.24	1.09	2.97	4.13	0.99	0.99
North Button	1.34	1.12	0.19	1.49	4.43	5.25	0.92	0.89
Middle Button	0.46	0.67	0.40	0.69	1.99	2.50	0.99	0.99
Outram	1.04	0.94	0.26	1.26	3.52	3.85	0.91	0.88
Neil	3.09	2.03	0.08	2.34	10.40	12.49	0.94	0.87

classic lentic habitat for odonates. Several small water bodies, streams and small rivers also provide habitat diversity, ranging from sediment and large woody debris in flowing water to vegetation-choked reaches, pools and bank areas. The high habitat complexity at multiple spatial scales provides a wide variety of odonata habitat, which in turn results in high species richness of odonata in Andaman and Nicobar Islands.

Twenty species of odonates under four families and 16 genera were recorded during the period of study. Out of these *Lathrecista asiatica asiatica, Neurothemis fluctuans* and *Orthetrum sabina sabina* were most common and abundance species in Great Nicobar Biosphere Reserve. The family Aeshnidae and Calopterygidae were representing only one species, *Gycantha dravida* and *Vestalis gracilis,* respectively. The high similarity index value indicated that two locations of Great Nicobar Island are quite similar in odonate community structure. The croplands in Gandhi Nagar supported more number of species in terms of richness and abundance. The Great Nicobar Island supports a more diverse odonate community in the Andaman and Nicobar Islands.

Thirty one species of odonates under four families and 25 genera were recorded during the period of study. Out of these *Crocothemis servilia servilia, Lathrecista asiatica asiatica, Orthetrum sabina sabina* and *Tremea limbata similiata* were most common and abundant species in all islands of Richie's archipelago. The family Calopterygidae, Lestidae, Protoneuridae, Platycnemididae and Platystictidae were represents only one species each, namely, *Vestalis gracilis, Lestes praemorsa praemorsa, Prodasineura verticalis andamanensis, Copera marginipes* and *Drepanosticta annandalei,* respectively. The diversity and evenness patterns observed were almost certainly influenced by relatively rare species. All the species observed are associated with lentic habitats. Most of the dragonflies observed oviposit in open water and most of the damselflies are associated with shallow water with emergent vegetation into which they oviposit endophytically. The croplands and grassland in Richie's archipelago offered these oviposition cues; hence, there should have been no differences in species occurrence based upon presence or absence of suitable habitat.

The ecology of the Odonata of Andaman and Nicobar Islands is very poorly known and therefore only a limited discussion of the habitat requirements of the recorded species can be given. At the very least, this work will serve as a foundation for the development of additional investigations and conservation strategies for Odonata in Andaman and Nicobar Islands. More intensive studies on the Odonata fauna of Andaman and Nicobar Islands are needed to better understand the impact of the modification and destruction of the habitat these islands in Andaman and Nicobar Islands.

References

Benke AC (1976) Dragonfly production and prey turn over. Ecology 57:915–927

Chhotani C, Lahiri AR, Mitra TR (1983) Contributions to the odonate fauna (Insecta) of Andaman and Nicobar Islands with descriptions of two new species. Rec Zool Surv India 80:467–494

Corbet PS (1999) Dragonflies, behaviour and ecology of Odonata. Cornell University Press, New York, 829 p

Cordoda-Aguilar A (2008) Dragonflies: model organisms for ecological and evolutionary research. Oxford University Press, Oxford, 288 p

Fraser FC (1924) Report on a collection of dragonflies (Odonata) from Andaman Islands. Rec Ind Mus 26(5):409–414

Fraser FC (1933) Fauna of British India including Ceylon and Burma. Odonata, vol 1. Taylor & Francis, London, 423 p

Fraser FC (1934) Fauna of British India including Ceylon and Burma. Odonata, vol II. Taylor & Francis, London, 398 p

Fraser FC (1936) Fauna of British India including Ceylon and Burma. Odonata, vol III. Taylor & Francis, London, 461 p

Kalkman VJ, Clausnitzer V, Dijkstra KDB, Orr AG, Paulson RP, van Tol J (2008) Global diversity of dragonflies (Odonata) in freshwater. Hydrobiologia 595:351–363

Lahiri AR (1975) Report on the faunistic survey (Odonata) of the South Andaman Islands. Rec Zool Surv India 68:365–366

Lahiri AR (1998) New records of Odonata (Insecta) from Little Andaman Island. Fraseria (NS) 5:57–59

Lahiri AR, Mitra B (1993) New records of dragonflies (Insecta) Odonata from Bay Islands. J Andaman Sci Assoc 9:96–99
Ludwig JA, Reynolds JF (1988) Statistical ecology, a premier on methods and computing. A Wiley-Interscience Publication, New York, 337 p
Mitra TR (1995) Odonata. In: Alfred JRB (ed) Fauna of Indravati Tiger reserve, Conservation area, series 6. Zoological Survey of India, Kolkata, pp 11–17
Mitra A (2002) Dragonfly (Odonata: Insecta) Fauna of Trashigang Dzongkhag, Eastern Bhutan. In: Gyeltshen T, Sadruddin (eds) Environment and life support systems of the Bhutan Himalaya, vol I. Sherubtse College, Kanglung, pp 40–70
Mitra A (2006) Current status of the Odonata of Bhutan: a checklist with four new records. Bhutan J Renew Nat Resour 2(1):136–143
Mitra B, Maiti PK (1992) Biogeogrphical analysis of the entofauna of the Great Nicobar Islands, Indian Ocean. Proc Zool Soc Calcutta 45(Suppl):501–508
Nandy S, Babu R (2009) On a collection of dragonflies (Odonata: Anisoptera) form Andaman and Nicobar Islands. Rec Zool Surv India 109(Part 7):35–51
Ram R, Chandra K, Yadav K (2000) Studies on the Odonata fauna of Andaman and Nicobar islands. Rec Zool Surv India 98(3):25–60
Samways MJ (2008) Dragonflies and damselflies of South Africa. Pensoft, Sofia Belgaria, 297 p
Selys LED (1853) Synopsis des Catperygines. Bull Acad Belg Sci 20(Annex):73 p
Selys LED (1863) Synopsis des Agrionines, Quetrieme Legion: Platycnemis. Bull Acad Belg Sci 2(16):150–176
Selys LED (1871) Synopsis des Cordulines. Bull Acad Belg Sci 2(32):519–565
Subramanian KA (2009) A checklist of Odonata of India. Zoological Survey of India, Kolkata, 36 p
Yeh WC, Veenakumari K (2000) Description of *Gynacantha andamanae* spec. Nov. from South Andaman Island, India Ocean (Anisoptera: Aeshnidae). Int J Odonatol 3(2):163–167

Freshwater Molluscs of India: An Insight of into Their Diversity, Distribution and Conservation

11

Basudev Tripathy and Amit Mukhopadhayay

Abstract

Freshwater molluscs are integral part of aquatic ecosystem and play an important role in the biogeochemical cycle. There are many species which are distributed both in estuarine and freshwater ecosystem. However, the endemicity is high in the Western Ghats and northeastern parts of India. Also, there are intra-variations among species that make freshwater Mollusca important in terms of taxonomy. This chapter deals with thorough detailing about the available information on freshwater gastropods and bivalves of India with their economic importance and medical value as well as taxonomic detailing on the status and conservation and management of the freshwater molluscs and their habitats in India.

Keywords

Mollusca • Diversity • Endemism • Western Ghats • Conservation • India

Introduction

Molluscs are an important group for aquatic biodiversity and, where abundant, play an important role in ecosystem functioning (Vaughn et al. 2004). They form an important component of most biological monitoring programmes that rate water quality and status of aquatic systems based on invertebrate assemblages (Tonapi 1980; Ponder 1994; Seddon 1998; Strong et al. 2008). Bivalves in particular, as they accumulate toxic substances to a greater extent than other organisms, are used to monitor water quality (Salanki et al. 2003; Bogan 2008).

Freshwater molluscs are essential to the maintenance of wetland ecosystems, primarily due to their control of water quality and nutrient balance through filter-feeding and algal-grazing and, to a lesser degree, as a food source for predators including a number of fish species, and in some parts of the world, they compose a significant food resource, especially for the rural poor and tribal. In some regions, they are one of the most threatened groups of freshwater taxa (Kay 1995).

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The impact of developments such as dams, and siltation caused by deforestation and agricultural clearance, has not been adequately researched, and there is little awareness of the complex life histories of some groups such as unionid mussels that rely on the maintenance of migratory fish runs to carry their parasitic larvae to the river headwaters. Many species are also restricted to microhabitats, such as the riffles (areas of fast current velocity, shallow depth, and broken water surface) between pools and runs (areas of rapid nonturbulent flow).

Review of Literature

Studies of freshwater molluscs of India were at their peak during the late nineteenth and early twentieth centuries. Prashad (1928) and Preston (1915) contributed much to our knowledge on the taxonomy and distribution of molluscs in the region. Later, the Zoological Survey of India surveyed northeastern Indian states and published checklists of species occurring in different states (e.g. Fauna of West Bengal, Fauna of Meghalaya and the Fauna of Tripura). Recently, Nesseman et al. (2007) contributed to our knowledge of the freshwater molluscs of the Ganga river basin in India and Nepal. However, there are some taxonomic issues that need to be addressed urgently (e.g. the species recently described by Nesseman et al. (2007) needs further clarification). The taxonomic status of several species, including *Lymnaea shanensis* and *Parreysia olivacea*, collected from lakes in Myanmar need to be verified as these species have not been collected again since they were described. There has been little recent study of molluscs across large parts of the region, including Bhutan, parts of Nepal, and Myanmar, as well as several states in India.

We have attempted here to consolidate the freshwater Mollusca of India in brief including information about their origin, ecology, distribution, identification characters, habitat, edible form and parasites, medical importance, and conservation and recommendation.

Zoogeographical Origin of Freshwater Mollusca Fauna in India

The freshwater molluscs are distinguished into two natural groups, namely, primary freshwater and secondary freshwater (Subba Rao 1989). Nesemann et al. (2007) mentioned another two that is peripheral freshwater fauna of marine origin and peripheral freshwater fauna of terrestrial origin. The primary freshwater molluscs are confined exclusively to the freshwater habitats, i.e. which have their main evolution and distribution since the Paleozoic period in continental freshwater. The secondary freshwater are those which have their main evolution and distribution since the Paleozoic period in marine habitats. They are secondarily invading freshwater habitats since carbon period (Nesemann et al. 2007). There are many species which are distributed both in estuarine and freshwaters. Such genera as *Neritina, Clithon, Septaria, Scaphula* and *Novaculina* belong to this category. These genera are primarily freshwater with tolerance to saline waters. The family Stenothyridae and subfamily Iravadiinae include primarily estuarine or saline water species, occasionally occurring in freshwaters. Among bivalve the genera *Villorita, Geloina, Batissa* and *Tanysiphon* are primarily estuarine, rarely occurring in freshwaters. One species of the family Assiminedae is also an estuarine species occasionally found in freshwater also.

Habitat

Freshwater molluscs are common in ponds, lakes, quiet water pools, and flowing waters like perennial rivers, irrigation canals, etc. The malacofauna of the streams may be somewhat different from that of the stagnant waters. Most of the endemic freshwater molluscs are found in the Western Ghats and Nilgiri and are remarkable for their characteristics.

Gastropods are generally found attached to submerged vegetation, rocks, sticks, bricks, etc., but bivalves live partly buried in the sand or mud. Similar to the gastropods, the bivalves exhibit variations in shell depending upon the ecology of the species and may produce ecophenotypes (Subba Rao 1989).

Anhydrobiosis

Freshwater molluscs are usually faced with an annual dry season. Gastropods and bivalves show varying capacity to survive desiccation. Many snails can overcome this by aestivation either under dead vegetation, rocks, bricks or debris or actively burrowing at least the aperture of the shell in the mud. Some shells are capable of anaerobic respiration. With the advent of favourable conditions, the molluscs resume to their normal activities. The discontinuous and transient nature of freshwater bodies leads to isolation of snails or bivalves into small local populations. Nevertheless, much remains to be worked on the ecology of Indian freshwater molluscs.

Role of Freshwater Molluscs in the Ecosystem

Freshwater molluscs are one of the most diverse and threatened groups of animals (Vaughn et al. 2004; Lydeard et al. 2004). They are mostly unobtrusive and are not normally considered charismatic creatures, rarely attracting the attention of the popular media, unless in a negative light, as some species play a significant role (as a vector) in the transmission of human and livestock parasites and diseases (Sinha and Srivastava 1960). This is unfortunate, as they also play a key role in the provision of ecosystem services and are essential to the maintenance of wetlands, primarily due to their contribution to water quality and nutrient cycling through filter-feeding, algal-grazing, and as a food source to other animals (Strayer et al. 1999; Vaughn et al. 2004, 2008; Howard and Cuffey 2006). Some species are of high commercial value as food or ornaments (e.g. clams and some mussels and snails).

Freshwater Molluscs Used as Food

The freshwater molluscs are important as additional resources of protein for the increasing human population of our country. An increase in the shell production can augment our protein-rich food supply. It has been observed that at least 22 freshwater species are used as food and there is regular sell of shellfish in several markets of eastern (West Bengal) and northeastern states (Table 11.1). Shellfishes are harvested from the natural resources by different methods and brought to the markets. There are no regular markets in some places, but still people use the shellfish as food very frequently. It is very popular among poor and tribal people of India.

Freshwater Molluscs and Diseases

In India, millions of people and their livestock are infected with schistosomiasis, amphistomiasis, and paragonimiasis and other trematode parasites. Efforts to control schistosomiasis and other snail-borne diseases depend to a great extent on knowledge of the freshwater snails which serve as intermediate hosts for the parasites.

Freshwater molluscs are the carrier for schistosomiasis (Bilharziasis) in humans. The only report of this disease in the assessment region is in Gimi Village in Ratnagiri District of Maharashtra State (Gaitonde et al. 1981). The freshwater molluscs species *Ferrissia tenuis* (LC) (Bourguignat 1862) is a target species for control programmes against *Schistosoma haematobium*. Other species from which schistosome infection has been reported are in *L. exustus* and *L. luteola* (Table 11.2). The question of the transmission of urinary schistosomiasis elsewhere in India still remains a mystery. Future research should focus on this (Table 11.3).

Distribution

In India distribution of the freshwater molluscs shows some peculiarity that is scattered and discontinuous distribution of major species.

Table 11.1 Common use of freshwater mollusca as food and other purpose in various parts of India

Name	Common name/local name	State used as food
Gastropoda		
Bellamya bengalensis (Lamarck)	Googli, Ghongi (Hindi, Kurmali)	Arunachal Pradesh (Triap), Bihar, Jharkhand, Manipur, Meghalaya, Mizoram, Odisha, West Bengal
	Chota Genda (Ho)	
	Rookai/Ketla/Baska (Santhali), Googli, Shamuk (Bengali)	
	Genda Shamuk/Jal Ghanti (oriya). Thoroi (Manipur), Echalok (Garo), Mattah (Khasi), Sipuru/Dhan Samuk (Baghmara), Chenkal (Mizo), Chikangbook (Riang)	
Bellamya dissimilis (Mueller)	Googli, Ghongi (Hindi, Kurmali)	Jharkhand, Bihar, Meghalaya, Odisha
	Chota Genda (Ho)	
	Rookai/Ketla/Baska (Santhali), Googli, Shamuk (Bengali)	
	Genda Shamuk/Jal Ghanti (oriya). Thoroi (Manipur), Echalok (Garo), Mattah (Khasi), Sipuru/Dhan Samuk (Baghmara)	
Angulyagra oxytropis (Benson)	Thoroi (Manipur)	Manipur
Cipangopaludina lecythis (Benson)	Chenkal (Mizo), Chikangbook (Riang), Thoroi (Manipur)	Manipur, Mizoram
Pila globosa (Swainson)	Ghonga (Hindi, Kurmali, Mundari)	Bihar, Jharkhand, Odisha, West Bengal
	Genda (Ho, Oriya)	
	Marang rakai (Santhali), Shamuk (Bengali)	
Pila theobaldi (Hanley)	Yafu (Garo), Mattah (Khasi), Hamuk/Tomka Samuk (Bagmara)	Meghalaya
Brotia (*Antimelania*) *costula* (Rafinesque)	Mochra Samuk (Bengali), Lai Thoroi (Manipur), Echalu (Garo), Mattah (Khasi), Sipuru rodong *Baghmara	Arunachal Pradesh, Manipur, Meghalaya, West Bengal (North Bengal)
Paludomus (*Paludomus*) *blanfordiana* Nevill	Chenkal (Mizo), Chikangbook (Riang), Thoroi (Manipur)	Arunachal Pradesh, Manipur, Mizoram
Paludomus (*Paludomus*) *conica* (Gray)	Thoroi (Manipur), Achhilu (Garo), Mattah (Khasi), Sipuru/Samuk (Baghmara), Chenkal (Mizo), Chikangbook (Riang)	Arunachal Pradesh, Manipur, Meghalaya, Mizoram
Paludomus (*Paludomus*) *pustulosa* Annandale	Chenkal (Mizo), Chikangbook (Riang)	Mizoram
Paludomus (*Paludomus*) *regulata* Benson	Echalok (Garo), Mattah (Khasi), Sipuru/Samuk (Baghmara), Chenkal (Mizo), Chikangbook (Riang)	Meghalaya, Mizoram
Bivalvia		
Solenaia soleniformis (Benson)	Tuikep (Mizo), Clampy (Beta)	Manipur
Lamellidens corrianus (Lea)	Chachni/Katla (Kurmali/), Sunti (Ho), Jhinuk/Samuk (Oriya), Baska/Sunti (Santhali) Jhinuk//Katli (Bengali) Kongran (Manipuri)	Bihar, Jharkhand, Orissa, West Bengal, Manipur
Lamellidens generosus (Gould)	Kongran (Manipuri)	Manipur

Lamellidens marginalis (Lamarck)	Chachni/Katla (Kurmali/), Sunti (Ho), Jhinuk/Samuk (Oriya), Baska/Sunti (Santhali) Jhinuk//Katli (Bengali), Yafi (Garo), Mattah (Khasi), Jhinai (Bagmara)	Bihar, Jharkhand, Odisha, West Bengal, Meghalaya
Lamellidens phenchooganjensis (Preston)	Tuikep (Mizo), Clampy (Beta)	Mizoram
Parreysia (*Parreysia*) *burmanus* (Blanford)	Kongran (Manipuri)	Manipur
Parreysia (*Parreysia*) *favidens* (Benson)	Chachni/Katla (Kurmali/), Sunti (Ho), Jhinuk/Samuk (Oriya), Baska/Sunti (Santhali) Jhinuk//Katli (Bengali) Kongran (Manipuri), Tuikep (Mizo), Clampy (Beta)	Bihar, Jharkhand, Orissa, West Bengal, Manipur, Mizoram
Parreysia (*Parreysia*) *sikkimensis* (Lea)	Kongran (Manipuri), Tuikep (Mizo), Clampy (Beta)	Manipur, Mizoram
Parreysia (*Radiatula*) *caerulea* (Lea)	Chachni/Katla (Kurmali/), Sunti (Ho), Jhinuk/Samuk (Oriya), Baska/Sunti (Santhali) Jhinuk//Katli (Bengali) Kongran (Manipuri), Tuikep (Mizo), Clampy (Beta)	Bihar, Jharkhand, Orissa, West Bengal, Mizoram
Parreysia (*Radiatula*) *occata* (Lea)	Kongran (Manipuri)	Manipur
Trapezoideus exolescens exolescens (Gould)	Kongran (Manipuri), Tuikep (Mizo), Clampy (Beta)	Manipur, Mizoram

Table 11.2 Disease associated with freshwater mollusca in India

Schistosomiasis				
Intermediate host	Host	Trematode species	Distribution	Reported by
Ferrissia tenuis	Man, monkey	*Schistosoma haematobium* (Bilharz)	Ratnagiri, Maharashtra	Gadgil and Shah (1952)
Indoplanorbis exustus	Horse, donkey, camel, sheep, goat, cattle, buffaloes, zebra, antelope	*Schistosoma indicum* Montgomery	Throughout India	Dutta and Srivastava (1955)
Lymnaea luteola	Dog, pig, cat, sheep, goat, rabbit, guinea pig, rat	*Schistosoma incognitum* Chandler	Uttar Pradesh, Tamil Nadu, Bihar, Jharkhand, West Bengal	Dutta and Srivastava (1955)
f.australis, f. succinea, f. ovalis				
Indoplanorbis exustus, Lymnaea luteola, Lymnaea acuminata	Buffaloes, bandicoot, cattle, goat, guinea pig	*Schistosoma spindle* Montgomery	Throughout India	Dutta and Srivastava (1955)
Indoplanorbis exustus, Lymnaea luteola	Cat, buffalo, goat	*Schistosoma nasale* Rao	Throughout India	Dutta and Srivastava (1955)
Lymnaea luteola	Buffaloes, rabbit guinea pig, mouse	*Orientobilharzia dattai* (Dutta and Srivastava)	Bareilly (UP)	Dutta and Srivastava (1955)
Lymnaea auricularia, Lymnaea acuminata rufescens	Cattle, buffalo, goat, horse, donkey, mule, camel	*Orientobilharzia turkestanicum* (Skrjabin)	Kashmir	Dutta and Srivastava (1955)
Amphistomiasis				
Bithynia (*Dignostoma*) *pulchella* (*Benson*), *Lymnaea auricularia Lymnaea luteola*	Highly pathogenic to man, pig	*Gastrodiscoides hominis*	Throughout India	Mukherjee and Chauhan (1965)
Indoplanorbis exustus				
Gyraulus convexiusculus				
Paragonimiasis				
Terebia granifera, Melanoides tuberculata	Brain, spinal cord and other organs of man, cat, dog, fox, pig, goat, cattle	*Paragonimus* spp.	Various part of India	Mukherjee and Chauhan (1965)
	Diseases: Jackson epilepsy, Eosinophilic meningitis and other nervous diseases			

Table 11.3 Medical importance of freshwater mollusca

Species	Medicinal importance	Economic importance	Reported by
Bellamya spp.	(1) Soup prepared from the flesh used to cure asthma, arthritis, joint swelling, rheumatism and quick healing of wound	Commonly used as food in various part if India. Mainly tribal people, lower income group and some section of middle class people taken as a food. Soft fleshy part is a very prestigious food items in some places	Dey (2008)
	(2) The snails cleaned and kept in water for few hours and then water is used like an eye drop to cure conjunctivitis		
Pila globosa	Soup prepared from the eggs used to cure thee rickets of the children	Used as food by the tribal and lower income group	Dey (2008)
		These are also valuable resource of food for ducks and hybrid Magur (fishes) in Sundarban area	
Lamellidens marginalis, Lamellidens corrianus	(1) Soup prepared used to cure cardiac aliments and blood pressure	They produced the precious item pearl. These pearls are various in size and shape and having good luster	Dey (2008)
	(2) Curry and soup is used for faster growth and sound health		
	(3) Shell ash after burning mixed with honey used for the remedy of giddiness, nervousness and dehydration during the summer months		
	(4) Shell lime water used for killing of intestinal parasites		
Parreysia (P) favidens	(1) Soup prepared used to cure cardiac aliments and blood pressure	This species used as food by a section of tribal and lower economic people. It is also used to feed the ducks	Dey (2008)
	(2) Shell lime water used for killing of intestinal parasites		
Polymesoda bengalensis		This species is also economically very important. Huge quantities of these shells are collected from the different parts of Sunderbans and brought to the shell factories at canning where they powered by crushing them and used as calcium resources in poultry feed	

The freshwater gastropod fauna belongs to the clades Neritimorpha, Caenogastropoda and Heterobranchia (including the Pulmonata) (Strong et al. 2008). They are distributed in a wide range of habitats including rivers, lakes, streams, swamps, springs, temporary ponds, drainage ditches and other ephemera land seasonal waters. Highest diversity occurs in the tropics with decreasing species richness and endemicity at higher latitudes (Strong et al. 2008) and altitudes. The Neritidae, Assimineidae and Iravadiidae are brackish water marine families. In the assessment region, seven species from Assimineidae and two species from Iravadiidae are represented, and they are exclusively brackish water species.

Thirteen gastropod families are in 33 genera comprising 112 species (Table 11.1) from the Caenogastropoda and Pulmonata. The Thiaridae is the most dominant family representing 19 % of species within the region followed by Planorbidae (17 %) and Lymnaeidae (9 %). In terms of genera representation, the Planorbidae has the highest number of genera with 19 %, followed by Neritidae (13 %) and Bithyniidae (13 %).

Freshwater bivalves of the India belong to five families (16 genera and 74 species). Family Unionidae is the dominant group, containing 66 % of species found in the region, followed by Sphaeriidae (21 %) and Corbiculidae (10 %) (Table 11.4). Family Solecurtidae is represented by only one species, *Novaculina gangetica*, endemic to coastal areas of West Bengal.

Many type localities need to be resurveyed to confirm if described range-restricted freshwater molluscs are still present or have already become extinct and to confirm the taxonomic status of previously described species. Except for a few commonly occurring species, information on ecology, population structure, and dynamics, distribution, and habitat preference is not known. A greater degree of taxonomic research and training is also required to ensure that widely accepted taxonomic concepts are adopted. Taxonomic research is central to ecological studies and conservation, but it is one of the most neglected disciplines (Stuart et al. 2010), especially in counties rich in biodiversity but poor in resources. Training in taxonomic expertise and enhanced communication and outreach are basic requirements of biodiversity conservation. Taxonomic knowledge of freshwater molluscs of India is severely lacking. Preston's Fauna of British India written in 1915 is still the fundamental book comprising the taxonomic account of freshwater gastropod and bivalves of the Indian subcontinent, though Subba Rao (1989) updated the taxonomic knowledge of the region. Since then the taxonomic knowledge has not been developed among regional taxonomists. There are many under- and unexplored areas that can be expected to contain both undescribed species and new populations of currently known species, but there are hardly any new descriptions of molluscs in the region in the decades that have passed since Subba Rao (1989) with few exceptions. It is possible that many of the data deficient species, and especially those that have not been re-collected since description, may be synonyms of common or widespread species when fresh material is collected for study. There is an urgent need to undertake a thorough taxonomic review of the molluscs, combined with the collection of fresh study material and research into species distributions.

Many species are widely distributed in India and its neighbouring countries. However, some species are highly restricted in distribution particularly in streams of the Western Ghats. For example, *Cremnochonchus syhadrensis, C. conicus,* and *C. carinatus* belong to the family Littorinidae (periwinkles) and are the only freshwater genus in an otherwise entirely marine family; they are adapted to the spray zone of perennial waterfalls from a few localities in the Karnataka and Maharashtra region of the Western Ghats. Another restricted range species is *Pseudomulleria dalyi* (Etheridae), an endemic cemented bivalve confined to couple of rivers in the central Western Ghats that is also a rare Gondwanaland relict (Madhyastha 2001). The family Etheridae shows unique discontinuous distribution, with recognized genera, viz., *Acostea* (South America), *Pseudomulleria* (India), and *Etheria* (Africa) (Smith 1898; Bogan and Hoeh 2000). The hill stream genus *Turbinicola* (Pilidae), which is an inhabitant of streams around Khandala, in Maharashtra resembles the South American hill stream genus *Asolene*, suggesting convergent

Table 11.4 Up-to-date list of species, identifying characters, their habitat and distribution

Name	Key character for identification	Habitat	Distribution
Neritina (*Neritina*) *pulligera* (Linn.)	The last whorl is so greatly expanded that earlier whorls are completely enclosed; wide columellar callus, outer lip with deep orange band	Found in rivers and streams, near the upper limit of tidal influence and on stones	Andaman and Nicobar Islands and Tamil Nadu
Neritina (*Dostia*) *platyconcha* (Annandale and Prashad)	Shell thin, translucent, broadly oval, slightly truncated posterior, columellar plate separated from the lower margin of the shell and extend more than half way across its mouth	Rivers (tidal mudflats) Feed as grazer on diatoms.	Known from type locality only (Kahadak river)
Neritina (*Dostia*) *violacea* (Gmelin)	Shell thick, ovate, crepidula shape, whorls 2, spire minute anteriorly twisted inwards, protruding out as a beak; periostracum yellowish brown	Found in creeks and rivers with tidal influence, adhering to the roots and branches of the trees and also creeping on the mud flats	Andaman Islands, Andhra Pradesh, Goa, Gujarat, Karnataka, Kerala, Odisha, Tamil Nadu and West Bengal
Neritina (*Neripteron*) *auriculata* (Lamarck)	Shell semiglobular, aperture wide. Periostome broad and produced into two auricles or wings at the upper and lower columellar sides	The species neither survive in higher salinity nor occur in pure freshwater (tidal mudflats) of estuarine Feed as grazer on diatoms	Andaman and Nicobar Islands and Tamil Nadu
Neritina (*Vittina*) *perottetiana* (Recluz)	Shell semi-globose and smooth, operculum thin and externally light grey, inner columellar margin straight with 5–10 denticulation or sometimes smooth	Hill streams	Tamil Nadu (endemic to Western Ghats only)
Neritina (*Vittina*) *smithi* (Wood)	Shell oval, whorls 5, apex blunt, columellar margin with 13–15 teeth. Shell glistering, white or dull brown with strong black, longitudinal, undulating and interrupting lines and bands	Amphibious life style in the upper tidal zone, Gangetic estuary attached with rocks or bricks. They preferred shadowed loam and mud under dense woody riparian vegetation (Nessman 2007)	Tributaries of the Bay of Bengal, Ganga estuaries, downstream of Hugli River in West Bengal: Barrackpore
Neritina (*Vittina*) *turrita* (Gmelin)	Shell thick, oblong, globose, whorls 4; inner columellar margin with 16–17 distinct teeth	Tidal mud flats, attached with tree roots, coral reef boulders	Nicobar Islands: Kamorta and Car Nicobar
Neritina (*Vittina*) *variegata* Lesson	Shell oval, short and distinct spire, smooth surface with black spiral bands or zigzag markings, columellar callus with orange spots, inner with 8–11 denticles	Tidal mud flats attach with stones and tree roots	Andaman and Nicobar Islands
Neritodryas subsulcata (Sowerby)	Shell blackish brown with yellowish brown markings. Sculpture consists of conspicuous broad spiral ribs with distinct grooves in between and crossed by longitudinal striation	Tidal mud flats, attached with tree roots, coral reef boulders, stones, Jetties' wall	Andaman and Nicobar Islands

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Theodoxus (*Clithon*) *bicolor* (Recluz)	Shell is generally olive green or olive brown with small dark squares and the spire is more produced	Mountain stream, attached with tree roots, coral reef boulders	Andaman and Nicobar Islands
Theodoxus (*Clithon*) *corona* (Linnaeus)	Shell small with shouldering body whorl, spine present or absent	Found in streams with moderate salinity	Nicobar Islands (Katchal)
Theodoxus (*Clithon*) *reticularis* (Sowerby)	Shell yellowish olive or green with oblique angulated red or black thin lines, often forming a coarse reticulation or network, a well-developed tooth on the inner columellar margin	Found in estuarine water rarely extending to the freshwater	West Bengal, Tamil Nadu: Porto Novo
Septaria lineata (Lamarck, 1816)	Cap-like shell, with the last whorl greatly expanded. The operculum reduced to a small quadrangular plate	On rocks in perennial and rapidly flowing streams near the zone of tidal influence; also found in saline water	Andaman Islands, Tamil Nadu (Coleron River) and West Bengal: 24 Parganas (South)
Septaria porcellana (Linnaeus)	Shell thick, apex is generally projecting beyond the posterior margin	Attached with rocks in freshwater streams	Andaman and Nicobar Islands
Taia crassicallosa (Annandale and Rao)	Shell globose, spire short and broad, ridges well developed; squamous tubercles, columellar callus greatly thicken	Large lakes, wetlands of northeastern region	Manipur: Imphal, Jiribam, Bishenpur, Tripura
Bellamya bengalensis (Lamarck) Form *typica* Form *annandalei* (Kobelt) Form *balteata* (Benson) Form *colairensis* (Annandale) Form *doliaris* (Gould) Form *eburnean* (Annandale) Form *gigantea* (Reeve) phase *halophila* (Kobelt) Form *mandiensis* (Kobelt)	Shell thin, more or less smooth, with three or more colour bands; embryonic shell delicate and thin, with three primary rows of chaetae, low ridges, the lower most well developed, sometimes developing into a keel, secondary ridges bearing chaetae may develop between the primary ones	Ponds, ditches, small water bodies, rivers, streams. They are mainly benthic	Common throughout India
Bellamya crassispiralis (Annandale)	Shell bluntly acuminate, whorls tumid, body whorl transverse and oblique, anterior margin strongly sinuate with six delicate ridges	Chakpi stream	Manipur Valley (known by type)
Bellamya crassa (Benson)	Shell olive brown, globose without colour bands, spire small and blunt, shell surface sculptures with fine wavy spiral lines	Ponds, burrowing in mud or sand in shallow waters, often in groups	Andhra Pradesh, Assam, Karnataka, Meghalaya, Odisha, Gujarat, West Bengal

Bellamya dissimilis (Mueller)	Spire high, narrow and swollen, body whorl with one slightly elevated ridge or broad and obscure, pale spiral band	Prefers stagnant waters, large wetlands, paddy field and even temporary water bodies. It is rarely found form river	Common throughout India Up to the elevation of 6,000 ft
Bellamya micron (Annandale)	Shell thin, transparent, small, ovately conical, finely, minutely striate; whorls 5, rounded aperture sub oval, outer lip thin	Habitat unknown	Manipur Valley (known by type)
Angulyagra microchaetophora (Annandale)	Shell small, thin, imperforate, sharply acuminate, a blunt peripheral ridge on the body whorl; columellar strongly arched, outer lip sharp. Spiral whorls with two fine spiral ridges	Occurs in ponds on floating grass stems and longer part of plant that float on the water surface	Nagaland, Assam, Manipur
Angulyagra oxytropis (Benson)	Shell large, broadly conical, perforate with prominent spiral ridges, outer lip thin but not sharped	Occurs in large lakes, ponds, wetland, on floating grass stems	Manipur Valley, Meghalaya, Tripura (South)
Cipangopaludina lecythis (Benson)	Shell olive green when fresh, spire conical, apex acuminate, whorls tumid and flattened above, suture deep, aperture large and broadly oval, outer lip sharp and tinged with black	Lakes and large wet lands	Manipur Valley (Loktak lake, Meghalaya, Tripura
Pila globosa (Swainson) Var. *incrassatula* (Nevill) Var. *minor* (Nevill)	Shell globose, inflated body whorl, depressed spire, suture shallow, colour bands present inside the aperture	Lives in temporary water bodies which are dry for at least one time per year. It inhabits large wetlands, pool, ditches and occasionally in the river	Assam, Bihar, Himachal Pradesh, Jharkhand, Maharashtra, Madhya Pradesh, Meghalaya, Orissa, Rajasthan, Uttar Pradesh, West Bengal
Pila scutata (Mousson) Var. *compacta* (Reeve)	Shell ovoid or semi-globose with large body whorl, spire elongated, whorls descending step-like, suture deeply impressed without carination, olivaceous green with faint brownish spiral bands in young adults	Creeks of estuarine tidal influence within mudflats	Andaman and Nicobar Islands
Pila scutata compacta (Reeve)	Shell larger, thicker and stouter with strong vertical striations, columellar callus much broader, aperture more ovoid, darker in colour with faint transverse colour bands	Small pools, wetlands and sometimes in river bed; creeks of estuarine tidal influence within mudflats	Andaman and Nicobar Islands, Jharkhand
Pila theobaldi (Hanley)	Shell large, whorls globose, umbilicus widely open, aperture without colour bands	Lakes, rivers, small wetlands	Manipur, Meghalaya, Tripura
Pila virens (Lamarck)	Body whorl highly inflated and shouldered above; spire short, suture deep and distinctly canaliculated, aperture ovate	Estuarine backwater; wet lands, lakes, pools, paddy fields	Andhra Pradesh, Kerala, Maharashtra Tamil Nadu

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Pila (*Turbinicola*) *saxea* (Reeve)	Shell oblong-ovate, rather solid, with a narrow umbilicus, spire rather obtuse, whorls a little depressed round the upper part, obsoletely angled and then rounded; olive, aperture pyriformly oblong, columellar lip thinly reflected	Hill streams around Khandala and Igatpuri, Western Ghat	Maharashtra
Valvata piscinalis (Mueller)	Shell globose, brownish yellow, whorls 5–6, deeply and narrowly umbilicate, depressed at the apex, with dense, fine longitudinal striations and faint spiral ridges	Lakes, slow running rivers	Kashmir
Mainwaringia paludomoidea (Nevill)	Shell conical, imperforate, spire acuminate, bright yellowish brown, body whorl with three distinct, broad dark brown bands showing through the aperture, sculpture with spiral striae	Attached on the trunks and aerated root of mangroves trees submerged at high tide	Gangetic delta
Cremnoconchus syhadrensis (Blanford)	Shell globose, perforate, periostracum olive green to brown, whorls 4 ½, body whorl large, suture distinct, sculptured with distinct spiral granular ridges in the upper part and fine spiral striae in the lower half, aperture oval, a broad; white band in between two brown bands inside the aperture	Hill streams	Maharashtra (Western Ghats)
Cremnoconchus (*Lissoconchus*) *carinatus* (Layard)	Shell ovately conical, spire short and exerted, whorls inflated, sharply keeled in the middle; sculptured with minute longitudinal striations; shell olive-yellow, marked with two indistinct broad brown bands, seen distinctly in the aperture	Hill streams	Maharashtra (Western Ghats)
Cremnoconchus (*Lissoconchus*) *conicus* (Blanford)	Shell ovately conical, suture distinct, angle at the periphery	Hill streams	Maharashtra (Western Ghats)
Potamopyrgus (*Indopyrgus*) *nevilli* (Thiele)	Shell oval, smooth; spire short and blunt, body whorl large, aperture slightly oblique, margin thickened, operculum thin, transparent and paucispiral	Estuarine creeks	Not known beyond Andaman's
Bithynia tentaculata kashmirensis (Nevill)	Shell conically ovate, spire more pointed, aperture pyriformly ovate	Very common in paddy fields	Kashmir
Bithynia troscheli (Paasch)	Shell small, ovately fusiform, suture rather deep, aperture ovate	Very common in paddy fields	Kashmir

Bithynia (*Digoniostoma*) *cerameopoma* (Benson)	Shell oblong-ovate, whorls 5, suture impressed, umbilicus moderately narrow and deep	Stagnant shallow water of the lower Gangetic plains, such as paddy fields and oxbow lakes, occasionally occur in slow running rivers and streams	Andhra Pradesh, Assam, Bihar, Delhi, Jharkhand, Madhya Pradesh, Meghalaya, Punjab, Rajasthan, West Bengal
Bithynia (*Digoniostoma*) *evezardi* (Blanford)	Spire conical, shell sculpture with regular close, impressed spiral lines	Stagnant shallow water, occasionally occur in slow running rivers and streams	Maharashtra
Bithynia (*Digoniostoma*) *pulchella* (Benson)	Shell elongate, spire longer than body whorl, suture depressed, umbilicus almost closed and aperture oval	It lives in the lentic part of the rivers and wetland ponds within mud. High density also occurs within polluted water	Throughout India
Bithynia (*Digoniostoma*) *textum* Annandale	Shell oval, whorls 4 ½, spire shorter than the body whorl	Lakes, rivers	Manipur: Thoubal (endemic to Manipur)
Gabbia orcula Frauenfeld *Var. producta* (Nevill)	Shell globosely conic, smooth, almost imperforate, whorls 4, slightly rounded, body whorls swollen, suture deep, columellar margin not much reflected	Stagnant water with dense vegetation, e.g. wetland, small ponds and paddy fields	Andhra Pradesh, Assam, Bihar, Delhi, Jharkhand, Maharashtra, Manipur, Punjab, Rajasthan, Uttar Pradesh, West Bengal
Gabbia stenothyroides (Dohrn)	Shell ovate, whorls 4–5, convex, smooth, body whorl proportionately larger, spire short	Wetland, small ponds and paddy fields	Andhra Pradesh, Maharashtra, Tamil Nadu
Gabbia travancorica (Benson)	Shell conically globose, whorls 4 ½, columellar margin ridge-like	Stagnant water bodies and back water	Andhra Pradesh, Kerala
Mysorella costigera (Kuester)	Shell ornamented by strongly raised spiral ridges weaker with finer and spiral ridges between them. Shell uniformly pale horny brown	Occurring in muddy bottom in plains of Chennai	Andhra Pradesh, Karnataka, Pondicherry, Tamil Nadu
Tricula gravely (Prashad)	Shell elongate, suture oblique, aperture rounded, outer lip uniformly thickened	Found in still creeks of the plains, attached on weeds	Still creek among small islands in the bed of Narmada River at Hoshangabad, Madhya Pradesh
Tricula montana (Benson)	Shell conically ovate, suture oblique, curve, canaliculated, aperture rounded, outer lip uniformly thickened	Found on the stems and leaves of aquatic plant in the stream floating through marsh at Bhimtal Lake	Assam, Uttarkhand: Bhimtal
Stenothyra blanfordiana (Nevill)	Shell sub-ventricose, ovate, spire short, spiral whorls increasing irregularly, body whorl swollen, aperture bi-angulate, suboval	River bed within mudflats	Orissa, Tamil Nadu, West Bengal
Stenothyra deltae (Benson)	Shell small, thick, sculptured with spiral punctured lines; periostracum thick and often spiral rows of spine	Found crawling on the mud at the upper region of bank of river	West Bengal

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Stenothyra foveolata (Benson)	Shell ovately conical with acute apex, suture shallow, sculpture with spiral pits or punctuate markings, aperture oblique ovate	Gangetic river bed within mud	Bihar, West Bengal
Stenothyra hungerfordiana (Nevill)	Shell small, almost cylindrical, apex obtuse	Creeks of tidal influence	Andaman's only
Stenothyra minima (Sowerby)	Shell small, ovately turbinate, narrowly perforate, whorls 5, smooth, regularly increasing, body whorl convex and rapidly descending in front	Riverbeds	Gujarat, Maharashtra Orissa
Stenothyra nana (Prashad)	Shell ovately conical, imperforate; whorls 4, increasing very rapidly, body whorl large, sub-rhomboidal in dorsal view	Hugli River and its tributaries	West Bengal
Stenothyra ornata (Annandale and Prashad)	Shell imperforate, ovately conical; apex acute, spiral whorls distinctly keeled in the middle, last 4 whorls with spiral rows of blunt, flattened, blackish spines	Hugli River and its tributaries	West Bengal
Stenothyra soluta (Annandale and Prashad)	Shell thick, globose, with flattened spire, concave at the apex	Hugli River and its tributaries with some tidal influence	West Bengal: Gangetic delta. It is a brackish water species
Stenothyra woodmasoniana (Nevill)	Shell ovately conical, spire acute, concavely excavated, body whorl subangulate, flattened with rounded umbilical region; sculpture smooth or may appear malleated under large magnification	Hugli River and its tributaries with some tidal influence	West Bengal: Gangetic delta. It is a brackish water species
Gangetia miliacea (Nevill)	Shell minute, less than 5 mm, ovate or sub-cylindrical, aperture large, triangular area between aperture and body whorl absent	Ganga river on stony substrate and form Yamuna River at Allahabad from dense submerged macrophytes	Bihar: Patna, Kerala, Orissa, Uttar Pradesh, West Bengal
Iravadia annandalei (Preston)	Shell elongated, whorls 6; sculptured with indistinct, irregular, spiral lirae, interstices, not deep, transverse obsolete	Back water	Kerala: Cochin; Tamil Nadu: Ennur back water
Iravadia ennurensis (Preston)	Whorls 5, spire less pointed, lower margin of columella not produced	Back water	Tamil Nadu: Ennur back water, Chennai
Iravadia funerea (Preston)	Shell fusiform, whorls 3, sculpture with coarse spiral lirae showing traces of transverse striations	Back water	Kerala: Cochin back water
Iravadia princeps (Preston)	Whorls 7, spire less pointed, lower margin of columella produced	Back water	West Bengal: outskirts of Kolkata

Assiminea francessi (Wood)	Shell elongate, apex pointed, whorls seven rapidly increasing in the width; aperture oblique, ovate, body whorl with three brown-reddish spiral bands	Estuarine species with tidal influence; it is found up to Barrackpore in Hugli River	West Bengal
Thiara (*Thiara*) *amarula* (Linnaeus)	Shell large, dark brown, spire decollated, body whorl longer than the spire; body whorl with crown of spines near the periphery and suture, project upwards from shoulder, strong spiral sculpture confined to the base of the shell	Creeks of tidal influence	Great Nicobar
Thiara (*Thiara*) *rudis* (Lea)	Whorls regularly increasing; sculptured with axial ribs and strong spiral ridges forming nodules	Prefers slow moving water	Throughout India
Thiara (*Thiara*) *scabra* (Mueller)	Shell with spiral ridges, sculptured with vertical ribs bearing prominent spines directed obliquely outward, spire almost equal to the body whorl	Prefers slow moving water. Occurs in slow or fast moving water as well as stagnant water	Throughout India
Thiara (*Sermyla*) *riqueti* (Grateloup)	Shell small, elongate, whorls 8. Regularly increasing; sculpture with undulating axial and spiral ridges	Kerala back water, slowly running low land rivers and streams with rich invertebrate fauna	Kerala: Cochin, Quilon and Trivandrum; Maharashtra: Mumbai
Faunus ater (Linnaeus)	Shell with a long spire, 18–20 regularly increasing, 5–6 whorls strongly striated	Water within tidal influence	Goa, Nicobar Islands
Melanoides crebra (Lea)	Shell sculpture with broad equidistance spiral ridges	Estuarine water within tidal influence and very low salinity	Andaman and Nicobar Islands
Melanoides nevillei (Brot)	Shell sculptures partly with spiral striae on lower portion of whorl and well developed on the upper whorl	Estuarine water within tidal influence and very low salinity	Andaman and Nicobar Islands
Melanoides nicobarica (Reeve)	Sculpture almost smooth; spiral striae on the upper whorls	Estuarine water within tidal influence and very low salinity	Andaman and Nicobar Islands
Melanoides peddamunigalensis (Ray and Roy Chowdhury)	Sculpture uniformly strong throughout the shell and outer lip curved at upper angle	Slowly running low land rivers and streams and other water bodies	Andhra Pradesh: Nalgonda; Tamil Nadu
Melanoides tuberculata (Muller)	Sculpture with vertical ribs and spiral striae, distinct and raised on the upper whorls, but flatter on the lower ones	Occurs in all possible water bodies of stagnant and slow moving freshwater ponds, tanks, canals, streams, ditches, drains, etc.	Throughout India except Kashmir
Stenomelania aspirans (Hinds)	Shell very slender, spire attenuated, whorls of the spire not folded, shell with fine spiral lines throughout the body	Estuarine water within tidal influence and with very low salinity	Andaman and Nicobar Islands

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Stenomelania plicaria (Born)	Shell very slender, spire attenuated upper whorls of the spire strongly folded, lower ones smoother with spiral striae	Estuarine water within tidal influence and with very low salinity	Andaman and Nicobar Islands
Stenomelania punctata (Lamarck)	Shell without spiral ridges, broader, spire not attenuated	Estuarine water within tidal influence and with very low salinity	Andaman and Nicobar Islands
Stenomelania torulosa (Bruguiere)	Sculptured with strong spiral ridges, broken into rectangular nodules towards the suture	Estuarine water within tidal influence and very low salinity and sometimes occur on slow running water of canals	Andaman and Nicobar Islands, Andhra Pradesh, Tamil Nadu
Tarebia granifera (Lamarck)	Shell small, spire very sharp, sculptures with distinct spiral rows of nodules	Slowly running lowland rivers and streams with rich invertebrate fauna and good water quality condition	Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, West Bengal
Tarebia lineata (Gray)	Shell with distinct dark, spiral line on the body whorl present	All types of rivers and streams in low land. Organically polluted water also prefers by this species	Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal
Tarebia semigranosa (von dem Busch)	Shell large, spire not very sharp, sculptured with distinct rows of granules	Estuarine water within tidal influence and with very low salinity	Andaman and Nicobar Islands
Brotia (*Antimelania*) *costula* (Rafinesque)	Shell high conoid or turreted, spire longer than the body whorl, aperture more or less rounded	Fast running streams and rivers of lowlands with rich invertebrate	Andhra Pradesh, Arunachal Pradesh Assam, Manipur, Meghalaya, Mizoram, Tripura Uttar Pradesh, West Bengal,
Sulcospira huegeli (Philippi)	Shell ovoid, conical, spire equal or less than body whorl; aperture oval, somewhat expanded at the base	Habitat not known	Assam, Karnataka, Kerala, Meghalaya
Paludomus (*Paludomus*) *annandalei* (Preston)	Shell conoidal, apex eroded, sculptured with coarse spiral striae below the suture and on the basal part of the whorls	Hill streams	Western Ghats
Paludomus (*Paludomus*) *blanfordiana* (Nevill)	Body whorl with three characteristics chocolate brown broad bands, which very distinctly visible through aperture	Brahmaputra basin and hill stream	Assam, Arunachal Pradesh, Meghalaya

Paludomus (*Paludomus*) *conica* (Gray)	Shell globose conical, whorls 5, sculptured with three to four spiral ridges in the sutural region often ornamented with dark spiral bands	A few small lowland rivers and streams with pebbly, gravel or sand substrate	Meghalaya, Tripura
Var. *kopilensis* (Nevill)			
Paludomus (*Paludomus*) *inflatus* (Brot)	Body whorl abruptly enlarged and globular, flat below the suture and then arched: sculptured with distinct unequal spiral furrows	Hill streams	Kerala, Tamil Nadu
Paludomus (*Paludomus*) *obesus* (Philippi)	Shell globose, elongated and eroded spire; whorls depressed around the upper part, yellowish brown to olive, columellar callus thick and expanded	Hill streams	Maharashtra: Western Ghats
Paludomus (*Paludomus*) *ornatus* (Benson)	Shell ovately conical, spire acuminate, whorls 6, sculpture smooth except 2–3 spiral ridges in the spiral region; inside three dark bands, columella thick and arched	Hill streams	Assam: Brahmaputra valley
Paludomus (*Paludomus*) *pustulosa* (Annandale)	Shell ovate, thick, uniformly black, with a tumid body whorl, sculptured with coarser longitudinal lines	Hill streams	Manipur, Mizoram
Paludomus (*Paludomus*) *regulata* (Benson)	Shell large, ovately globose, spire acuminate; suture deep, sculpture with groove-like spiral ridges; body whorl with 4 dark brown bands	Hill streams	Meghalaya: Garo Hills, Khasi Hills, Mizoram and West Bengal
Paludomus (*Paludomus*) *reticulata* (Blanford)	Shell not shouldered but sculptured with reticulate spiral striations, form axial granulation	Hill streams	Assam, Meghalaya
Paludomus (*Paludomus*) *rotunda* (Blanford)	Shell globose, sculptured with reticulate spiral striations, which form regular axial granules	Hill streams	Assam, Meghalaya
			Endemic to northeast India
Paludomus (*Paludomus*) *stephanus* (Benson)	Whorls conspicuously shouldered, crown with short and pointed spines	Hill streams	Meghalaya: Khasi Hill, Jaiantia Hill
Paludomus (*Paludomus*) *transchauricus* (Gmelin)	Shell conical, first few whorls with keeled spiral ridges; colour yellowish brown with dark brown spots running in lines and waves	Hill streams	Andhra Pradesh, Kerala, Maharastra, Tamil Nadu, West Bengal
Paludomus (*Philopotamis*) *sulcatus* (Reeve)	Shell ovate, prominent and eroded spire; whorls 3–5, rounded, very closely spirally grooved and intermediate ridges closely decussated with longitudinal striae	Hill streams	Kerala: Western Ghats
Paludomus (*Stomatodon*) *stomatodon* (Benson)	Shell overly conical, spire rather low, aperture posteriorly angular, columellar margin broad and with distinct tooth anteriorly	Mountain streams near Kerala	Restricted to Western Ghats, Kerala

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Paludomus (*Tanalia*) *loricatus* (Reeve)	Shell sculptured with prominent, nodules spiral ridges	Rapid flowing streams with slightly acidic water	Assam
Paludomus (*Tanalia*) *neritoides* (Reeve)	Shell oblong ovate, sculptured with fine spiral ridges; aperture large with broad columellar callus	In the bed of the river along with the mud	Kerala
Lymnaea stagnalis (Linnaeus)	Shell ovately turreted, yellowish horny, spire produced and sharply acuminated; whorls 5–6	Lakes, pods, paddy fields	Kashmir
Lymnaea (*Pseudosuccinea*) *acuminata* (Lamarck)	Shell thin, ovate, spire short, acuminate, body whorl much inflated, a little angular above, with a large aperture	Occurs in permanent water bodies with abundant vegetation	Throughout India
Form *typica* (Lamarck)			
Form *brevissima* (Annandale and Rao)			
Form *chlamys* (Benson)			
Form *gracilior* (Martens)			
Form *hians* (Sowerby)			
Form *malleata* (Annandale and Rao)			
Form *patula* (Troschel)			
Form *rufescens* (Gray)			
Lymnaea (*Pseudosuccinea*) *biacuminata* (Annandale and Rao)	Shell thin, fragile, narrow and elongate spindle shaped; aperture large, ovoid; columella slightly twisted and has a broad fold; umbilicus completely occluded; sculptured with curved longitudinal striae	Occurs in permanent water bodies with abundant vegetation	Andhra Pradesh, Uttaranchal
Lymnaea (*Pseudosuccinea*) *horae* (Annandale and Rao)	Shell with well-developed and broader spire, with an extra half whorl of the apex; sculptures minutely decussated with numerous, close set of longitudinal striae	Found in clear water with muddy substratum, on rotten twigs of trees which were floating in water or partly embedded in mud at the bottom	Thumarkar nullah, near Railway bridge, Sorupeta, Assam
Lymnaea (*Pseudosuccinea*) *luteola* (Lamarck)	Shell thin, glossy, body whorl less inflated and laterally compressed a little; spire comparatively longer and gradually tapering; aperture angulately narrows above	This species are found in particular habitat. It is often found in temporary water bodies which dry up in summer and overcome the unfavourable conditions by burrowing in the mud	Throughout India
Form *typica* (Lamarck)			
Form *australis* (Annandale and Rao)			
Form *impura* (Troschel) Form *ovalis* (Gray)			
Form *succinea* (Deshayes)			

Lymnaea (*Pseudosuccinea*) *ovalior* (Annandale and Prashad)	Shell globose, oviform with a short spire. The base of the spire as broad as upper portion of the body wall	Loktak Lake	Manipur: Bishenpur
Galba andersoniana (Nevill)	Shell small, globosely elongated, perforate, smooth, whorls 5, spire short, columellar margin thicken and reflected covering the perforation	Found in small streams, seepages and temporary collections of water in cool and wet places	Himachal Pradesh, Kashmir
Galba hookeri (Reeve)	Upper margin of whorls broadly flattened; spire very short; aperture wide; columellar callous thick, columellar fold broad	Clear cold spring-feed ponds with dense chara spec, vegetation. Small- to medium-sized streams with macrophytes and detritus accumulation	Sikkim (very common in high altitude and endemic from north Himalayan region)
Galba truncatula (Mueller)	Shell sculptured with very fine spiral striation; columellar fold broad and forms a flat projection over the umbilicus	Found in small streams, seepages and temporary collections of water in cool and humid places. Often found outside the water bodies under wet dense vegetation	Kashmir
Radix auricularia (Linnaeus)	Body whorl not much inflated, spire not canalized	It is a Palaearctic species which has its distribution extended to Kashmir (Dal Lake and other water bodies near Srinagar)	Kashmir (commonly found around Acchabal)
Radix brevicauda (Sowerby)	Spire extremely short; body whorl greatly inflated	In lakes and slow running streams	Kashmir
Radix lagotis	Spire moderately excreted; spire is larger, shape of the aperture being more or less constant	Cold water bodies, lakes	Kashmir; Ladakh: Leh
Form *costulata* (von Martens)			
Form *defilippi* (Issel)			
Form *solidissima* (Kobelt)			
Form *striata* (Andreae)			
Radix persica (Issel)	Shell not much large, outer lip well expanded, extends beyond the body whorl posteriorly; columella distinctly reflected and twisted	It inhabits large rivers and streams, common in the Ganga river in Bihar and Uttar Pradesh. It is found in middle mountains in stony or rocky riverbeds, attach to hard substrate	Andhra Pradesh, Delhi, Himachal Pradesh; Jammu and Kashmir, Mizoram, Punjab, Uttar Pradesh
Stagnicola tungabhadraensis (Ray)	Shell elongate, turreted, perforate, whorls 6, rounded rapidly increasing in size, body whorl large, columella twisted and strongly reflected over the perforation	Main canal near Tungabhadra project area	Andhra Pradesh: Kurnool
Physa acuta (Draparnaud)	Shell moderate, ovate, sinistral, transparent but hick and sharply pointed apex; body whorl large and around	The species prefers polluted water, found commonly in irrigation channels, dams and streams in or near town and may be well adapted to undergo anhydrobiosis	Delhi, Maharashtra

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Planorbis planorbis tangitarensis (Germain)	Shell flattened, compressed and angulations not very distinct, with distinct 5 whorls	Occurs in lakes, wetlands	Kashmir
Planorbis rotundatus (Poiret)	Shell thick, rounded; whorls 5, gradually increasing, rounded without any angulation; aperture oval	Occurs in lakes, wetlands	Kashmir
Gyraulus barrackporensis (Clessin)	Whorls rapidly increasing, boy whorl more rounded and more dilated at its extremity, aperture very oblique	Various types of slow running and stagnant water bodies	Uttar Pradesh; West Bengal
Gyraulus convexiusculus (Hutton)	Shell small, discoidal, with 4–5 depressed whorls, umbilicus wide, transparent, periphery sub-angulate, closely and obliquely stria tulate; aperture overtly lunate,	Various types of running and stagnant water bodies	Throughout India
Gyraulus euphraticus (Mousson)	Compressed body, strongly carinate, opaque, sculptured coarsely and irregularly, body whorl deviates from spiral whorl	Lakes, ponds and slowly running rivers and streams with rich plant growth	Bihar, Manipur, Jharkhand, Punjab, West Bengal
Gyraulus labiatus (Benson)	Body whorl with remarkable deviation from main axis, a whitish rib present within the aperture	Small- to large-sized stagnant water bodies with rich vegetation, slowly running rivers	Andhra Pradesh, Himachal Pradesh < Madhya Pradesh, Maharashtra, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal
Gyraulus ladacensis (Nevill)	Body whorl rounded not angular but slightly compressed in the middle towards the extremity, suture deep, umbilicus less wide, aperture obliquely ovate	Old water lakes with rich vegetation	Ladakh
Gyraulus pankongensis (von Martens)	Body whorl convex above and below neither carinate not angular, deeply umbilicate	Cold water lakes	Kashmir
Gyraulus rotula (Benson)	Aperture ovate-lunate, sculpture with longitudinal striae sometimes so strong to be called subcostal	Lakes, ponds, large water bodies with rich vegetation	Maharashtra, Uttar Pradesh
Gyraulus saltensis (Germain)	Body whorl very large and well dilated at the extremity, not deeply umbilicate	Salt range	Punjab
Camptoceras lineatum (Blanford)	Shell with strong spiral lines, whorls 2 ½, well-defined suture and angulated at its margin	Lakes, ponds and their effluents. Slowly running streams with rich microphytes	Assam, Manipur: Loktak Lake, Uttar Pradesh

Camptoceras subspinosum (Annandale and Prashad)	Shell with strong spiral; whorls 4, suture not impressed and to angular at the margin, spiral lines subspinose	Large lakes with rich vegetation	Kashmir
Camptoceras terebra (Benson)	Shell elongated, at least 3 times as long as broad, sculpture without strong spiral lines	Large lakes with rich vegetation	Uttar Pradesh, West Bengal: Mogra (Hugli Dist)
Segmentina (*Polypylis*) *calatha* (Benson)	Shell conoidal, whorls rapidly increasing in size, side of the keel rounded	Common species of swamps, ponds, lakes and wetlands, in decaying plant and leaf-litter	Kashmir, Gangetic plain; widely distributed in northern India and Tripura
Segmentina (*Polypylis*) *taia* (Annandale and Rao)	Shell more conoidal, whorls gradually increasing in size, side of the keel forming a small angle	Lakes, large stagnant water bodies	Andaman: Port Blair
Segmentina (*Polypylis*) *trochoidea* (Benson)	Shell small, trochoid, whorls 3 ½, periphery more acute, umbilicus small or absent	Rare species of stagnant waters, lakes, lakes, ponds in submerged dense vegetation	Karnataka, Tamil Nadu, West Bengal
Hippeutis fontanus (Lightfoot)	Shell small, lenticular, much drepressed, paucispiral; whorls very rapidly increasing, carinate; aperture obliquely heart shaped	Common species of swamps and wetlands, on macrophytes	Kashmir
Hippeutis (*Helicorbis*) *umbilicalis umbilicalis* (Benson)	Body whorl being abruptly wide, round, convex above, flattened below, bluntly angulate at the periphery, aperture heart shaped	Occur in ponds, lakes, swamps amidst dense vegetation	Assam, Bihar, Manipur, Uttar Pradesh: Kumaon Lake, West Bengal
Indoplanorbis exustus (Deshayes)	Shell large, thick, discoidal, sinistral, rounded at periphery, aperture ear shaped, suture deeply impressed	Occur in wetlands, ponds, lakes, swamps, ditches, amidst dense vegetation	Widely distributed
Ferriss*ia baconi* (Bourguignat)	Apex blunt reflected to the right	It is occasionally found attached on stones or wooden material in a few lowland streams in the Ganga river	Bihar, Orissa, West Bengal
Ferrissia ceylanica (Benson)	Apex sharply pointed, very little reflected	Lakes	Manipur: Imphal
Ferrissia tenuis (Bourguignat)	Shell minute, thin opaque, fragile, sculptured smooth, aperture oblong; brown or blackish externally, dull yellow internally	Attached to stones, pebbles or floating objects in river streams with moderate flow. Breeds in the month of January. Eggs are laid singly on decaying leaves, etc., in a gelatinous mass	Nilgiri Hills, Maharastra
Ferrissia verruca (Benson)	Shell suboval, small, thin, outline asymmetrical bilateral. Apex blunt, not elevated, blackish in colour	Found on floating stems, water plants and leaves in pond	Throughout India
Ferrissia viola (Annandale and Prashad)	Surface smooth with thin minute rugulose deposit. Dark brown or blackish in colour	Found on the lower side of floating grass stems in a small sluggish muddy stream	Manipur: Bishenpur, Nagaland: Dimapur
Paracrostoma tigrina (Kohler and Glaubrecht) (2007)	Data not available	Hill streams	Western Ghats

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Paracrostoma martini (Kohler and Glaubrecht) (2007).	Data not available	Hill streams	Western Ghats
Bivalvia			
Scaphula celox (Benson)	Shell small, tumid, inside of the valves white, elongately rhomboidal with a prominent keel along the diagonal teeth of the valve, hinge teeth 15–20, umbon prominent	Ponds, lakes, rivers mudflats of tidal influence	Madhya Pradesh, Orissa, West Bengal
Scaphula deltae (Blanford)	Strong ribs parallel to the posterior keel and far greater timidity of the valves, nearly twice as thick as the height	Ponds, lakes, rivers mudflats of tidal influence	Gangetic delta, Kolkata: Rabindra Sarobar; Orissa: Mahanadi river
Scaphula nagarjunai (Janaki Ram and Radhakrishna)	Shell very small, diagonal keel developed up to the extreme end of posterior extremity	Large lakes	Andhra Pradesh: Guntur, Khammam
Arcidopsis footei (Theobald)	Shell elongate, a strong ridge running back and down from the beaks, ventrally strongly compressed in the anterior region	River system	Western Ghats
Physunio (*Velunio*) *velaris* (Swerby)	Shell small, thin rather compressed; sculpture smooth; anterior extremity very narrow posterior side winged, ventral margin arcuted, raising abruptly anterior wards, beaks very acute, prominent, lunule excavated; cardinal teeth large, pale green, nacre white	Ponds, rivers, lakes	Assam
Scabies crispata (*Gould*)	Shell strongly and deeply sculptured, zigzag radial lines, with nodules; ridges transverse in the anterior region and vertical in the posterior region of the shell	Ponds, rivers, lakes	Assam: Sibsagar
Solenaia soleniformis (Benson)	Shell soleniformis, elongate and rather narrow; compressed, anterior end narrower; posterior end broader and sloping; hinge without teeth	Ponds, rivers, lakes	Assam: Daleswari in Barak River, Cacher; Mizoram
Lamellidens consobrinus (Lea)	Shell broad, dorsal margin obliquely truncate posterior end	Large wet lands, ponds, rivers beds, lakes	Andhra Pradesh, Maharashtra, Puducherry, Tamil Nadu
Lamellidens corrianus (Lea	Umbon less prominent, colour uniformly dark	Ponds, rivers beds, lakes	Common throughout India
Lamellidens generosus (Gould)	Posterior wing well developed	River beds, ponds, small water bodies	Arunachal Pradesh, Jharkhand
Lamellidens jenkinsianus (Benson)	Shell transversely elongated, thick broader, umbones more distinct and convex, anterior posterior side sloping end short and rounded	Upper river beds with muds	Assam: Upper Brahmaputra (Tezpur); Bihar: Bhagalpur
Sub sp. daccaensis (Preston)			
Sub. sp. obesa (Hanley and Theobald)			

Lamellidens marginalis (Lamarck)	Umbon prominent, colour brown with a lighter band along the margin	Pools, ditches, large water bodies, rivers, lakes	Widely distributed
Lamellidens phenchooganjensis (Preston)	Shell elongately ovate, less thick, umbones flat, anterior side angled, posterior margin obtusely rounded	Large water bodies, rivers, lakes	Mizoram
Parreysia (*Parreysia*) *annandalei* (Preston)	Shell oval, umbones rather small lateral teeth strong, curved, posterior and anterior scar small and deeply excavated	Large water bodies, rivers, lakes	Assam
Parreysia (*Parreysia*) *burmanus* (Blanford)	Shell ovate, solid, dark brownish, sculptured with coarse-corrugated ridges in anterior region and rather irregular nodulose in the rest	Large water bodies, rivers, lakes	Manipur: Bishenpur
Parreysia (*Parreysia*) *corbis* (Benson)	Shell oval, inequilateral, thin, subventricose, concentrically zoned with bluish green and ochraceous yellow	Large water bodies, rivers, lakes	Assam
Parreysia (*Parreysia*) *corrugata* (Mueller)	Shell elliptical to oval, smooth; umbones prominent; lunule well marked, sculptured with somewhat radiating, oblique, linear ridges, green in colour	Large water bodies, rivers, lakes	Throughout India
Subsp. l*aevirostris* (Benson)			
Subsp. *nagpoorensis* (Lea)			
Parreysia (*Parreysia*) *favidens* (Benson)	Shell thick and heavy, inflated, with strong zigzag ribs on beak, unequilateral and angulate both on anterior and posterior margins, cardinal teeth strong and broad	Lakes, west land, ponds, pools, rivers	Andhra Pradesh, Assam, Bihar Jharkhand, Maharashtra Meghalaya, Mizoram, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal
Var. *assamensis* (Preston)			
Var. *chrysis* (Benson)			
Var. *deltae* (Benson)			
Var. *marcens* (Benson)			
Var. *plagiosoma* (Benson)			
Var. *viridula* (Benson)			
Parreysia (*Parreysia*) *gowhattensis* (Theobald)	Shell thick, anterior side curved and short, posterior side long and truncated and suddenly sloping on the posterior margin	Brahmaputra Basin,	Assam
Parreysia (*Parreysia*) *rajahensis* (Lea)	Shell triangular, inflated, posteriorly angulated; umbon elevated, pointed; sculptured with prominent growth lines	River bed, wet land	Narmada River, Rann of Kutch; Sepree and Sahib Ganj; West Bengal: Kolkata
Parreysia. (*Parreysia*) *sikkimensis* (Lea)	Shell short, broad and ovate, anterior end rounded; posterior gradually tapering; anterior muscle scar deep and oval, posterior semilunar	Cold water lakes	Arunachal Pradesh; Assam, Mizoram, Uttar Pradesh, West Bengal

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Parreysia (*Parreysia*) *smaragdites* (Benson)	Shell with narrow anterior broad posterior; lunule prominent	Brahmaputra river basin	Assam
Parreysia (*Parreysia*) *triembolus* (Benson)	Shell thick with large teeth; posterior end tapering	Rivers, Narmada river basin	Assam, Uttar Pradesh, West Bengal
Parreysia (*Radiatula*) *andersoniana* (Nevill)	Shell smaller, thin, umbon indistinct, not at all raised; sculpture strong on umbonal region, pallial line prominent	River bed	Assam, West Bengal
Parreysia (*Radiatula*) *bonneaudi* (Eydoux)	Sculpture only on umbonal region and with vertical marking on the rest of the surface	River bed	Andhra Pradesh, Assam, Manipur
Parreysia (*Radiatula*) *caerulea* (Lea) Subsp. *gaudichaudi* (Eydoux)	Shell elongate, variable in shape, sculpture restricted to the upper half of the valves in the adult, posterior umbonal carina very distinct	River bed, Gangetic delta	Andhra Pradesh, Assam, Jharkhand, Meghalaya, Mizoram, Orissa, Punjab, Rajasthan, Uttar Pradesh, West Bengal
Parreysia (*Radiatula*) *cylindrica* (Annandale and Prashad)	Shell thick, dorsal margin straight and anterior margin broadly rounded, umbonal region sculptured with corrugated ridges	River bed	Maharashtra Endemic
Parreysia (*Radiatula*) *involuta* (Benson)	Shell compressed in front, swollen in the umbonal region with a few longitudinal corrugations, beaks incurved	River bed	Assam
Parreysia (*Radiatula*) *khadakvaslaensis* (Ray)	Shell elongated more inflated, posterior end pointed; sculpture appears to be a little more pronounced	River bed	Maharashtra: Pune
Parreysia (*Radiatula*) *lima* (Simpson)	Shell small with broad posterior end; umbo much anterior, sculpture more prominent on umbona region, zigzag and transverse lines prominent on posterior side, finer on anterior	River bed	Assam, Sikkim, and West Bengal
Parreysia (*Radiatula*) *nuttalliana* (Lea)	Shell small, smooth, devoid of any sculpture; umbon prominent, olive green in colour	River bed	Assam: Cachar
Parreysia (*Radiatula*) *occata* (Lea)	Shell rhomboidal, narrow, sculptured with granular ridges throughout the surface	Gangetic delta, and its tributaries, river bed	Assam, Madhya Pradesh, Manipur, Meghalaya, Rajasthan, Uttar Pradesh, West Bengal

Parreysia (*Radiatula*) *olivaria* (Lea)	Shell small, thin, devoid of any sculpture; umbon prominent and middle; olive green colour	River bed	Assam, Meghalaya, Uttar Pradesh, West Bengal
Parreysia (*Radiatula*) *pachysoma* (Benson)	Shell more elongate, inflated; umbon pronounced, with much stronger hinge, radial sculpture absent.	River bed	Andhra Pradesh, Assam, Meghalaya, Orissa, West Bengal
Parreysia (*Radiatula*) *shurtleffiana* (Lea)	Shell having some typical sculpture on umbonal region and on anterior slope.	River bed	Bihar, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh
.*Parreysia* (*Radiatula*) *theobaldi* (Preston)	Shell broad and elongate; sculpture absent on dorsal surface	River bed	Assam, Manipur
Trapezoideus exolescens exolescens (Gould)	Shell thin, trapezoidal, brownish yellow, compressed, umbones depressed, anterior end narrow, short, posterior side dilated, posterior wing not distinct	River bed	Assam, Manipur, Mizoram, Nagaland
Pseudomulleria dalyi (E.A. Smith)	Shell irregularly quadrate, periostracum deep brown or blackish brown, nacre mixture of white, greenish, bluish, olive and pinkish, margin olive brown	Streams	Western Ghats (Karnataka and Maharashtra)
Neosolen aquaedulcioris (Ghosh)	Shell thin, elongated; anterior end truncated, posterior end rounded, one small long cardinal tooth in the right valve, anterior adductor scar long, triangular, posterior small, rounded	Lakes of tidal influence and Gangetic delta	Orissa: Chilka Lake, West Bengal: Sundarbans
Tanysiphon rivalis (Benson)	Shell small, thin elongately ovate with greenish periostracum; umbo anterior; ligament short external; hinge with three cardinal teeth in each valve; anterior twp smaller and posterior flattened	Gangetic delta	West Bengal: River Ganges
Novaculina gangetica (Benson)	Shell oblong with truncated extremities, periostracum olivaceous	Rivers Ganges	West Bengal: River Ganges
Corbicula annandalei (Prashad)	Umbon central, prominent, greatly inflated and curved forwards, hinge very feeble	Back water of Kerala	Known from type locality only Kerala: Varkala
Corbicula assamensis (Prashad)	Shell thin, ovate, anterior short, rounded, posterior broad and truncate, umbones slightly marked, striae not deep, shining light yellow colour	Brahmaputra river bed	Assam
Corbicula bensoni (Deshayes)	Shell subtrigonal, transversely ovate, thin, striae fine and microscopic	Gangetic river belt	Bihar: Bhagalpur; West Bengal: Kolkata, Hugli, Nadia

(continued)

Table 11.4 (continued)

Name	Key character for identification	Habitat	Distribution
Corbicula cashmiriensis (Deshayes)	Ventral margin evenly arched, ending posteriorly in a distinct truncated beak in full-grown specimens; sculptured with prominent-raised ribs; hinge broad and strongly developed	River belt	Kashmir Endemic
Corbicula krishnaea (Ray)	Shell small, thin, striae regular and distinct, escutcheon bearing distinct ribs	Krishna river	Known from type locality only Krishna river, near Sangli, Pune and Maharashtra
Corbicula peninsularis (Prashad)	Shell ovately triangular, dorsal margin convex, posteriorly down into a regular beaklike structure, pallial line wide	Estuarine water with tidal influence	Known from type locality Bombay
Corbicula striatella (Deshayes)	Shell thick, sculpture strong, hinge with prominent teeth	River	Throughout India
Batissa inflata (Prime)	Shell oblique; umbo more anteriorly placed, anterior margin short and more sloping, posterior margin curved	Creeks of tidal influence	Andaman and Nicobar Islands
Batissa similis (Prime)	Umbo slightly anterior, anterior margin short and less sloping, posterior margin curved and biangulate	Creeks of tidal influence	Andaman and Nicobar Islands
Polymesoda (*Geloina*) *bengalensis* (Lamarck)	Shell subtrigonal, tumid, solid, thick, unequilateral; periostracum blackish brown, coarsely striated	Estuarine water with low salinity	Orissa: Mahanadi estuary; West Bengal: Gangetic delta; Nicobar Island
Polymesoda (*Geloina*) *erosa* (Solander)	Shell large, subtrigonal, unequilateral, solid, periostracum thin yellowish or thick and brownish	Back waters and estuaries	Andhra Pradesh: Krishna; Andaman and Nicobar Islands: Lawrence and Havblock Islands, Car Nicobar, Kondul, Trinket Island, Goa, Maharashtra
Villorita cornucopia (Prashad)	Shell high and narrow, umbones broad, high and recurved umbonal region with coarse concentric ridges, ligament very long and thick. Anterolateral short with a groove	Found in backwater of South India, occasionally in freshwater	Kerala back water
Pisidium (*Pisidium*) *casertanum* (Poli)	Shell ovate, subcordate, strong, somewhat tumid, feeble but distinct concentric striae, ligament pit long and deep extending to about the middle of the hinge plate; juveniles yellowish, full grown shells deep yellow with darker olive bands	Upper cretaceous Mud dwellers Hill streams	Kashmir

Pisidium (*Afropisidium*) *clarkeanum* (G. and H. Nevill)	Shell inflated, moderately thick, umbo projecting greatly over the hinge, surface pale yellow with close set striae	Ponds, lakes, wetlands, rivers	Andhra Pradesh: Cuddapah; Bihar: Harrapur, Bhagalpur; Jharkhand, Maharashtra: Mumbai; Manipur: Chandel; Tamil Nadu: Nilgiris (7,400 ft); Uttar Pradesh: Roorkee; West Bengal: Kolkata, 24 Parganas (South)
Pisidium (*Afropisidium*) *ellisi* (Dance)	Shell semitransparent, thin, dorsal margin sloping steeply on the posterior side, ventral margin gently curved, periostracum yellowish brown	Hill streams	Sikkim
Pisidium (*Afropisidium*) *nevillianum* (Theobald)	Shell thin, large, trigonal and porcellaneous, striae all over umbones prominent and round	Narmada river, Gangetic river	Madhya Pradesh: Narmada River; Uttar Pradesh: Roorkee
Pisidium (*Europisidium*) *mitchelli* (Prashad)	Shell subtrigonal, large very tumid, thin and fragile, distinct closed-set striae all over, deep horn colour, shining	Marshall Lake an altitude of 4,500 ft.	Kashmir
Pisidium (*Odhnerpisidium*) *atkinsonianum* (Theobald)	Shell medium, orbiculately ovate, dorsal margin slightly sloping with well-marked shoulder on the posterior slope; anterior margin sub-truncate	Jongla Lakes at an altitude of ~ 10,000 ft, large lakes	Manipur: Senapati; Meghalaya: Khasi Hill (East), Jaiantia Hills; Sikkim, West Bengal: Darjeeling
Pisidium (*Odhnerpisidium*) *kuiperi* (Dance)	Shell thin, semitransparent; umbones broad, central, not prominent; dorsal margin with a steeper slope posteriorly; ventral margin almost straight; sculpture with fine striae	Mud dwellers	Sikkim
Sphaerium austeni (Prashad)	Shell thick, elongately ovate, subequilateral, opaque, swollen; umbone prominent	Hill streams	Manipur, Nagaland
Sphaerium indicum (Deshayes)	Shell small, ovately rhomboid, unequilateral with fine concentric striae; right valve with a well-developed cardinal	Plains and hill streams	Throughout India
Sphaerium kashmirensis (Prashad)	Shell subquad rare, subequilateral, swollen, umbone prominent, incurved and tumid, sculptured with well-marked closely situated concentric striae	Walur Laker at an altitude of 5,180 ft and 0.5–10 m depth.	Kashmir

evolution (Prashad 1928). Some species such as *Sulcospira huegeli* show a disjunct distribution, being found in the central and southern Western Ghats and in northeastern Indian states (Subba Rao 1989).

Recently, two new species of freshwater molluscs belonging to the genus *Paracostoma* have been described from the Western Ghats (Köhler and Glaubrecht 2007). The genus *Paracostoma* is monophyletic and is restricted to few streams in the central Western Ghats and nested within a clade of Southeast Asian taxa composed of *Brotia* and *Adamietta*. These authors argue that the "origins of the Indian biota are more complex and diversethan assumed under the standard Mesozoic vicariance model." Hence, zoogeographically, the Western Ghats freshwater mollusks offer a great opportunity for biologists.

A few sporadic studies were carried out in northern Western Ghats, mainly from Pune by Tonapi (1971), and Tonapi and Mulherker (1963). Recently, Patil and Talmale (2005) reviewed land and freshwater molluscs of Maharashtra State and listed 72 species and varieties. Most of these studies were concentrated on distributional aspects and no indepth study on ecology. In India very scant attention has been paid to the biology and ecology of molluscs and in particular of bivalves (Subba Rao 1989), and therefore the ecological needs of a great majority of the Indian freshwater molluscs are not known. Apart from Volume IV of Fauna of British India by Preston (1915), there are only two other books that deal with Indian freshwater molluscs; these are Subba Rao (1989) and Ramakrishna and Dey (2007). The book on *Indian Freshwater Molluscs* gave updated information on the distributions with maps (Ramakrishna and Dey 2007).

Freshwater molluscs of the Western Ghats region are better known than in other parts of India or other species-rich areas within South and Southeast Asia. This assessment is based on the scattered published work, mostly coming from the northern Western Ghats and our own field studies. Still, a large amount of work needs to be done, examining the ecosystem services these species provide, the impact of aquatic-invasive plants, the distribution patterns, population status and dynamics of molluscs, and their species-specific threats. Most of the data deficient species identified here have not been collected since their description (often in nineteenth or early twentieth century) or have very meagre collection details. In many cases, the description of the species is based on either single specimen or very few specimens, and no natural history or ecology is detailed. It is important to revisit the type localities of these species to get adequate information on ecology and threats, to see if they are still present or have already become extinct, and in many cases to confirm their taxonomic status (Budha et al. 2011). Here we consolidate our study on the basis of available literature and personal findings from different surveys in Tables 11.4 and 11.5.

Endemism

A detailed study on endemism of freshwater molluscs available reveals that 47 species are endemic from India out of the 202 listed of which 33 are gastropods and 14 are bivalves (Fig. 11.1a, b). Two species are endemic from Andhra Pradesh, one from Punjab, seven species from Assam, three from Manipur, one from Meghalaya, two from Mizoram, 13 from West Bengal, two from Tamil Nadu, six from Maharashtra, three from Andaman and Nicobar Islands, five from Kerala Backwater and three from Jammu and Kashmir are endemic species.

Endemism from North Himalayan Region

Mollusca are originated from various invasion of freshwater fauna into the Himalayas since the Pliocene period (low-middle mountain fauna). The transitional zone of Nepal and the Himalayas has mixed freshwater faunas, from Oriental and Palaearctic regions with numerous hitherto neglected endemics, such as *Tricula* species and *Pisidium* spp. They are originated from several so-called inner valleys of the Himalayas which were seasonal lakes and wetlands during Pleistocene glaciations (Nesemann et al. 2007).

Table 11.5 Statewise distribution of freshwater Mollusca of India

Sl. No.	States	Families	Genera	Species	%
1	Andaman and Nicobar Islands	10	20	51	25.24
2	West Bengal	14	21	65	32.17
3	Bihar	13	19	55	27.22
4	Orissa	11	16	40	19.80
5	Andhra Pradesh	13	24	43	21.28
6	Kerala	13	23	60	29.70
7	Maharashtra	10	19	60	29.70
8	Jammu and Kashmir	8	16	35	17.32
9	Delhi	9	12	17	8.41
10	Madhya Pradesh	7	7	25	12.37
11	Jharkhand	9	8	23	11.38
12	Sikkim	5	5	9	4.45
13	Arunachal Pradesh	4	5	5 (partly worked out)	2.4
14	Meghalaya	10	14	43	21.28
15	Manipur	11	16	52	26
16	Nagaland	9	16	21	10.5
17	Rajasthan	6	8	13	6.4
18	Tripura	8	14	30	14.85

Endemism from Northeastern Himalayan Region

Northeastern Himalayan region shows a high degree of endemism especially within bivalves comparative to the other parts of India. Consistency for the long period of endemism is probably due to the geographical barrier and selective habitat by the species. Among the 64 bivalve species from India, 14 species are endemic from this region i.e. about 21 %, among gastropods it is quite less i.e. near about 6 %, and among gastropods eight species are endemic from this region. Some species mentioned known from type locality also is not reckoned here as endemic because further information on the availability of the particular species is not yet ascertained.

Endemism from Western Ghats

Nearly 212 species of freshwater molluscs have been reported from India (Subba Rao 1989). Of these, only 60 species were recorded from the Western Ghats hot spot by Shivaramakrishnan et al. (1998); however, it is likely that many species were missed. This is substantiated by recent records of species such as *Arsidopsis footi* and *Neritina reticulata*, two species of *Paracrostoma* and five new species of *Cremnochonchus* from the Western Ghats. This region is also home to some of the most important zoogeographical and Gondwanaland relict species, such as *Pseudomulleria dalyii* (Etheridae), a cemented freshwater pearl species, and three species of *Cremnochonchus* (Littorinidae) found in the spray zones of waterfalls at high elevations in the Western Ghats. With very few ecological studies having been carried out on these unique and cryptic freshwater taxa in India, it is critical to work out their habitat requirements and distributions for their suitable conservation strategies to be developed.

In Western Ghats, two species of Neritidae (*Neritina pulligera* and *Neritina violacea*), three species from Corbiculidae (*Villorita corbiculoides*, *V. cornucopia* and *V. cyprinoides*) and two species from Iravadiidae (*Iravadia funereal* and *I. ornata*) are found exclusively in brackish water.

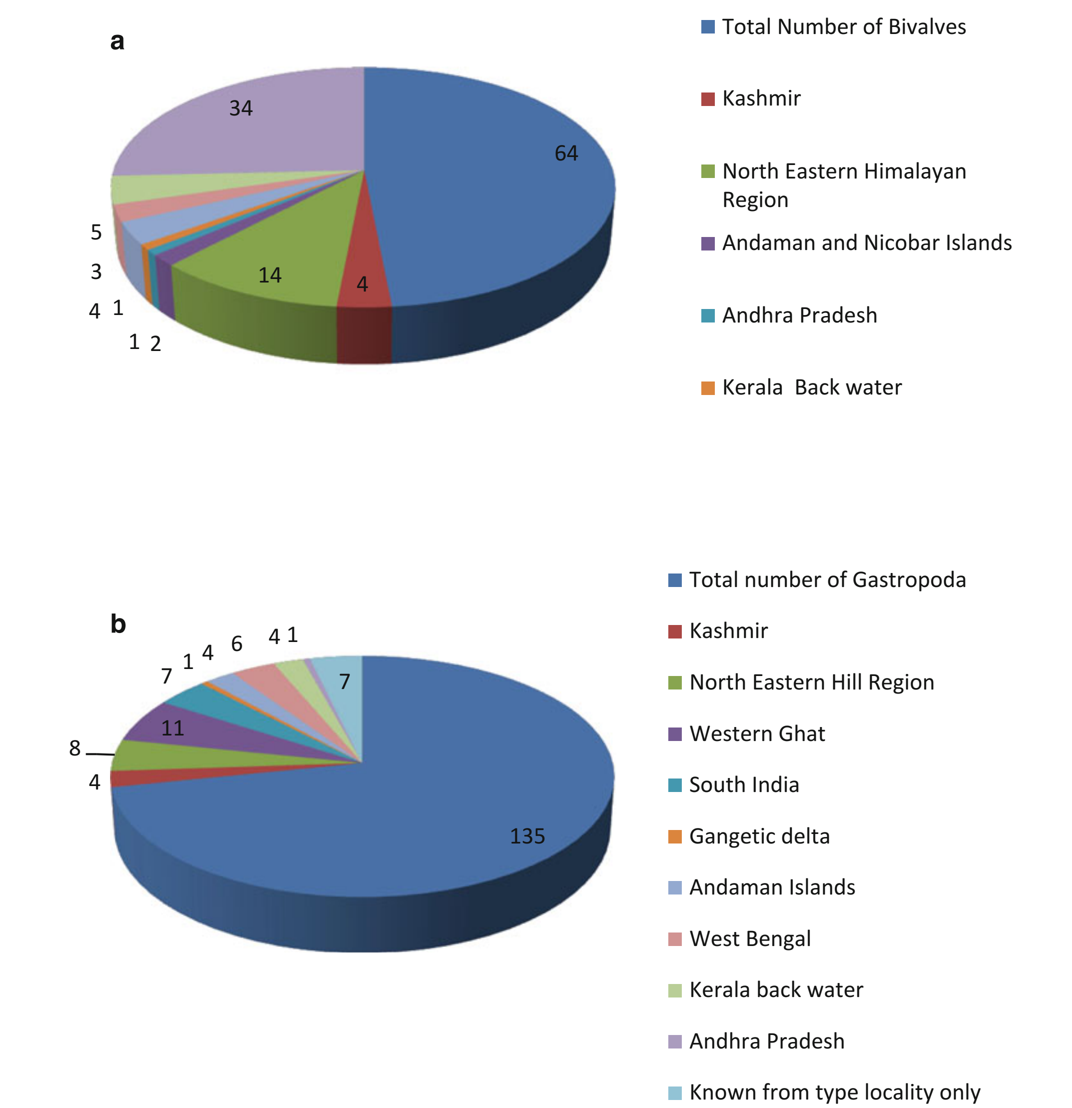

Fig. 11.1 (**a**, **b**) Distribution of endemic freshwater mollusks of India

The genus *Villorita* (Corbiculidae) is confined to the backwaters and estuaries of the west coast. These species cannot withstand high salinity levels and are usually found in the upper regions of the backwaters where the salinity is below 15 %. Here they burrow into the soil to escape unfavourable condition during summer when salinity increases above 15 % (Cherian 1968, Aravind et al. 2010).

A total of 77 species of freshwater molluscs is studied of which 52 gastropods (12 families and 23 genera) and 25 bivalve species (five families and eight genera) of which 28 species are endemic from this region (Aravind et al. 2010).

Conservation

Molluscs play essential roles in almost every known ecosystem. Many molluscs are links in food chains, the pathways between green plants and the animals that are food for humans and other animals. Molluscs show a great specialization of ecological niches in freshwater environments, making them more vulnerable to modifications in their environment (Bouchet 1992; Lydeard et al. 2004). Freshwater environments are some of the most fragile and highly threatened ecosystems in the world. Consequently, molluscs in the freshwater systems have suffered a severe decline in the diversity, distribution and abundance due to human-induced alteration of habitats, pollution, siltation, deforestation, poor agricultural practices, the destruction of riparian zones and invasion by introduced species (Biggins et al. 1995; Pimm et al. 1995). In India, because of urbanization to accommodate more and more people by destructing natural habitat like lakes, pools, ditches, small water bodies, making dams, etc., lead to extinction of species from that area within a very short time span. Speciation is a natural procedure which is controlled by natural selection, but loss of speciation by human being is a great loss of biodiversity with unasserted valuable assets. Agricultural and urban water pollution, over harvesting, dams, urban development and mining are the major threats to freshwater molluscs today.

Conservation Strategies and Implementation of Key Models

1. Conservation strategies for freshwater mollusca should emphasize establish biological monitoring programmes at the local level to aid in the assessment of the current status of regional molluscan diversity. Monitoring programmes are multipurpose management tools which will provide for:
   (a) Data on the biotic and abiotic characteristic of the environment which identify regions of greatest molluscan diversity
   (b) Immediate warning of nonacceptable impacts of human activities and their waste products on the environment
   (c) A long-term database to evaluate and forecast natural changes and impacts of human activities
   (d) Identification of endangered habitats and threatened species
   (e) Identification of stocks of molluscs of potential use in fisheries, the shell trade, and biomedical research
2. Establish baseline from distributional information available in systematic works and unpublished information for mapping habitat and at species level.

Conservation Status of Freshwater Mollusca in India

According to a report of IUCN, seven species (12 %) are assessed as threatened which are *Cremnochonchus syhadrensis*, *C. carrinatus*, *Arcidopsis footei* and *Pseudomulleria dalyi* are assessed as Endangered and *Cremnochonchus conicus*, *Parreysia khadakvasiensis* and *Scaphula nagarjunai* are assed as vulnerable. The majority (88 %) are assed as least concern (Aravind et al. 2010). However, much on the conservation status is not adequately known in the absence of baseline data on their distribution and population with respect to time and space and therefore, more information is required on this.

Role of Govt. Organizations Towards Freshwater Mollusca Conservation and Management

The Zoological Survey of India, since its inception, has in its custody and care collections of the natural history museum, in Calcutta, India, that are over 200 years old, as well as subsequent collections made by scientists and staff of ZSI since 1916. As per Section 39 of the Biological Diversity Act 2002 of India, ZSI is notified as *Designated National Repository for Zoological Collections* (NZC) of India. The NZC housed at ZSI now contains more than 3,000,000 authentically identified specimens comprising over 90,000 known species of animals. The NZC, the *national heritage* of the country, was acquired from the museum of the Asiatic Society of Bengal, the zoological section of the Indian Museum, and collections through various surveys till now which started in the early part of nineteenth century. Many distinguished naturalists such as John McClelland, Edward Blyth, W. Blanford, H. Blanford, T. Cantor, Francis Day, H.H. Godwin Austen, T. Hardwicke, B. Hodgson, G. Nevill, H. Nevill, F. Stoliczka, W.M. Sykes, W. Theobald, S.R. Tickell, J. Anderson and H. Wood-Mason significantly contributed in documenting the fauna of Indian subcontinent which are part of the NZC. This work mainly based on the available literature on freshwater Mollusca from India, specimens present in the NZC of ZSI and specimens received in Mollusca section of ZSI from different parts of the country for identification. The authors also have personally collected and examined large number of specimens through field surveys conducted by the Mollusca section of ZSI. ZSI cannot alone able to successfully conserve the national biodiversity with limited strength. Therefore, universities, colleges, schools and nongovernment organizations require capacity building on further studies on molluscan taxonomy, diversity and conservation in India.

References

Aravind NA, Rajashekhar KP, Madhyastha NA (2010) A review of ecological studies on patterns and processes of distribution of land snails of the Western Ghats, India. In: Proceeding of World Congress of Malacology, 222 p

Biggins RG, Neves RJ, Dohner CK (1995) Draft national strategy for the conservation of native freshwater mussels. U.S. Fish and Wildlife Service, Washington, DC, 26 p

Bogan AE (2008) Global diversity of freshwater mussels (Mollusca, Bivalvia) in freshwater. Global diversity of freshwater animals. Hydrobiologia 595:139–147

Bogan AE, Hoeh WR (2000) On becoming cemented: evolutionary relationships among the genera in the freshwater bivalve family Etheriidae (Bivalvia: Unionoida). In: Harper E, Taylor JD, Crame JA (eds) The evolutionary biology of the Bivalvia. Geological Society special publication, 177. Geological Society, London, pp 159–168

Bouchet P (1992) Extinction and preservation of species in the tropical world: what future for Molluscs? Am Conchocol 20:20–24

Bourguignat JR (1862) Malacologie du Lac des Quatre-Cantons et de ses environs. J.B. Baillière et fils, Paris, 4 pl

Budha PB, Aravind NA, Daniel BA (2011) The status and distribution of freshwater molluscs of the Eastern Himalaya. In: Allen DJ, Molur S, Daniel BA (compilers) The status and distribution of freshwater biodiversity in the Eastern Himalaya, Cambridge/Gland/Coimbatore: IUCN/Zoo Outreach Organisation, pp 42–53, 88 pp + viii + DVD

Cherian PV (1968) A collection of molluscs from the Cochin Harbour Area. In: Proceedings of symposium on Mollusca. Marine Biological Association of India, Cochin. Part-1, pp 121–136

Dey A (2008) Commercial and medicinal important molluscs of Sunderbans. Recordings of the Zoological Survey of India, Occ. Paper No. 286, pp 1–54

Dutta SC, Srivastava HD (1955) Studies on the life history of Orientobilharzia turkestanicum (Skrjabin, 1913) (Preliminary report). Curr Sci 33:752–753

Gadgil RK, Shah SN (1952) Human schistosomiasis in India. J Med Sci 6:760–763

Gaitonde BB, Sathe BD, Mukerji S, Sutar NK, Athalye RP, Kotwal BP, Renapurkar DM (1981) Studies on schistosomiasis in village Gimvi of Maharashtra. Indian J Med Res 74:352–357

Howard JK, Cuffey KM (2006) The functional role of native freshwater mussels in the fluvial benthic environment. Freshw Biol 51:460–474

Kay A (1995) The conservation biology of molluscs. In: Proceedings of a symposium, Edinburgh, Scotland, 67 p

Köhler F, Glaubrecht M (2007) Out of Asia and into India – on the molecular phylogeny and biogeography of the endemic freshwater gastropod Paracrostoma Cossmann, 1900 (Caenogastropoda: Pachychilidae). Biol J Linn Soc 91:627–651

Lydeard C, Cowie RH, Ponder WF, Bogan AE, Bouchet P, Clark SA, Cummings KS, Frest TJ, Gargominy O, Herbert DG, Hershler R, Perez KE, Roth B, Seddon M, Strong EE, Thompson FG (2004) The global decline of non-marine molluscs. BioScience 54:321–330

Madhyastha NA (2001) Pseudomulleria dalyi (Acostea dalyi): a rare cemented bivalve of Western Ghats. Zoos' Print J 16:573

Mukherjee RP, Chauhan BS (1965) Studies on the trematode faune of India – Part V. Subclass Digenea: Paramphistomidae Fischoeder (1901). J Zool Soc India 17:150–225

Nesseman HS, Sharma G, Sharma SN, Khanal B, Pradhan DN, Tachamo RD (2007) Aquatic inverbrates of the Ganga River System: (Mollusca, Annelida, Crustacea). 1:11–96

Patil SG, Talmale SS (2005) A checklist of land and freshwater mollusca of Maharashtra state. ZOO's Print J 20(6):1912–1913

Pimm SL, Russel GL, Gittleman JL, Brooks TM (1995) The future of biodiversity. Science 269:347–350

Ponder WF (1994) Australian freshwater Mollusca: conservation priorities and indicator species. Mem Qld Mus 36:191–196

Prashad B (1928) On a collection of land and freshwater fossil molluscs from the Karewas of Kashmir. Rec Geol Surv India 56(4):356–360

Preston HB (1915) The fauna of British India including Ceylon and Burma: mollusca (freshwater Gastropoda and pelecypoda). Taylor & Francis, London 224 p

Ramakrishna, Dey A (2007) Handbook on Indian freshwater molluscs. Zoological Survey of India, Kolkata

Salanki J, Farkas A, Kamardina T, Rozsa KS (2003) Molluscs in biological monitoring of water quality. Toxicol Lett 140–141:403–410

Seddon M (1998) Red listing of Molluscs: a tool for conservation? J Conchol (Spec Publ) 2:27–44

Sinha PK, Srivastava HD (1960) Studies on Schistosoma ìncognitum Chandler, 1926. II. On the life history of the bloodfluke. J Parasitol 46:629–641

Sivaramakrishnan KG, Madhyasta NA, Subramanian KA (1998) Field guide to Aquatic Macroinvertebrates. Project Lifescape. Developed for Western Ghats Biodiversity Monitoring Network. Centre for Ecological Sciences, Indian Institute of Science, Bangalore, 67 p

Smith EA (1898) Description of Rhaphaulus perakensis, n.sp., with a list of the known species of the genus. Proc Malacol Soc Lond 3:17–19

Strayer DL, Caraco NF, Cole JJ (1999) Tranformation of freshwater ecosystems by bivalves, a case study of zebra mussels in the Hudson River. Bioscience 49:19–27

Strong EE, Gargominy O, Ponder WF, Bouchet P (2008) Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia 595:149–166

Stuart SN, Wilson EO, McNeely JA, Mittermeier RA, Rodríguez JP (2010) The barometer of life. Science 328:177

Subba Rao NV (1989) Handbook of freshwater molluscs of India. Zoological Survey of India, Calcutta

Tonapi GT (1971) Studies on the freshwater and amphibious Mollusca of Poona with notes on their distribution. Part II. J Bombay Nat Hist Soc 68:115–176

Tonapi GT (1980) Freshwater animals of India (An ecological approach). Oxford & IBH Publ. Co., New Delhi

Tonapi GT, Mulherker L (1963) On the freshwater Mollusca of Poona. J Bombay Nat Hist Soc 60(1):104–170

Vaughn CC, Gido KB, Spooner DE (2004) Ecosystem processes performed by unionid mussels in stream mesocosms: species roles and effects of abundance. Hydrobiologia 527:35–47

Vaughn CC, Nichols SJ, Spooner DE (2008) Community and foodweb ecology of freshwater mussels. J North Am Benthol Soc 27(2):409–423

12 Aquatic Oömycetology: A New Field of Futuristic Research

S.K. Prabhuji, Ashutosh Tripathi, Gaurav K. Srivastava, and Richa Srivastava

Abstract

Water moulds, particularly the aquatic oömycetes, form part of the rich aquatic fungal flora of ponds and rivers and the soils of nearby areas. Class Oömycota has orders like Lagenidiales, Leptomitales, Rhipidiales, Peronosporales and Saprolegniales with their related families. Cellulose containing cell walls, biflagellate (dissimilar) zoospores, diploid life cycle pattern and its algal affinities have led to its taxonomic shifting from true fungi to pseudo-fungi and were kept under Heterokontophyta (Kingdom: Chromalveolata) with algae – the Stramenopiles. The Oömycota were once classified as fungi because of their filamentous growth and because they feed on decaying matter like fungi. The cell wall of oömycetes, however, is not composed of chitin, as in the fungi, but is made up of a mix of cellulosic compounds and glycan. The nuclei within the filaments are diploid, with two sets of genetic information, not haploid as in the fungi. The free-swimming spores, which are produced, bear two dissimilar flagella, one with mastigonemes; this feature is common in the chromists, as is the presence of the chemical mycolaminarin, an energy storage molecule similar to those found in kelps and diatoms. Thus, although oömycetes are in the minority as heterotrophic chromists, they quite definitely belong with these other chromist groups. With its separate entity as a group of pseudo-fungi, oömycetes need to be identified as an individual branch of study called – 'Oömycetology'. The investigations on higher fungi have moved forward at a constant pace and are touching new heights; however, the scientific explorations and advanced studies in the field of water moulds (Oömycetology) are continuously going down in general and in the Indian scenario in particular and have arrived at the verge of extinction. Therefore, a special attention is

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required to revitalize it so that the studies in this branch of mycology may go on to regain its proper place. Taxonomy, ecology, physiology, biochemistry and fish mycopathology have been done in this field but have been restricted to a few working groups and limited centres of study. Majority of the researches in this field have been focused on taxonomic studies and molecular characterization only followed by the studies on fish mycopathology. The studies on ecology, physiology and biochemistry of this group of pseudo-fungi are very meagre; however, early initial studies done on all these aspects may pave way for more advanced studies in the future. Further, the ecological data obtained and hypothesis given from one geographical region need to be confirmed from other different geographical areas. The detailed studies in physiology and biochemistry of these members should be done to understand clearly the metabolic phenomenon therein. Therefore, this particular branch has enormous possibilities of investigations in the future.

Keywords
Oömycetology • Watermoulds • Taxonomy • Ecology • Fish-mycopathology • Physiology • Biochemistry

Introduction

Since the inception of the studies on mycology, the investigations on higher fungi have, undoubtedly, moved forward at a constant pace and are touching new heights. However, the graph of scientific explorations and advanced studies in the field of water moulds is continuously going down as far as the Indian scenario is concerned and has arrived at the verge of extinction. Therefore, a special attention is required to revitalize it so that the studies in this branch of mycology may go on to regain its proper place (Prabhuji 2005).

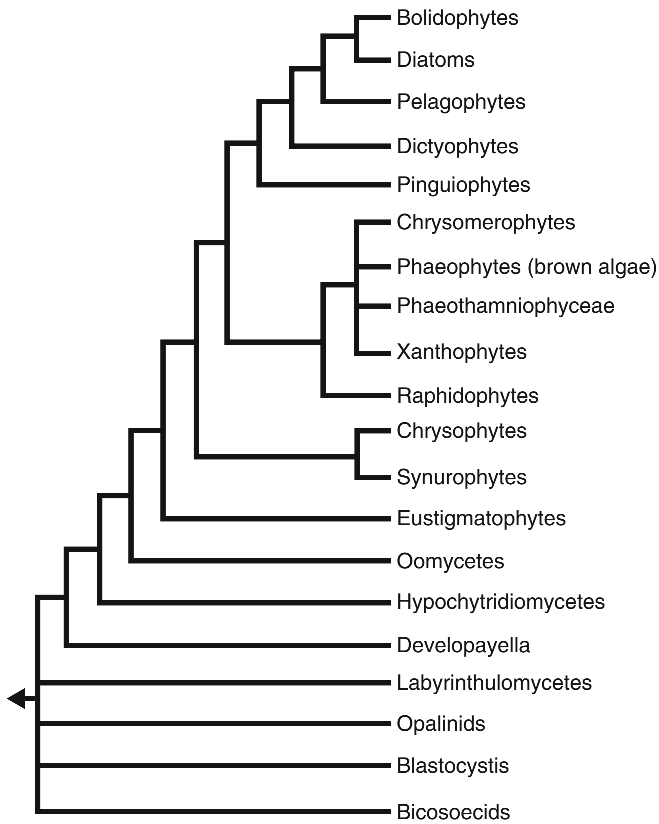
Water harbours a vast majority of microorganisms, especially in embankment areas of freshwater ponds and rivers. Water moulds, particularly the aquatic phycomycetes, form part of the rich aquatic fungal flora of ponds and rivers and the soils of nearby areas. Among aquatic phycomycetes the members of family Saprolegniaceae are of special interest because of their facultative parasitic nature, i.e., they are saprophytes as well as parasites of fishes under certain set of conditions. The first references to any of the Saprolegniaceae appear to have been those of Ledermüeller (1760), of Wrisberg (1765) and of Spallanzani (1777). For a long time they were regarded as algae and were described by most of the workers under the generic name *Conferva*, which included, in its Linnaean application, the filamentous aquatic plants generally. The earliest binomials appear to be those of Flora Danica (1780), *Byssus aquatica*, and of Schränk (1789), *Conferva piscium*. Previous workers had observed these fungi on flies in water, but as the name indicates, Schränk's observation was the first record of their occurrence on fishes. The earliest figures of these fungi are those of Flora Danica (1780), of Dillwyn (1809) and of Lyngbye (1819). Gruithuisen (1821) described a fungus on the remains of a dead snail and for the first time figured the escaping zoospores. Carus (1823) described a fungus on Salamander larvae with spores collected in the form of a globe at the mouth of a sporangium and called it *Hydronema*. In an appendix to Carus's paper, Nees von Esenbeck (1823) established the genera *Saprolegnia* (Gruithuisen's fungus) and *Achlya* (Carus's fungus) on the distinctive difference in the escape of the zoospores, which we recognize as their salient features even today. This early report, however, seemingly did not initiate more than sporadic interest in these genera until after 1850, when de Bary substantiated Nees' circumscription. Kützing (1843) created the family name **Saprolegniaceae**, which was, later, defined by Pringsheim (1858). Later, the oömycetes were

Table 12.1 Major distinctions between the Oömycota in the Chromista and the true fungi (Chytridiomycota, Glomeromycota, Zygomycota, Ascomycota and Basidiomycota)

Characters	Oömycota	True fungi
Sexual reproduction	Heterogametangia. Fertilization of oöspheres by nuclei from antheridia-forming oöspores	Oospores not produced; sexual reproduction results in zygospores, ascospores or basidiospores
Nuclear state of vegetative mycelium	Diploid	Haploid or dikaryotic
Cell wall composition	Beta glucans, cellulose	Chitin. Cellulose rarely present
Type of flagella on zoospores, if produced	Heterokont of two types: one whiplash and directed posteriorly and the other fibrous, ciliated and directed anteriorly	If flagellum produced, usually of only one type: posterior, whiplash
Mitochondria	With tubular cristae	With flattened cristae

After Rossman and Palm (2006)

Fig. 12.1 The Stramenopiles



accepted as a class of heterotrophic organisms, probably derived from heterokont algal ancestry (Bessey 1950; Copeland 1956). Manton (1952, 1965), on the basis of his studies on the fine structure of flagella, confirmed the algal ancestry, and Vogel (1960), too, confirmed it on the basis of modes of lysine synthesis. The chemical composition of the hyphal wall (Novaes-Ledieu et al. 1967) and an assessment of the significance of microtubules versus flattened cristae within mitochondria (Turian 1962) have also established the specific identity of these fungi.

Later, cellulose containing cell walls, biflagellate (dissimilar) zoospores, diploid life cycle pattern and its algal affinities have led to its taxonomic shifting from true fungi to pseudo-fungi (Table 12.1) and were kept under Heterokontophyta (Kingdom: Chromalveolata) with algae – the Stramenopiles (Figs. 12.1 and 12.2). The Oömycota were once classified as fungi,

Kingdom: Chromalveolata

Phylum: Heterokontophyta

Class: Oomycota

Orders (& families)

Lagenidiales
Lagenidiaceae
Olpidiosidaceae
Sir olpidiaceae
Leptomitales
Leptomitaceae
Peronosporales
Albuginaceae
Peronosporaceae
Pythiaceae
Rhipidiales
Rhipidaceae
Saprolegniales
Ectrogellaceae
Haliphthoraceae
Leptolegniellaceae
Saprolegniaceae
Thraustochytriales

Fig. 12.2 Systematic position of Oömycota

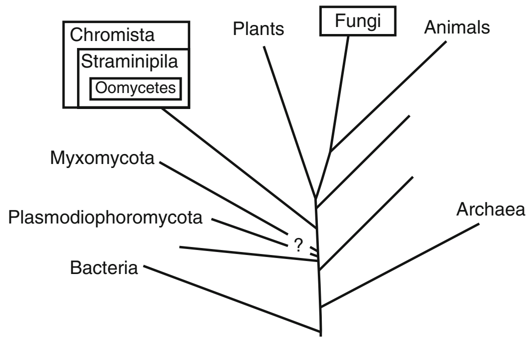


Fig. 12.3 Common ancestry of Oömycota

because of their filamentous growth and because they feed on decaying matter like fungi (Alexopoulos et al. 1996). The cell wall of oömycetes, however, is not composed of chitin, as in the fungi, but is made up of a mix of cellulosic compounds and glycan. The nuclei within the filaments are diploid, with two sets of genetic information, not haploid as in the fungi. The ultrastructure, biochemistry and molecular sequences of these organisms indicate that they belong with the Chromista (Fig. 12.3). The free-swimming spores, which are produced, bear two dissimilar flagella, one with mastigonemes; this feature is common in the chromists, as is the presence of the chemical mycolaminarin, an energy storage molecule similar to those found in kelps and diatoms. Thus, although oömycetes are in the minority as heterotrophic chromists, they quite definitely belong with these other chromist groups. Molecular sequences show their phylogenetic roots with the Chromista, the chromophyte algae and other Protista, rather than the true fungi (Dick 1990, 1997; Kwon-Chung and Bennett 1992; Rossman and Palm 2006).

This algal affinity was postulated as early as 1858 by Pringsheim (Barr 1992) and is supported by analysis of small subunit ribosomal RNA sequences (Bruns et al. 1991; Ariztia et al. 1991; Wainwright et al. 1993). The oömycetes may be related to the progenitors of the heterokont algae, representing an evolutionary sideline that never acquired plastids (Christensen 1990; and Bhattacharya et al. 1992). Alternatively, they may have evolved from algae, having lost their plastids and adopted saprobic and parasitic strategies in the shadows of freshwater pools, within soils and inside plants (Dawkins 1989). With a few important exceptions, the organisms studied by mycologists satisfy the following criteria: (i) absorptive mode of nutrition, (ii) growth by polarized hyphal extension and (iii) reproduction involving the formation of spores. While some fungi do not seem to exhibit hyphal growth, the fact that even *Saccharomyces cerevisiae* produces invasive pseudo-hyphae under certain nutritional conditions (Gimeno et al. 1992) suggests that polarized growth is an almost universal hallmark of the fungi. A marked propensity towards parasitism is a fourth characteristic that seems to be increasingly applicable to fungi; while this does not apply to all species, most classes of fungi contain parasitic members, and there are a growing number of reports of fungi regarded as saprobes establishing parasitic symbioses with plants and animals (Sternberg 1994; Plattner and Hall 1995). The oömycetes conform to this working definition on all counts, but this does not of course unite them with the other fungi in a monophyletic group. This conflict can only be resolved (while retaining the reference to oömycetes as fungi) if mycologists can agree to maintain two distinct meanings of the term fungus: (i) the strict taxonomic epithet covering members of the Kingdom Fungi and (ii) a practical reference to microorganisms studied by mycologists that share the characteristics outlined above. So, oömycetes qualify as fungi, just as euglenoids and red algae are algae despite the fact that their origins are remote from those of the green algae from which the land plants evolved. If justification for mycological research on oömycetes is necessary, then one has only to look at the literature on tip growth to understand that oömycetes like *Saprolegnia ferax* represent superb experimental subjects because their hyphae grow faster and larger than those of most fungi with chitinous walls (Money 1997) and to consider the way in which research on steroid hormones in oömycetes has shaped our view of the physiological sophistication of the fungi (Mullins 1994). It is also worth remembering that the entire field of plant pathology might be said to have originated with Berkeley's study of the oömycete *Phytophthora infestans*. It is, of course, important to think carefully about the relevance of information gleaned from experiments on oömycetes to other fungi and vice versa, and authors should ensure that such caveats are included in their discussion of data. But if mycologists can agree on a practical definition of the fungi, research on oömycetes will continue to enrich our understanding of all organisms and all of the fungi that absorb their food, ramify through their surroundings in the form of tip-growing hyphae and produce clouds of spores in air and in water (Money 1998).

Biodiversity and Taxonomic Studies

The members of saprolegniaceae typically exhibit the complete life cycle, i.e. the presence of vegetative reproduction by production of gemmae, asexual reproduction by formation of zoosporangia producing biflagellate zoospores under favourable conditions and sexual reproduction by formation of male (antheridia) and female (oögonia) gametangia producing respective gametes under unfavourable conditions (DeBary 1860). Investigations carried out by a vast array of aquatic mycologists from mid-nineteenth to the early twenty-first century and the Klebsian Principles have led us to enunciate certain general concepts regarding sexual reproduction in Saprolegniaceae (Hawksworth 1991). These are as follows:

1. Particular inorganic salts in a growth medium favour the development of sexual apparatus.
2. A distinct correlation does exist between the mass (weight) of the vegetative growth and abundance of male and female gametangial production.
3. Carbon-nitrogen ratio (C/N ratio) and certain combination of its sources (Pieters 1915) stimulate production of male gametangia in excess production of female gametangia while others are antagonistic to the male gametangial production.
4. The variation in the concentration of constituents in a medium affects (Horn 1904) the structural changes in the sexual apparatus.
5. The production of female gametangia may not be stimulated by addition of inorganic salts to a nutrient-rich medium (Obel 1910).
6. The sexual apparatus appears more frequently to develop on older hyphae than on younger hyphae, which indicates towards the effect of age factor of vegetative phase on the production of gametangia (Klebs 1899; Obel 1910). However, it does not necessarily mean that sexual reproductive process starts only when the asexual sporulation ceases (Gow and Gadd 1995; Moore 1997).

The family Saprolegniaceae is, at present, having 17 genera (Johnson et al. 2002). These are ***Achlya*** Nees von Esenbeck, ***Aphanodictyon*** Huneycutt ex Dick, ***Aphanomyces*** deBary, ***Aplanopsis*** Höhnk, ***Brevilegnia*** Coker and Couch, ***Calyptralegnia*** Coker, ***Couchia*** W.W. Martin, ***Dictyuchus*** Leitgeb, ***Geolegnia*** Coker, ***Leptolegnia*** deBary, ***Phragmosporangium*** Seymour, ***Plectospira*** Drechsler, ***Protoachlya*** Coker, ***Pythiopsis*** deBary, ***Saprolegnia*** Nees von Esenbeck, ***Sommerstorffia*** Arnaudow and ***Thraustotheca*** Humphrey. Prabhuji et al. (2010) has recorded the occurrence of the eighteenth genus.

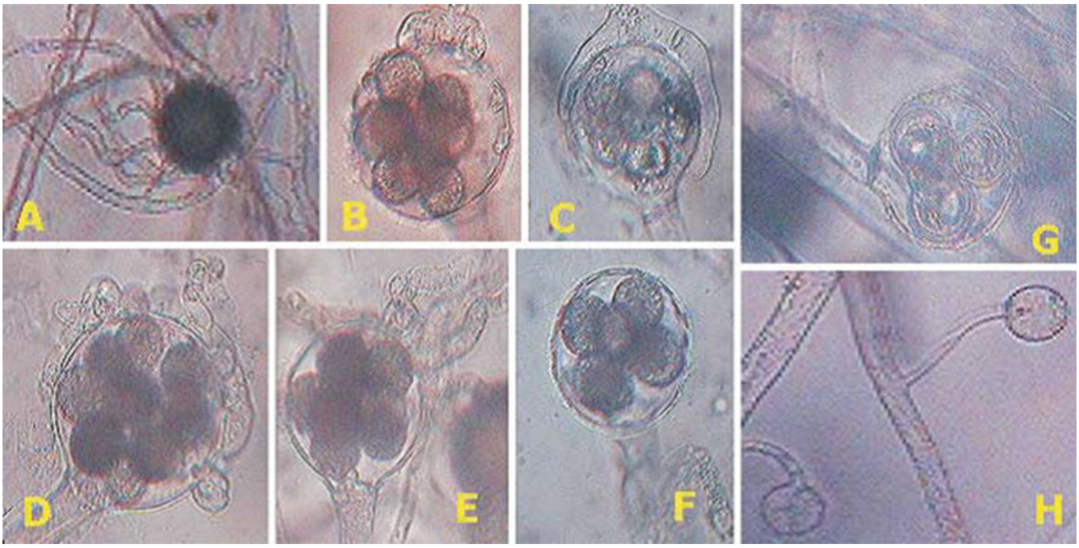


Fig. 12.4 Photomicrographs of sexual apparatus in *Achlya diffusa* (After Prabhuji 2010). (**a**) Oögonium with many antheridial branches attached. (**b**) Oögonium with eggs (oöspheres) and finger-shaped branched antheridium. (**c**) Antheridium encircling it. (**d**) Several coiled antheridial branches. (**e**) Coiled monoclinous antheridial branches and one hypogynous antheridium. (**f**) Oögonium with distinct wall pitting. (**g**) Eccentric oöspores. (**h**) Abortive oögonia

The Indian work on the taxonomy, phenology and distribution of water moulds has been initiated by Chaudhuri and Kochhar (1935) and followed by Chaudhuri and Lotus (1936), Hamid (1942), Dayal and Thakurji (1966, 1968), Srivastava (1967a), Khulbe and Bhargava (1977), Prabhuji and Srivastava (1977, 1978), Khulbe (1980), Prabhuji (1984a, b), Prabhuji et al. (1984), Prabhuji and Sinha (1993, 1994) and Prabhuji (2005). However, the studies made on water moulds in India, particularly the members of Saprolegniaceae (Fig. 12.4), have been restricted to a few centres and a few groups of scientists. Therefore, a lot of work in this field is required to have a full spectrum of systematics and distribution, particularly the genetic biodiversity of water moulds in the country.

The techniques used for the isolation of water moulds are different for the water and the soil samples.

From Water Samples

The water samples are brought to the laboratory safely without any leakage. The bottles are slightly shaken, and aliquots of 15 ml samples are placed in sterilized Corning Petri dishes up to 1 cm depth and 4–5 boiled hempseed cotyledons are floated over it and incubated at 20–22 °C. As the hyphal growth appears within 48–72 h on the baits, they are thoroughly washed with thin stream of sterilized water and transferred to Petri dish containing sterilized, deionized water at 18–20 °C. The sporangial structures have been observed and identified the genera on the basis of sporangial discharge.

Another method, known as 'Trapping Technique', is a generally successful technique for collecting saprolegnoid fungi directly from aquatic habitat. Various types of traps can be easily constructed from common laboratory materials, like aluminium tea balls or a pair of handled plastic tea strainers jointed together oppositely to form a net ball with handle. These traps, containing 4–5 boiled hempseed cotyledons, are attached to a wire or nylon line and submerged in a favourable location. The time for submergence varies for these 'traps' with water temperature (in summer days it should be 2–3 days whereas in winter season it should be 5–7 days). The baits, removed from these traps, are first placed in a small sterile bottle containing sterilized water and brought to the laboratory safely for observation.

From Soil Samples

About 10 g weight of collected soil is placed in a fresh bottle containing 25 ml distilled deionized water and is shaken vigorously for few minutes and then poured into the Petri dish to a depth of about 1 cm. After the particulate matter has settled down within 1–2 h, 4–5 boiled hempseed cotyledons are floated on the water and are incubated at 20–22 °C. Following the appearance of hyphal growth on the hempseed baits within 48–72 h, they are transferred to sterilized Corning Petri dishes containing sterilized, deionized water and incubated at 18–20 °C and are identified on the formation of reproductive structures there.

The identification and characterization of these members must be based on pure cultures. For the purpose two different techniques have been used:

1. A young, actively growing colony is removed from the gross culture, washed thoroughly several times and blotted between sterilized, dry pieces of filter paper to remove excess of water and bacteria. A tuft of hyphae is cut from this culture and is, then, transferred to an isolation medium (Table 12.2) and incubated at 18–20 °C. With the growth on the semi-solid medium, bacteria-free hyphal tips are removed aseptically along with a small block of agar and transferred to the fresh media. If the growth is not free from contamination after one transfer to the medium, additional transfers usually ensure pure cultures.
2. Small bits of boiled hempseed cotyledons are added to an actively growing gross culture and the fungus is allowed to develop zoosporangia on this fresh bait. A micropipette is placed opposite a discharge pore and the zoospores are collected as they emerge from the zoosporangium. The zoospore suspension, thus collected, is then placed within the glass ring partially submerged in the glucose-glutamate agar (Table 12.2), and the plate is incubated at 18–22 °C. When the hyphae appear outside the glass ring, they are removed along with a small block of agar and transferred to a Petri dish containing enough sterilized, deionized water to cover the block. The fungus, developing in this culture, is bacteria-free.

Endophytic Hyper-parasitism

It is beyond the scope of this article to deal in extenso with the organisms parasitizing the members of oömycetes. However, certain important contributions in this field have been given. The first substantial publication is that of Fischer (1882) describing the biology of parasitism on water moulds. Another important contribution explaining host-parasite relation is of Held (1972, 1973, 1974). Members of oömycetes have been found to be parasitized by several unicellular forms like *Phlyctochytrium* (Sparrow and Dogma, 1973; Johnson, 1975, 1976; Milanez, 1967; Johnson and Howard 1972; Karling, 1976), *Rhizophydium* (Beneke and Rogers, 1970;

Table 12.2 Composition of glucose-glutamate isolation and culture medium

EDTA	200 mg	Zinc chloride	40.0 mg
Pot. hypophosphate	87 mg	Ferric chloride	1.3 mg
Pot. dihydr. phos.	68 mg	DL-Methionine	50.0 mg
Mag. chloride	160 mg	Sod. monoglutamate	500.0 mg
Calcium chloride	66 mg	D-glucose	3.0 g
Manganese chloride	75 mg	Water	1.0 l

Modified from Scott et al. (1963b)
Agar (Difco purified): 15.0 g
pH adjusted to 6.5 with pot. hydroxide

Dogma, 1975; Karling, 1946, 1966; Milanez, 1966), *Hyphochytrium* (Ayers and Lumpsden, 1977), *Olpidiopsis* (Holland, 1958; Howard and Johnson, 1969; Khulbe and Bhargava, 1981; Milanez, 1966; Milanez and Beneke, 1968; Miller, 1965; Scott, 1960; Scott et al., 1963a; Shanor, 1940; Srivastava, 1964, 1966, 1975, 1982; Srivastava and Bhargava, 1963; Johnson, 1977), *Rozella* (Johnson, 1955, 1977; Howard and Johnson, 1969; Ou, 1940; Prabhuji et al., 2010) and several others.

This particular aspect has been least explored and needs extensive studies on endophytic hyperparasites of the members of Oömycota.

Ecological Studies

Studies of the ecology of fungi, particularly water moulds, have been carried out with little attention paid to the ecological aspects. The field aspects of the ecology of water moulds have lagged behind laboratory investigations of such parameters as the effects of temperature, nutrition and pH on growth and reproduction. The emphasis has been on laboratory analyses in the development of knowledge of the ecology of water moulds, with the least attention paid to the ecology for some time. There is a vast array of work by aquatic mycologists on the occurrence, seasonal periodicity, population density and distribution of water moulds in water bodies and soils in different geographical areas of the globe using various sampling techniques (Fig. 12.5).

Periodicity refers to the seasonal variation in the occurrence of water moulds with respect to fluctuations of temperature, pH (Lounsbury 1930), light, nutrients and other physico-chemical factors in aquatic and terrestrial habitats. Attempts to interpret or compare and contrast the various existing reports on periodicity are limited often by incomplete accounts of sampling and lack of statistical analyses, among others. For example, most reports do not mention the latitude or altitude of the sampling sites. Nevertheless, the importance of these parameters has been established (Prabhuji 2005). The debris in water, although consisting mainly of decaying vegetation, also contains animal remains. Only in certain cases, however, sample collections have been made mostly or exclusively from only one of the two types of organic matter; for example, Cutter (1941) collected *Aphanomyces helicoides* (=*A. laevis*) and *A. amphigynous* from insect exuviae. Thus, it may be that the animal populations of a habitat also affect the distribution pattern of water moulds.

In studies on the distribution and abundance of water moulds in a shallow lake of Japan, Suzuki (1961) obtained variable results and reported a curious pattern of diurnal migration of planonts. The number of zoospores found in samples taken in the morning and evening of a clear day was approximately the same at the surface, bottom and middle region of the lake. He suggested that the zoospores occurring in these horizontal regions had migrated up from the bottom layers of water. At night, the highest concentration of water mould zoospores was in surface waters. Samples taken on cloudy days indicated that the motile spores (zoospores) were concentrated at the lake surface throughout the day. During prolonged periods of rain, water mould propagules were evenly distributed in the lake from surface to the bottom. Suzuki (1961) speculated that the oxygen level in water drove the diurnal vertical migration of the zoospores of water moulds. He further stated that during the summer and winter, there was no diurnal migration of water mould zoospores in the shallow lakes. Clausz (1970) studied a somewhat deeper lake than that explored by Suzuki and reported a non-random distribution of water moulds. Assuming the nutrient sources in the water to be adequate, Clausz (1970) attributed the observed vertical distribution to the influence of oxygen level.

The mineral content of water bodies has also been found to affect the water mould populations and to regulate their distribution significantly. Suzuki and Nimura (1961a) reported that out of a group of five lakes, three species of water moulds – *Saprolegnia* sp. (unidentified), *Saprolegnia diclina* and *Aphanomyces* sp. (unidentified) – were found only in a lake having no detectable levels of iron, manganese, calcium, chloride or sulphate. Suzuki and Nimura (1962) analysed the water mould

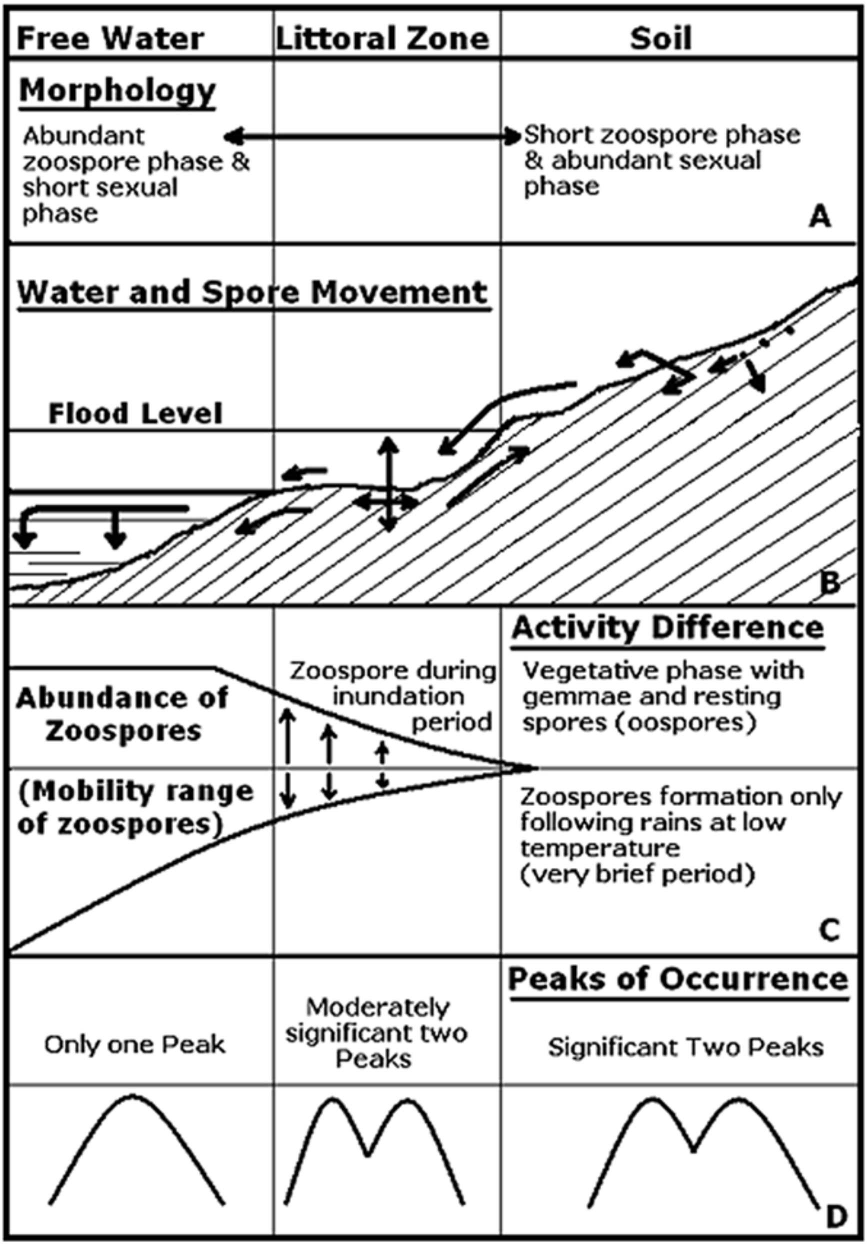


Fig. 12.5 (**a**–**d**) Occurrence and distribution of water moulds in water bodies, littoral zones and in soils (After Prabhuji 2011)

populations and hydrochemical characteristics of a cluster of three lakes connected by a common watercourse that were rich in sulphate, chloride and calcium but deficient in nitrate and phosphate. Each lake harboured the spores of water moulds but the species composition differed significantly among the three bodies of water.

Prabhuji (2005) has suggested there is a relationship between the geographical distribution of Saprolegniaceae and oöspore type. Prabhuji (1979, 1984a) had pointed to the dominance of the members of Saprolegniaceae with eccentric oöspores in the tropics. Perusal of earlier records, particularly for the occurrence of eccentric and centric/sub-centric forms of Saprolegniaceae, reveals a very interesting and characteristic pattern of global distribution of Saprolegniaceae. For example, studies made in the Indian subcontinent (Prabhuji 1984a; Srivastava 1967a, b) and Brazil (Milanez 1967, 1968, 1970; Milanez and Beneke 1968), both within tropical regions of the globe, have shown a distinct dominance of eccentric forms over centric and sub-centric forms. By contrast, investigations conducted in United Kingdom (Dick and Newby 1961; Dick 1966), Canada (Dick 1971), Iceland (Howard et al. 1970), United States of America (Miller and Ristanovic 1969) and Denmark (Lund 1934, 1978), which represent temperate regions of the world, indicate dominance of centric and sub-centric forms over the eccentric forms of Saprolegniaceae. Based on such studies, a distinct eccentric and centric (including sub-centric forms) 'Occurrence Zones' of the world may be identified for the members of Saprolegniaceae (Prabhuji 2011). Further studies in other tropical and temperate regions may yield data that further confirm this hypothesis.

Many of the traditional water and soil sampling methods have been found to yield ecologically viable results, although some are either unfeasible or fail to provide statistically significant data. The methods adopted by various aquatic mycologists for quantitative assessment of water mould propagules in water samples have not been found to provide reliable data. By contrast, quantitative methods applied to soil samples appear to yield reliable data. The occurrence, distribution and periodicity of water moulds in water bodies and soil have also been reviewed, along with altitudinal and global distribution patterns in relation to oöspore type (Prabhuji 2010, 2011). These findings point to the need for further work to develop new methods that yield reliable quantitative data from water as well as soil samples. Further studies made in different geographical regions of the globe would definitely strengthen or modify these observations.

Physiological and Biochemical Studies

The saprolegniaceae, in common with many other fungi, are rather efficient machines for the conversion of substrate to substance given the proper conditions. Ample evidence is to be found in the overflow from their metabolism – the accumulation of such compounds as fats, carbohydrates and the organic acids and the increases in dry weight and colony size (Johnson et al. 2002).

Actively growing cultures of water moulds reach their maximum growth yield rather quickly under favourable conditions and then decline due to loss in mycelial dry weight. Darnaud (1972) visualized that this pattern of colonial development took place in three phases, namely, active growth, stationary phase and autolysis, which is usually represented by 2–8, 8–30 and 3–90 days period, respectively. Jain and Prabhuji (1985) have given, for the first time, a growth equation for *Saprolegnia luxurians* (Bhargava & Srivastava) Seymour and derived the value of a constant. They divided the sigmoid curve of growth in two parts – the exponential and straight line part and decline and stationary part – and indicated that the period for these parts varies in different members due to which the value of constant varies.

Miller and Ristanović (1975) studied the nutritional variability in *Saprolegnia*. Nutritional requirements affecting the metabolism have also been studied by Obel (1910), Moreau and Moreau (1936a, b, 1938) and Harrison and Jones (1975). Basically, the physiological and biochemical studies on the members of oömycetes have been done on the following four fundamental lines:

(a) Nutritional requirements during growth and development
(b) Asexual reproductive physiology
(c) Sexual reproductive physiology
(d) Effects of various physico-chemical factors on the life cycle

The physiology and biochemistry behind the production of zoosporangia in water moulds have been studied by several aquatic mycologists (Salvin 1940, 1941; Cantino,1961; Nagai and Takahashi 1962; Murphy and Lovett 1966; Griffin 1966; Griffin and Breuker 1969; Sati and Mer 1989).

Heterothallism and the concept of sexual hormones in *Achlya* has been given by Raper (1936, 1951) and was later followed by several workers including Whiffen (1945), Zeigler and Linthicum (1950), Faro (1972), Tingle (1972) and Schneider and Yoder (1973). Light, pH and temperature conditions have been found to affect the reproductive physiology of the oömycetes (Reischer 1949; Szaniszlo 1965; Lee 1965; Lee and Scott 1967; Prabhuji 1980; Prabhuji and Srivastava 1982; Prabhuji et al. 2009). Besides these, various plant growth regulators have also been found to affect the different stages of life cycle of oömycetes (Prabhuji et al. 2009, 2012b). However, a lot of work is further required for complete understanding of the metabolism of oömycetes.

Fish Mycopathological Studies

Out of three basic types of mycoses (fungal infection) in fishes, viz., dermatomycoses (infection of the skin), branchiomycoses (infection of the gills) and deep mycoses (infection of the deep tissues and the internal vital organs), the dermatomycosis is associated with the integument and can cause rapid destruction of the epidermis by the aquatic fungi (oömycetes). Deep mycosis is of two basic types: first one, the deep dermal mycosis and, the second, the mycosis of vital organs. In deep dermal mycosis which is just a type of dermatomycosis, the tissues beneath the surface of epidermis, i.e. dermal tissues together with scales as well as the underlying musculature, are involved whereas in the second type the infection involves the vital organs like brain, liver, kidney, intestines, etc.

Oömycetes that infect fishes produce easily recognized cottony mycelia on the surface of the affected animal; they have probably been recognized since antiquity (Arderon 1748; Spallanzani 1777; Bennet 1842; Goodsir 1842; Areschoug 1844; Unger 1844; Robin 1853; Berkeley 1864). In 1877, oömycetes were reported for the first time in European literature in association with an epizootic known as 'Salmon disease', and the causal organisms were identified and further studies were made (Stirling 1879–1980; Huxley 1882a, b; Willoughby 1968, 1969, 1971, 1977, 1978; Neish 1976, 1977). Generally, saprolegnian (oömycetous) infections are associated with the integument and can cause destruction of the epidermis, thus depriving the fish of the protection of the mucus. In cases where saprolegnian infections are restricted to the integument, it seems reasonable to suppose that the actual cause of death may be related to impaired osmoregulation and the inability of the fish to maintain its body-fluid balance (Gardner 1974; Hargens and Perez 1975).

Saprolegnian infections of fish are frequently associated with the wounds and lesions and also handling fish may predispose them to infection. The obvious inference, drawn from these observations, is that these fungi act as 'wound parasites'. The integument (skin) of fish in general and the mucus, in particular, both present a physical and a biochemical barrier to the initiation of infection, and if this barrier can be breached, an infection can proceed unrestrained.

An important point to emphasize is that saprolegnian fungi are not tissue specific and are capable of attacking virtually any tissue. This aspect has been most carefully documented in the detailed studies of Nolard-Tintigner (1971, 1973, 1974); however, several other studies have extended and confirmed the general applicability of these observations (Bootsma 1973; Dukes 1975; Wolke 1975; Neish 1977; Hatai and Egusa 1977; Papatheodorou 1980; Srivastava 1979, 1980a, b, c; Prabhuji et al. 1988; Srivastava et al. 1994; Prabhuji and Sinha 1994; Prabhuji et al. 1998, 2012a). Therefore, the common designation of saprolegniosis (a generalized term used for fish infection caused by oömycetous fungi) as a dermatomycosis is both incorrect and misleading. This contention has probably arisen as a result of the fact that these infections are usually initiated in the integument followed by the death of the fish before the infecting fungus may proceed beneath the skin or the underlying musculature. Do certain mycotoxins, produced by the fungal pathogen, adversely affect the metabolism of the host, sometimes resulting into a seize?

On the basis of his work on Pacific salmon, Neish (1976, 1977) has emphasized the role of 'stress' in initiating saprolegnian infections. Although more empirical evidences are required to substantiate this hypothesis, the available evidence is persuasive and provides a mechanism, which explains how physiological changes, which occur in fish, can predispose them to infection by parasites to which they are normally resistant. Various stressors, which include crowding, injury, suboptimal water temperature, handling, presence of noxious chemicals in sublethal concentrations, etc., acting singly or synergistically, operate through the pituitary-interrenal axis to produce an increase in the level of plasma corticosteroids. An increase in plasma corticosteroid levels can impair the inflammatory responses (McLeay 1975) and lead to an increase in corticosteroid-regulated protein catabolism and gluconeogenesis (Woodhead 1975). This may ultimately result into a protein deficiency, which contributes to the wasting of skeletal muscles and leads to a decrease in antibody production and collagen synthesis. Lack of collagen, in turn, impairs the ability of a fish to heal wounds and ulcers. High levels of plasma corticosteroids might also be associated with the fishes' osmoregulatory function (Olivereau 1962; Utida et al. 1972; Woodhead 1975), with the necessity to catabolize protein to obtain energy with the inability of fishes to clear the hormone (Woodhead 1975). Another important factor to be considered is the ascorbic acid metabolism of a fish. Fish, in general, have a dietary requirement for vitamin C (Ashley et al. 1975). It should be noted that an increase in the levels of plasma corticosteroids may also cause depletion of ascorbic acid reserves (Wedemeyer 1969, 1970). It should be emphasized that the 'stress hypothesis', given, is intended to be complimentary to other observations on mucus production. There is evidence which suggests that mucus production is controlled by the endocrine system. The main hormone involved in this activity appears to be prolactin; however, there is also evidence which does not support this viewpoint (Lam 1972). Presumably there might be an interaction between prolactin and the interrenal corticosteroids (Utida et al. 1972; Meier 1972). There may be a direct link between increased plasma corticosteroid levels in fish and their susceptibility to infection. These higher hormone levels may occur in response to the physiological requirements of a fish at certain period of its life like smoltification and sexual maturation.

The histopathological investigations (Sinha 1985; Prabhuji and Sinha 2010) on some freshwater fishes, viz., *Anabas testudineus, Channa punctatus, Chela laubuca* and *Colisa lalius,* have shown varying degrees of destruction of epidermis, hypodermis and underlying musculature by oömycetous fungi.

During December 1990 to January 1995, Prabhuji and Sinha (unpublished data) had the opportunity to make observations on more than four hundred diseased (in an epizootic form) fish specimens of *Channa punctatus, Puntius sophore, Catla catla, Colisa fasciatus* and *Carassius carassius.* The affected individuals had shown the symptoms of tail rot, bloated abdomen and the development of several degenerative lesions on the body. Although oömycetes have been found to be associated with the body lesions, as the study indicated, the fungal members have been designated to be the secondary pathogens; bacteria, probably, being the primary infecting agents. Bucke Maff et al. (1979), in their studies on an epizootic of perch (*Perca fluviatilis* L.), have reported the occurrence of large ulcerative lesions on the body and fins of the fish, culminating in deep necrotic areas associated with oedema and haemorrhage exposing the underlying musculature and skeletal structures. The fungal and bacterial populations, isolated from the lesions, have been the members of Saprolegniaceae and bacterial species of *Aeromonas, Pseudomonas* and occasionally myxobacteria. However, Bucke Maff et al. (1979) failed to reveal any virus particles, even after using electron microscopy.

Ichthyophonosis

The fungus *Ichthyophonus hoferi* Plehn and Mulsow has been found embedded in the infected fish tissues mostly as thick-walled, spherical, multinucleate structure called a 'resting spore'. The cytoplasm of these resting spores gives a positive PAS and Bauer reaction which indicates that it contains glycogen, a common carbohydrate reserve of fungi. Moreover, strong PAS reaction given by the wall of such spore indicates its polysaccharide nature and, thus, confirms the notion that *I. hoferi* is a fungus.

Schaperclaus (1953), Reichenbach-Klinke (1956) and Reichenbach-Klinke and Elkan (1965) have indicated towards the possibility of the presence of two forms of *Ichthyophonus*, i.e. salmonoid form and aquarium-fish form, on the basis of two different developmental patterns in this genus (Prabhuji and Sinha 2009). Earlier as well as the present-day studies, based on the histopathology of tumour tissues and of affected vital organs of fish, have provided sufficient data to indicate the occurrence of a wide range of polymorphism in *I. hoferi*. In this context the most extensive studies, however, are the detailed investigations by Sindermann and Scattergood (1954), Dorier and Degrange (1961), Amlacher (1965), Powles et al. (1968), Ruggieri et al. (1970), Sinha (1985), Prabhuji et al. (1988) and Prabhuji and Sinha (2009).

Infection of the lateral musculature causing the 'sandpaper effect' (roughening of the skin) has been observed by Sindermann and Scattergood (1954) in Atlantic herring. It may be due to the formation of large number of papules caused by proliferation of the fungus and the formation of necrotic areas in the sub-epidermal tissues. However, Srivastava et al. (1984), Sinha (1985) and Prabhuji and Sinha (2009) have found roughening of skin, raised spots and irregular tumourous galls on the skin of Carassius carassius. Reichenbach-Klinke (1956) has reported blindness and exophthalmos of serranid fish from the Mediterranean as a result of eye infection. He (Reichenbach-Klinke 1960) has also reported the cranial and dorsal ulceration.

Generally, no tissue or organ has been found to be immune from infection by *I. hoferi*; however, organs with a rich blood supply seem to be more frequently affected. I. hoferi elicits a severe focal granulomatous response resulting in cirrhosis and atrophy of the affected organs which can eventually lead to replacement of most of the normal tissue by reticuloendothelial granulation tissue. According to Amlacher (1965), the first tissue response of the host consists of an increased activity of the leucocytes, particularly the eosinophilic granulocytes. These leucocytes surround the parasite and many of them are destroyed. During this process, fibrocytes appear and eventually enclose (with one to several layers of long cells) the resting spore of the parasite, the leucocytes and the necrotic debris. The result is a characteristic granuloma consisting of the central, thick-walled, multinucleate resting spore surrounded by necrotic cells enclosed within a connective tissue capsule. In other cases the parasite may be surrounded by long, radially arranged cells or by epithelioid cells surrounded by a connective tissue capsule. Giant cells may also be found, particularly in infected kidneys. Empty resting spores, following germination and release of the plasmodium or spores, may often become infiltrated with connective tissues.

There have been persistent suggestions in the literature that natural *I. hoferi* infections of marine fish may be initiated by ingestion of infected crustaceans, particularly the copepods (Jepps 1937; Reichenbach-Klinke 1956, Reichenbach-Klinke and Elkan 1965; Sindermann and Scattergood 1954; Sindermann 1956, 1958). However, the definite evidences, in this context, are still lacking. Several experimental studies have shown that the infection is initiated after ingestion of food containing viable *I. hoferi* spores. Gustafson and Rucker (1956) found that feeding fish viscera from infected fish to rainbow trout, three species of Pacific salmon and a cottid resulted in infection of these fishes, but they were unable to establish infections in goldfish (*Carassius carassius*), guppies, squawfish or brown bullheads.

Sindermann (1958) also carried out infection experiments with immature Atlantic herring and

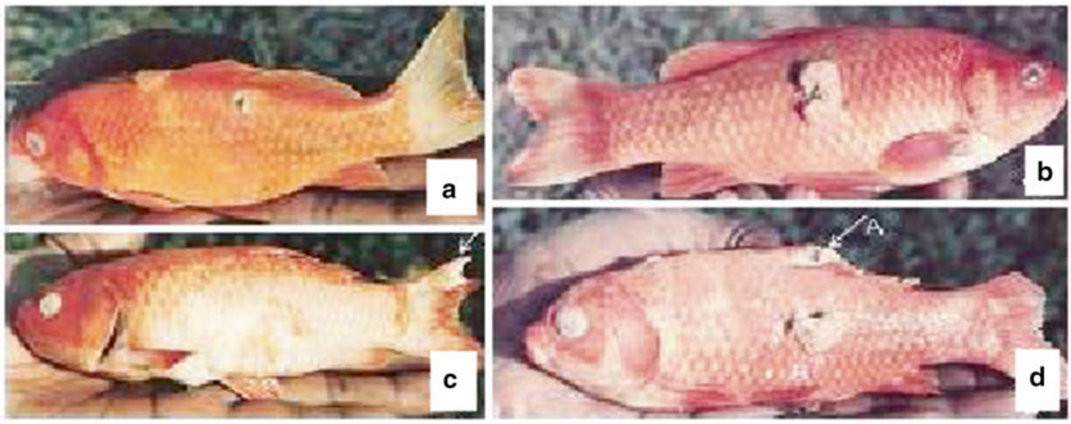


Fig. 12.6 Symptoms of *Ichthyophonus hoferi* on *Carassius carassius* (After Prabhuji and Sinha 2009). (**a**) Sandpaper effect and ulcerative condition. (**b**) A large irregular hyperplastic tissue mass. (**c**) A gall on the caudal fin. (**d**) A gall on the dorsal fin (*A*) and a large hyperplastic tissue mass

has presented some quantitative data regarding the dosage required to initiate infection. He found that a single exposure of 50 fish to 2×10 spores resulted in 'no infection', but several successive exposures to the same dose on successive days did result in infection. Using this information, Sindermann produced an experimental epizootic in 2000 immature Atlantic herring which resulted in infection of 23 % of this group – 8 % acute infections and 15 % chronic infections. Mortalities due to acute infections occurred within 2–4 weeks by massive invasion of the heart and degeneration and necrosis of body musculature and a minimum cellular response from the host. The chronic phase was characterized by a marked host cellular response leading to encapsulation of the parasite by fibrous connective tissue. Such a condition has often been found to exhibit pigment deposition around the spores in the muscles.

Besides the uncoordinated swimming movement of the fish, i.e. the swimming or reeling movement, the affected fish may also exhibit either or both the basic symptoms:

(a) Epithelioma or gall or tumour formation on the body surface
(b) Nodulation or necrosis of vital organs like brain, heart, liver, kidney, etc.

Significant epithelioma or gall or tumour formation has been reported (Fig. 12.6), for the first time, by Srivastava et al. (1984) and Sinha (1985) followed by Prabhuji and Sinha (2009). These abnormal hyperplastic structures appear as small or large tissue lumps developing on the body surface (dorsal, lateral, peduncle region or at the base of fins). On dissection the various vital organs of the infected fish, viz., heart, liver, brain, kidney, spleen, intestine and stomach, have been observed to exhibit nodulation and necrosis (Pettit 1911, 1913; Rucker and Gustafson 1953; Sindermann and Scattergood 1954; Dorier and Degrange 1961; Erickson 1965; Srivastava et al. 1984; Sinha 1985; Prabhuji et al. 1988; Prabhuji and Sinha 2009).

As far as control of fish diseases caused by oömycetes is concerned, many chemicals have been suggested; however, natural therapeutic agents are rare (Prabhuji et al. 1983, 1986). Most of the pure chemicals exhibit host toxicity and, therefore, may not be used en masse. Because of oömycetes' distinct physiology, most fungicides are ineffective against them. With the aid of genetic and genomic tools, oömycetes' genes encoding secreted proteins that control the outcome of infection are being identified. Ongoing genomic efforts promise to identify further genes and create the possibility of new control measures (Tyler 2001).

Further Researches Required

Members of oömycetes constitute an important place as decomposers in the natural ecosystem and are fundamentally facultative parasites. Studies in this particular group of pseudo-fungi are meagre and require more extensive research work on following lines:

- Biodiversity and taxonomic studies
- Distribution, periodicity and population density in different geographical regions of the globe
- Mineral requirements and their impact on the metabolism
- Effects of different physico-chemical factors and various biochemicals on the life cycle
- Qualitative and quantitative assessment of various biochemicals produced exogenously as well as endogenously
- Studies on endogenous hyper-parasitism by unicellular holocarpic forms
- Pathogenic studies on aquatic animals including histopathological investigations
- Enzymological studies (production of pectin methyl esterase, depolymerase and polygalacturonase) during parasitism in hypersensitive reaction (HSR)

References

Alexopoulos CJ, Mims CW, Blackwell M (1996) Introductory mycology, 4th edn. Wiley, New York

Amlacher E (1965) Pathologische und histochemische Befunde bei Ichthyosporidiumbefall der Regenbogenforelle (*Salmo gairdneri*) und am "Aquarienfisch Ichthyophonus", Z Fisch (N.F.) 13:85–112

Arderon W (1748) The substance of a letter from Mr. William Arderon F.R.S. to Mr. Henry Baker F.R.S.. Philos Trans R Soc 45(487):321–323

Areschoug JE (1844) *Achlya prolifera*, vaxandepa lefvande fisk, Ofvers. K Vetensk Akad Forh 1:124–126 (summarized in Flora: 28:59–60, 1845)

Ariztia EV, Andersen RA, Sogin ML (1991) A new phylogeny for chromophyte algae using 16S-like rRNA sequences from *Mallomonas papillosa* (Synurophyceae) and *Tribonema aequale* (Xanthophyceae). J Phycol 27:428–436

Ashley LM, Halver JE, Smith RR (1975) Ascorbic acid deficiency in rainbow trout and coho salmon and effects on wound healing. In: Ribelin WE, Migaki G (eds) The pathology of fishes. University of Wisconsin Press, Madison, pp 769–786

Ayers WA, Lumpsden RD (1977) Mycoparasitism of oospores of *Pythium* and *Aphanomyces* species by *Hyphochytium catenoides*. Can J Microbiol 23:38–44

Barr DJS (1992) Evolution and kingdoms of organisms from the perspective of a mycologist. Mycologia 84:1–11

Bennet JH (1842) On the parasitic fungi found growing in living animals. Trans R Soc Edinb 15(1844):277–294

Berkeley MJ (1864) Egg parasites and their relatives. Intellect Obs 5:147–153

Bessey EA (1950) Morphology and taxonomy of fungi. Blakiston, Philadelphia

Bhattacharya D, Medlin L, Wainright PO, Ariztia EV, Bibeau C, Stickel SK, Sogin ML (1992) Algae containing chlorophylls *ac* are paraphyletic: molecular evolutionary analysis of the Chromophyta. Evolution 46:1801–1817

Bootsma R (1973) Infections with Saprolegnia in pike culture (*Esox lucius* L.). Aquaculture 2:385–394

Bruns TD, White TJ, Taylor JW (1991) Fungal molecular systematics. Annu Rev Ecol Syst 22:525–564

Bucke Maff D, Cawley Maff GD, Craig JF, Pickering AD, Willoughby LG (1979) Further studies of an epizootic of perch, *Perca fluviatilis* L., of uncertain etiology. J Fish Dis 2:297–311

Cantino EC (1961) The relationship between biochemical and morphological differentiation in non-filamentous aquatic fungi. Symp Soc Gen Microbiol 11:243–271

Carus CG (1823) Beitrang zur Geschichte der unter Wasser an Verwesenden Thierkorpern sich erzeugenden Schimmel-oder Algen Gattungen, Nova Acta Acad Bd X:493

Chaudhuri H, Kochhar PL (1935) Indian water-moulds. I Proc Ind Acad Sci Sect B 2:137–154

Chaudhuri H, Lotus SS (1936) Indian water-moulds. II Proc Ind Acad Sci Sect B 3:328–333

Christensen T (1990) Plants, animals, algae and fungi, four non-taxonomic group designations. Taxon 39:93–94

Clausz JC (1968) Factors affecting oogenesis and oospore germination in *Achlya hypogyna*. J Elisha Mitch Sci Soc 84:199–206

Clausz JC (1970) Distribution of propagules of species of the Saprolegniaceae in the North Carolina Botanical Garden Lake and some possible controlling factors. Doctoral thesis, University of North Carolina, Chapel Hill, 103 pp

Copeland HF (1956) The classification of lower organisms. Pacific Book, Palo Alto

Cutter VM Jr (1941) Observations on certain species of *Aphanomyces*. Mycologia 33:220–240

Darnaud M (1972) *Achlya bisexualis* (Coker): élude du développement et de la biosynthése des lipids. Mise en évidence de quelques-unes de leurs particularities fondamentales. Ann Sci Nat Bot (12 Sér) 13:401–415

Dawkins R (1989) The selfish gene, 2nd edn. Oxford University Press, Oxford

Dayal R, Ji T (1966) The occurrence and distribution of aquatic fungi in certain ponds of Varanasi. Hydrobiologia 27:548–558

Dayal R, Thakurji (1968) Studies on aquatic fungi of Varanasi. V. a taxonomic study. Proc Nat Acad Sci. India 38(B):32–38

DeBary A (1860) Einige neue Saprolegnieen. Jahrb Wiss Bot 2:169–192

Dick MW (1966) The Saprolegniaceae of the environs of Blelham Tarn: sampling techniques and the estimation of propagule numbers. J Gen Microbiol 42:257–282

Dick MW (1971) The ecology of Saprolegniaceae in lentic and littoral muds with a general theory of fungi in the lake ecosystem. J Gen Microbiol 65:325–337

Dick MW (1990) Phylum Oömycota. In: Margulis L et al (eds) Handbook of Protoctista. Jones and Bartlett Publishers, Boston, pp 661–685

Dick MW (1997) Fungi, flagella and phylogeny. Mycol Res 101:385–394

Dick MW, Newby HV (1961) The occurrence and distribution of Saprolegniaceae in certain soils of South-east England. I. Occurrence. J Ecol 49:403–419

Dillwyn LW (1809) British Confervae, London

Dorier A, Degrange C (1961) L'evolution de l'Ichthyosporidium (*Ichthyophonus*) *hoferi* (Plehn et Mulsow) chez les salmonides d'elevage (truite arc en ciel et saumon de fontaine). Trav Lab Hydrobiol Piscic Univ Grenoble 1960/1961:7–44

Dukes TW (1975) Ophthalmic pathology of fishes. In: Ribelin WE, Migaki G (eds) The pathology of fishes. University of Wisconsin Press, Madison, pp 383–398

Erickson JD (1965) Report on the problem of *Ichthyosporidium* in a rainbow trout. Progve Fish Cult 27:179–184

Faro S (1972) The role of cytoplasmic glucan during morphogenesis of sex organs in *Achlya*. Am J Bot 59:919–923

Fischer A (1882) Untersuchungen über die Parasiten der Saprolegnieen. Jahrb Wiss Bot 13:286–371

Flora Danica (1780) Fasc. 14, Tom. V., Havniae

Gardner MLG (1974) Impaired osmoregulation in infected salmon, *Salmo salar*, L. J Mar Biol Assoc UK 54:635–639

Gimeno CJ, Ljungdahl PO, Styles CA, Fink GR (1992) Unipolar cell divisions in the yeast *S. cerevisiae* lead to filamentous growth: regulation by starvation and RAS. Cell 68:1077–1090

Goodsir J (1842) On the Conferva which vegetates on the skin of the Gold fish. Ann Mag Nat Hist 9:333–337

Gow NAR, Gadd GM (eds) (1995) The growing fungus. Chapman and Hall, London

Griffin DH (1966) Effect of electrolytes on differentiation in *Achlya* sp. Plant Physiol 41:1254–1256

Griffin DH, Breuker C (1969) Ribonucleic acid synthesis during the differentiation of sporangia in the water mold *Achlya*. J Bacteriol 98(2):689–696

Gruithuisen EP (1821) Die Branchienschnecke und eine aus ihren Ueberresten hervorwschsende lebendig gebahrende Conferve, Nova Acta Acad Bd X:437

Gustafson PV, Rucker RR (1956) Studies on an *Ichthyosporidium* infection in fish: transmission and host specificity, Special scientific report – fisheries, no. 166. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, pp 1–8

Hamid A (1942) Indian water-moulds. III Proc Ind Acad Sci Sect B 15:206–215

Hargens AR, Perez M (1975) Edema in spawning salmon. J Fish Res Bd Can 32:2538–2541

Harrison JL, Jones EBG (1975) The effect of salinity on sexual and asexual sporulation of members of the Saprolegniaceae. Trans Br Mycol Soc 65:389–394

Hatai K, Egusa S (1977) Studies on visceral mycosis of salmonid fry – characteristics of fungi isolated from the abdominal cavity of amago salmon fry. Fish Pathol 11:187–193

Hawksworth DL (1991) The fungal dimension of biodiversity: magnitude, significance, and conservation. Mycol Res 95:641–655

Held AA (1972) Improved culture methods for *Rozella* and for *Olpidiopsis*. Mycologia 64:871–886

Held AA (1973) Development of endoparasitic, zoosporic fungi. Bull Torrey Bot Club 100:203–216

Held AA (1974) Attraction and attachment of zoospores of the parasitic chytrid *Rozella allomycis* in response to host dependent factors. Arch Microbiol 95:97–114

Holland MM (1958) A preliminary survey of the fungus flora of caves. I. Aquatic Phycomycetes, Master's thesis, Virginia Polytechnic Institute, Blacksburg, p 50

Horn L (1904) Experimentelle Entwickelungsäunder ungen bei *Achlya polyandra* de Bary. Ann Mycol 2:207–241

Howard KL, Johnson TW Jr (1969) Aquatic fungi of Iceland: some filamentous, eucarpic and holocarpic species. Mycologia 61:496–510

Howard KL, Seymour R, Johnson TW Jr (1970) Aquatic fungi of Iceland: Saprolegniaceae. J Elisha Mitchell Sci Soc 86:63–79

Huxley TH (1882a) On Saprolegnia in relation to the salmon disease. Q J Microsc Soc 22(N.S.):311–333

Huxley TH (1882b) A contribution to the pathology of the epidemic known as the Salmon disease. Proc R Soc 33:381–389 (also appeared in Nature, London, 25:437–440)

Jain AK, Prabhuji SK (1985) Growth equation of *Saprolegnia*. Curr Sci 54:692–694

Jepps MW (1937) On the protozoan parasites of *Calanus finmarchicus* in the Clyde Sea area. Q J microsc Sci (N.S.) 79:589–658

Johnson TW Jr (1955) Inoculation studies with a polysporangiate *Rozella* parasitic in *Dictyuchus anomalus*. Am J Bot 42:119–123

Johnson TW Jr (1975) Aquatic fungi of Scandinavia: an unusual watermould from Norway. Mycotaxon 2:185–193

Johnson TW Jr (1976) Aquatic fungi of Scandinavia: some chytrids from Norway. Nor J Bot 23:139–151

Johnson TW Jr (1977) Aquatic fungi of Scandinavia: *Rozella septigena* Cornu. Nor J Bot 24:9–14

Johnson TW Jr, Howard KL (1972) Hyperparasitism of an *Achlya* from Iceland. Mycologia 64:1183–1187

Johnson TW Jr, Seymour RL, Padgett DE (2002) Biology and systematics of the Saprolegniaceae. http://www.ilumina-dlib.org

Karling JS (1946) Brazilian chytrids. IX. Species of *Rhizophydium*. Am J Bot 33:328–334
Karling JS (1966) Some zoosporic fungi of New Zealand. III. *Phlyctidium, Rhizophydium, Septosperma* and *Podochytrium*. Sydowia 20:74–85
Khulbe RD (1980) Occurrence of water moulds in some lakes of Nainital, Kumaon Hills, India. Hydrobiology 74:77–80
Khulbe RD, Bhargava KS (1977) Distribution and seasonal periodicity of water moulds in some lakes in Nainital Hills, India. Hydrobiology 54:67–72
Khulbe RD, Bhargava KS (1981) Studies in parasitic watermoulds of Kumaon Himalayas: the host range of five species of *Olpidiopsis*. Hydrobiology 76:45–47
Klebs G (1899) Zur physiologie der Fortpflanzung einiger Pilze. II. Saprolegnia mixta deBary. Jahrb Wiss Bot 33:5134–5593
Kützing FT (1843) Phycologia generalia. F.A. Brockhaus, Leipzig, p 306
Kwon-Chung KJ, Bennett JE (1992) Mycosis. In: Kwon-Chung KJ, Bennett JE (eds) Medical mycology. Lea and Fabiger, Philadelphia/London, pp 560–593
Lam TJ (1972) Prolactin and hydromineral regulation in fishes. Gen Comp Endocrinol Suppl 3:328–338
Ledermüeller (1760) Microscopic Augen. Und Gemuths-Ergotzungen
Lee PC (1965) Effect of light and temperature on the formation of sexual structures in the family saprolegniaceae. Doctoral thesis, Virginia Polytechnic Institute, p 68
Lee PC, Scott WW (1967) Effect of light and temperature on the formation of sexual structures in the family saprolegniaceae. Virg Polytech Inst Bull 2:35 p
Lounsbury JA (1930) Investigations on the nature of Protoachlya paradoxa Coker. Trans Wisconsin Acad Sci Arts Lett 25:215–225
Lund A (1934) Studies on Danish freshwater Phycomycetes, and notes on their occurrence, particularly relative to the hydrogen-ion concentration of the water. Kgl Danske Vidensk Selsk Skrift Naturv Math Afd IX 6(1):1–97
Lund A (1978) Occurrence of Saprolegniaceae in Danish soils. Nova Hedwigia 29:577–592
Lyngby HC (1819) Tentamen Hydrophytologiae Danicae. Havuiae, p 248
Manton I (1952) The fine structure of plant cilia. Symp Soc Exp Biol 6:306
Manton I (1965) Some phyletic implications of flagellar structure in plants. In: Preston RD (ed) Advances in botanical research, vol II. Academic, London/New York
McLeay DJ (1975) Variations in the pituitary-interrenal axis and the abundance of circulating blood-cell types in juvenile coho salmon, Oncorhynchus kisutch, during stream residence. Can J Zool 53:1882–1891
Meier AH (1972) Temporal synergism of prolactin and adrenal steroids. Gen Comp Endocrinol Suppl 3:499–508
Milanez AI (1966) A study of the aquatic Phycomycetes of the Gull Lake area in Michigan. Doctoral thesis, Michigan State University, p 248
Milanez AI (1967) Resting spores of *Phlyctochytrium planicrne* on Saprolegniaceae. Trans Br Mycol Soc 50:679–681
Milanez AI (1968) Aquatic fungi of the "cerrado" region of Säo Paulo State. I. First results. Rickia 3:97–109
Milanez AI (1970) Contributions to the knowledge of aquatic Phycomycetes of Säo Paulo State. I. Oömycetes from the West region. Rickia 5:23–43
Milanez AI, Beneke ES (1968) New records of aquatic Phycomycetes from Michigan. Mich Acad Arts Sci Lett 53:11–22
Miller CE (1965) Annotated list of aquatic Phycomycetes from Mountain Lake Biological Station, Virginia. Virg J Sci 16:219–228
Miller CE, Ristanovic B (1969) Studies on saprolegniaceous filamentous fungi. Ohio J Sci 69:105–109
Miller CE, Ristanovic B (1975) Systematic studies on some taxa of the Saprolegniaceae, Mikrobiologija. Acta Biol Iugosl 12:47–58
Money NP (1997) Wishful thinking of turgor revisited: the mechanics of fungal growth. Fungal Genet Biol 21:173–187
Money NP (1998) Why oomycetes have not stopped being fungi. Mycol Res 102(6):767–768
Moore D (1997) Review of the growing fungus. (Gow NAR, Gadd GM (eds), 1995). Mycologist 11:140
Moreau F, Moreau M (1936a) Action de la glycérine sur les Saprolégnées. Compt-Rend Hebd Séances Acad Sci 202:152–154
Moreau F, Moreau M (1936b) Action des sucres sur les Saprolégnées. Compt-Rend Hebd Séances Acad Sci 202:1086–1087
Moreau F, Moreau M (1938) Rechurches sur les Saprolégnées. Ann Sci Nat Bot (11e Sér.) 1:221–358
Mullins JT (1994) Hormonal control of sexual dimorphism. In: Wessels JGH, Meinhardt F (eds) Growth, differentiation and sexuality, vol 1. Springer, New York, pp 413–421
Murphy SMN, Lovett JS (1966) RNA and protein synthesis during zoospore differentiation in synchronized cultures of Blastocladiella. Dev Biol 14:68–95
Nagai M, Takahashi T (1962) Electron microscope observations on the zoospores of *Saprolegnia diclina*. Trans Mycol Soc Japan 3:19–23
Nees von Esenbeck CG (1823) Zusatz. zu: Carus, C.G. 1823: Betrag zur Geschichte der unter Wasser an verwesenden Thierkörpen sich erzeugenden Schimmel- oder Algen- Gattungen. Nova Acta Acad Leop-Carol 11:507–522
Neish GA (1976) Observations on the pathology of saprolegniasis of pacific salmon and on the identity of the fungi associated with this disease, PhD thesis, University of British Columbia, Vancouver, p 213 (original not seen; cited in Neish GA, Hughes GC (1980) Diseases of fishes: Book 6: fungal diseases of fishes. T.F.H. Publications Inc. Ltd., Neptune, p 159)
Neish GA (1977) Observations on saprolegniasis of adult sockeye salmon, *Oncorhynchus nerka* (Walbaum). J Fish Biol 10:513–522
Nolard-Tintigner N (1971) Cause de la mort dans la saprolegniose experimentale du poisson. Bull Acad r Belg Cl Sci 57:185–191
Nolard-Tintigner N (1973) Etude experimentale sur l'epidemiologie et la pathogenie de la saprolegniose

chez Lebistes reticulatus Peters et Xiphophorus helleri Heckel. Acta Zool Path Antverp 57:1–127
Nolard-Tintigner N (1974) Contribution a l'etude de la Saprolegniose des poisons en region tropicale. Acad r Sci Outré-Mer Cl Sci Nat Med (NS) 19:1–58
Novaes-Ledieu M, Jimenez-Martinez A, Villanueva JR (1967) Chemical composition of hyphal wall of Phycomycetes. J Gen Microbiol 47:237
Obel P (1910) Researches on the conditions of the forming of oögonia in *Achlya*. Ann Mycol 8:421–443
Olivereau M (1962) Modifications de l'interrenal du smolt (Salmo salar L.) au cours du passage d'eau douce en eaude mer. Gen Comp Endocrinol 2:565–573
Ou SH (1940) Phycomycetes of China. Sinesia 11:427–449
Papatheodorou V (1980) Les mycoses chez les poisons: Eltiologie-Pathogenie-Traitement, These le grade de Doctor, L'Inst National Polytechnique De Toulouse, p 188
Pettit A (1911) A propos du microorganisme producteur de la Traumelkrankheit: Ichthyosporidium ou Ichthyophonus. C.r. Seanc. Soc Biol 70:1045–1047
Pettit A (1913) Observations sur l'Ichthyosporidium et sur la maladie qu'il provoque Chez la truite. Ann Inst Pasteur Paris 27:986–1008
Pieters AJ (1915) The relation between vegetative vigor and reproduction in some Saprolegniaceae. Am J Bot 2:529–576
Plattner I, Hall IR (1995) Parasitism of non-host plants by the mycorrhizal fungus *Tuber melanosporum*. Mycol Res 99:1367–1370
Powles PM, Garnett DG, Ruggieri GD, Nigrelli RF (1968) *Ichthyophonus* infection in yellow-tail flounder (*Limanda ferruginea*) off Nova Scotia. J Fish Res Bd Can 25:597–598
Prabhuji SK (1979) Studies on some lower fungi occurring in certain soils of Gorakhpur, India, PhD thesis approved by University of Gorakhpur, Gorakhpur
Prabhuji SK (1980) Photo reactivation in two members of Saprolegniaceae. Environ India 3:77–78
Prabhuji SK (1984a) Studies on some water-moulds occurring in certain soils of Gorakhpur. J Ind Bot Soc 63:387–396
Prabhuji SK (1984b) Distribution of water-moulds within quadrates in the soils of Gorakhpur. Proc Nat Acad Sci India 54(B):21–32
Prabhuji SK (2005) Occurrence and phenology of the Oomycetes with special reference to Saprolegniaceae. In: Mukerji KG et al (eds) Frontiers in plant sciences. I.K. International, New Delhi, pp 129–142
Prabhuji SK (2010) Sexual reproduction in water moulds – I: general aspects related to family Saprolegniaceae. Int J Plant Rep Biol 2(1):17–30
Prabhuji SK (2011) The interdependence of watermoulds occurring in water and soil habitats affecting their population density, distribution and periodicity. Trop Ecol 52(3):309–322
Prabhuji SK, Sinha SK (1993) Two new watermoulds from India: *Allomyces recurvus* sp. nov. and *Brevilegnia indica* sp. nov. Neo Bot 1(1&2):31–38
Prabhuji SK, Sinha SK (1994) *Pythium multisporum* Poitras: its Morphology and Phenology in the soils of Padrauna, India, J. Living World 1(2):126–133
Prabhuji SK, Sinha SK (2009) Life cycle (reproductive) stages of *Ichthyophonus hoferi* Plehn & Mulsow, a parasitic fungus causing deep mycoses. Int J Pl Rep Biol 1(2):93–101
Prabhuji SK, Sinha SK (2010) Deep dermal mycoses in fresh-water fishes parasitized by certain oomycetous fungi. J Adv Zool 31(2):124–132
Prabhuji SK, Srivastava GC (1977) Some members of Saprolegniaceae occurring in certain soils of Gorakhpur. Geobios 4:258–259
Prabhuji SK, Srivastava GC (1978) Addition to lower fungi of India. Geobios 5:35–36
Prabhuji SK, Srivastava GC (1982) Effect of light and temperature on the growth and formation of oögonia in two members of Saprolegniaceae. Proc Nat Acad Sci India 52(B):91–100
Prabhuji SK, Srivastava GC, Rizvi SJH, Mathur SN (1983) 1, 3, 7- trimethylxanthine (caffeine), a new natural fish fungicide. Experientia 39:177–179
Prabhuji SK, Srivastava GC, Sinha SK (1984) Aquatic fungi of India: IV. *Brevilegnia* Coker & Couch. Kavaka 12(2):99–106
Prabhuji SK, Srivastava GC, Sinha SK (1986) Applicability of some amino acids as fish-fungicides. Proc Nat Acad Sci India 56(B):67–68
Prabhuji SK, Srivastava GC, Sinha SK (1988) Observations on the Histopathology of the vital organs of *Carassius carassius* L. parasitized by *Ichthyophonus hoferi* Plehn & Mulsow, In: Khulbe RD (ed) Proceedings of the national seminar on perspectives in aquatic biology, Nainital, pp 361–368
Prabhuji SK, Sinha SK, Singh SB (1998) Studies in aquatic fungi causing Dermatomycoses and deep mycoses in fish: *Colisa lalius* Ham. In: Proceedings of the Xth annual conference of Purvanchal Academy of Sciences, Azamgarh
Prabhuji SK, Singh AK, Tripathi A (2009) Effects of certain physicochemical factors on the life cycle of water-moulds – I: Saprolegnia diclina Coker. Vegetos 22(1):69–78
Prabhuji SK, Sharma N, Tripathi A, Srivastava R, Rai A, Saini S (2010) Life cycle of *Rozella allomycis* Foust an obligate parasite on *Allomyces arbuscula* Butler. Int J Plant Rep Biol 2(2):137–140
Prabhuji SK, Sinha SK, Deepanjali S (2012a) Deep mycoses in fish caused by water-moulds and stress hypothesis: a review. In: Sati SC, Belwal M (eds) Microbes: biodiversity and biotechnology. Daya Books, New Delhi, pp 397–416
Prabhuji SK, Kumar A, Srivastava R, Tripathi RP, Saini S (2012b) Studies on the effects of certain plant growth regulators on the life cycle of *Achlya diffusa* Har ex John. Vegetos 25(1):236–246
Pringsheim N (1858) Beiträge zur Morphologie und Systematik derAlgen. II. Die Saprolegnieen. Jahrb Wiss Bot 1:284–304

Raper JR (1936) Heterothallism and sterility in *Achlya* and observations on the cytology of Achlya bisexualis. J Elisha Mitchell Sci Soc 52:274–289

Raper JR (1951) Sexual hormones in *Achlya*. Amer Sci 39:110–120

Reichenbach-Klinke HH (1956) Augenschaden bei Meeresfischen durch den Pilz *Ichthyosporidium hoferi* (Plehn et Mulsow) und Bemerkungen zu seiner Verbreitung bei Mittelmeerfischen, Pubbl Stn Zool Napoli 29:22–32

Reichenbach-Klinke H-H (1960) Die Discus-Krankheit und ihre Ursachen. Aquar-u Terrar-Z 13:303–305

Reichenbach-Klinke H-H, Elkan E (1965) The principal diseases of lower vertebrates. Academic, New York, p 600

Reischer HS (1949) The effect of temperature on the papillation of oögonia of *Achlya colorata*. Mycologia 41:398–402

Robin C (1853) Histoire naturelle des vegetaux parasites qui croissent sur Phomme Et sur les animaux vivants. J.-B. Bailliere, Paris, p 702

Rossman AY, Palm ME (2006) Why are Phytophthora and other Oömycota not true fungi? Outlooks Pest Manage 17:217–219

Rucker RR, Gustafson PV (1953) An epizootic among rainbow trout. Progve Fish Cult 15:179–181

Ruggieri GD, Nigrelli RF, Powles PM, Garnett DG (1970) Epizootics in yellow-tail flounder, *Limanda ferruginea* Storer, in the western North Atlantic caused by *Ichthyophonus*, an ubiquitous parasitic fungus. Zool NY 55:57–62

Salvin SB (1940) The occurrence of five successive swarming stages in a non-sexual *Achlya*. Mycologia 32:148–154

Salvin SB (1941) Comparative studies on the primary and secondary zoospores of the Saprolegniaceae. I. Influence of temperature. Mycologia 33:592–600

Sati SC, Mer GS (1989) The possible correlations between certain asexual and sexual reproductive bodies in Saprolegniaceae. Proc Nat Acad Sci India 59(B):93–98

Schaperclaus W (1953) Fortpflanzung und systematik von *Ichthyophonus*. Aquar-u Terrar-Z 6:177–182

Schneider CL, Yoder DL (1973) Development of a methodology for the production of *Aphanomyces cochlioides* oöspores in vitro. J Am Soc Sugar Beet Technol 17:230–239

Schrank F von P (1789) Balersche Flora, München 2, 553

Scott WW (1960) The fungus flora of agricultural soils in Virginia. I. Aquatic Phycomycetes, Virg J Sci (N.S.) 11:125–129

Scott WW, Seymour R, Warren C (1963a) Some new and unusual fungi from Virginia. I. Lower Phycomycetes. Virg J Sci 14:11–15

Scott WW, Powell JR, Seymour R (1963b) Pure culture techniques applied to the growth of *Saprolegnia* spp. on a chemically defined medium. Virg J Sci 14:42–46

Shanor L (1940) Studies in the genus *Olpidiopsis*. III. Some observations on the host range of certain species. J Elisha Mitchell Sci Soc 56:165–176

Sindermann CJ (1956) Diseases of fishes of the western North Atlantic IV. Fungus disease and resultant mortalities of herring in the Gulf of Saint Lawrence in 1955. Res Bull Dept Sea Shore Fish Me 25:1–23

Sindermann CJ (1958) An epizootic in Gulf of Saint Lawrence fishes. Trans N Am Wildl Conf 23:349–360

Sindermann CJ, Scattergood LW (1954) Diseases of fishes of the western North Atlantic II. *Ichthyosporidium* disease of the sea herring (*Clupea harengus*). Res Bull Dept Sea Shore Fish Me 19:1–40

Sinha SK (1985) Studies in fungi causing fish diseases. Ph.D. thesis approved by the University of Gorakhpur, Gorakhpur

Spallanzani L (1777) Opuscules de physique. Geneve

Sparrow FK Jr, Dogma IJ (1973) Zoosporic Phycomycetes from Hispaniola. Archiv Microbiol 89:177–204

Srivastava GC (1964) Observations on Indian aquatic fungi. II. Occurrence of *Olpidiopsis varians* Shanor at Gorakhpur. Ind Phytopathol 17:249–253

Srivastava GC (1966) The host range of four species of *Olpidiopsis*. Trans Br Mycol Soc 49:69–72

Srivastava GC (1967a) Some species of Saprolegniaceae collected from Gorakhpur India. Hydrobiologia 30:281–292

Srivastava GC (1967b) Ecological studies on some aquatic fungi of Gorakhpur India. Hydrobiologia 30:385–404

Srivastava GC (1975) *Olpidiopsis indica* sp. nov. from India. Curr Sci 44:642–644

Srivastava AK (1979) Fungal infection of hatchlings of *Labeo rohita*. Mykosen 22(2):40

Srivastava RC (1980a) Fungal parasites of certain freshwater fishes of India. Aquaculture 21:387–392

Srivastava RC (1980b) Studies in fish mycopathology – a review, Part I. Mykosen 23(6):325–332

Srivastava RC (1980c) Studies in fish mycopathology – a review, Part II. Mykosen 23(7):380–391

Srivastava GC (1982) The host range of *Olpidiopsis indica*. J Ind Bot Soc 61:108–110

Srivastava GC, Bhargava KS (1963) Observations on Indian aquatic fungi. I. Three species of *Olpidiopsis* from Gorakhpur. Ind Phytopathol 16:271–274

Srivastava GC, Sinha SK, Prabhuji SK (1984) Water-moulds parasitizing *Carassius carassius* L. causing abnormal growth of fish tissues. J Ind Bot Soc 63(Suppl):25

Srivastava GC, Sinha SK, Prabhuji SK (1994) Observations on fungal infection of Chela laubuca Ham. With special reference to deep mycoses. Curr Sci 66(3):237–239

Sterling AB (1879–1880) Additional observations on fungus disease of salmon and other fish. Proc R Soc Edinb 10:371–378

Sternberg S (1994) The emerging fungal threat. Science 266:1632–1634

Suzuki S (1961) The diurnal migration of zoospores of aquatic fungi in shallow lake. Bot Mag (Tokyo) 74:138–141

Suzuki S, Nimura H (1961) Microbiological studies of the lakes of volcano Bandai. V. The microbial populations in the Sohara Lake group. Jpn J Limnol 22:15–23
Suzuki S, Nimura H (1962) The microbiological studies of the lakes of volcano Bandai. IX. The microbial populations in the Kawakami Lake group. Trans Mycol Soc Jpn 3:78–81
Szaniszlo PJ (1965) A study of the effect of light and temperature on the formation of Oogonia and oospheres in Saprolegnia diclina. J Elisha Mitchell Sci Soc 81:10–15
Tingle CL (1972) Some physiological aspects of oögonia formation in *Saprolegnia diclina*, Master's thesis, University of North Carolina, Chapel Hill, 41 p
Turian G (1962) Cytoplasmic differentiation and dedifferentiation in the fungus *Allomyces*. Protoplasma 54:323
Tyler BM (2001) Genetics and genomics of the oömycetes host interface. Trends Genet 17(11):611–614
Unger F (1844) Sur l'Achlya prolifera. Ann Sci Nat 3e ser Bot 2:5–20
Utida S, Hirano T, Oide H, Ando M, Johnson DW, Bern HA (1972) Hormonal control of the intestine and urinary bladder in teleost Osmoregulation. Gen Comp Endocrinol Suppl 3:317–327
Vogel HJ (1960) Two modes of lysine synthesis among lower fungi: evolutionary significance. Biochem Biophys Acta 41:172
Wainwright PO, Hinkle G, Sogin ML, Stickel SK (1993) Monophyletic origins of the metazoa: an evolutionary link with fungi. Science 260:340–342
Wedemeyer G (1969) Stress induced ascorbic acid depletion and cortisol production in two salmonoid fishes. Comp Biochem Physiol 29:1247–1251
Wedemeyer G (1970) The role of stress in disease resistance of fishes. Am Fish Soc Spec Publ 5:30–35
Whiffen AJ (1945) Nutritional studies of representative of five genera in the Saprolegniaceae. J Elisha Mitchell Sci Soc 61:114–123
Willoughby LG (1968) Atlantic Salmon disease fungus. Nature (London) 217:872–873
Willoughby LG (1969) Salmon disease in Windermere and the River Leven; the fungal aspect. Salmon Trout Mag no. 186:124–130
Willoughby LG (1971) Observations on fungal parasites of Lake District salmonids. Salmon Trout Mag no. 192:152–158
Willoughby LG (1977) An abbreviated life cycle of Saprolegnia in the salmonid fish. Trans Br Mycol Soc 69:133–135
Willoughby LG (1978) Saprolegniasis of salmonid fish in Windermere: a critical analysis. J Fish Dis 1:51–67
Wolke RE (1975) Pathology of bacterial and fungal diseases affecting fish. In: Ribelin WE, Migaki G (eds) The pathology of fishes. University of Wisconsin Press, Madison, pp 33–116
Woodhead AD (1975) Endocrine physiology of fish migration. Oceanogr Mar Biol A Rev 13:287–382
Wrisberg (1765) Observations de animalcules infusorlis satura, Gottingae
Zeigler AW, Linthicum B (1950) Some physiological aspects of fertility in *Achlya tuberculata*. J Elisha Mitchell Sci Soc 66:182–185

Amphibians of Doon Valley (Dehra Dun, Uttarakhand) with Their Systematics, Distribution, Ecology, Conservation Status and Threats

13

Akhlaq Husain*

Abstract

The amphibian fauna of Doon Valley belonging to ten species, eight genera and four families under single order has been dealt in this paper, with various English names and updated systematic account of species, tadpoles, distribution in the valley (eastern and western parts), Uttarakhand (including conservation areas), rest of India and elsewhere, habitat and ecology, conservation status and threats.

Keywords

Amphibians • Distribution • Ecology • Diversity

Introduction

The amphibian fauna of Dehra Dun and around has been worked out by various workers during the past (Tilak and Husain 1977; Ray 1995, 1999; Ray and Tilak 1995; Husain 2003; Mehta and Uniyal 2007; Bahuguna and Bhutia 2010), but no consolidated account of the species in the Doon Valley is available and hence the present study has been taken up for an update. Waltner (1974) provided geographical and altitudinal distribution of species in Himalaya. A total of ten species of toads and frogs belonging to eight genera, four families and single order have been collected from the valley, and as regards their conservation status, they all fall under 'Least Concern' category of IUCN (International Union for Conservation of Nature) Red List of Threatened Species. Interestingly, *Duttaphrynus stomaticus*, the Marbled Toad, occurs in deserts of Oman (in Arabian Peninsula) also and in contrast *D. melanostictus* in Nanda Devi Biosphere Reserve, in Himalayan Highlands Biogeographic Zonation (around the peak of Nanda Devi, 7,817 m in Uttarakhand, India).

Doon Valley

Doon Valley is a unique spindle-shaped, flat geomorphic terrain in the Garhwal Himalaya. It is bounded by the northern Siwaliks and Lesser Himalayan hills and in the south by Siwalik Hills. It is transversely bordered by Ganga in southeast and Yamuna in north-west. The north-western

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and north-eastern parts of the valley possess prominent relief 900–2,100 m and exhibit rough and rugged terrain with sharp rounded ridge crests. The whole of valley is receiving large amount of debris through strong denudation from its northern range of the Lesser Himalaya and the Siwaliks through a number of streams.

It lies between two intermittent ranges of the Himalaya – the Siwaliks and the Lesser Himalaya. It is bounded on all sides by mountains, with Mussoorie at the centre and the two extremities being Paonta Sahib (Himachal Pradesh) in the west and Haridwar in a semi-circular arc. The valley also forms a watershed between the Yamuna and Ganges river systems. In fact the Yamuna and Ganges are closest to each other as they pass through the extremities of the Doon Valley. On the drainage pattern, it is divisible into eastern and western alleys by Garhi Cantonment – General Mahadev Singh Road – Mohabbewala and Chandrabani Reserve Forest water divide.

Geologically, it is a topographic depression of irregular parallelogram shape with its longer axis running parallel to Lesser Himalayan Range. It lies between 29° 55′ and 30° 30′N Lat. and 77° 35′ and 78° 20′E Long. It is considered as 'piggy back' basin formed on the Siwalik folded trust sheet due to down-bucking

Climate: The climate is generally temperate, although it varies from tropical, from hot in summers to severely cold, depending upon the season and the altitude of the specific location. The nearby hilly regions often get snowfall during winter, but although the temperature in the valley can reach below freezing during severe cold wave, this is not a frequent occurrence. However, summer temperatures can reach up to 40 °C for a few days in the season, whereas winter temperatures are usually between 1.0 and 20.0 °C. During the monsoon season, there is often heavy and protracted rainfall.

Systematic Account of Species with Distribution, Ecology, Conservation Status and Threats

Class: Amphibia Blainville, 1816
Subclass: Lissamphibia Haeckel, 1866
(Recent Amphibians)
Order: Anura Fischer von Waldheim, 1813
(Frogs and Toads)
Suborder: Neobatrachia Reig, 1958
Family: Bufonidae Gray, 1825
(True Toads)
Genus: *Duttaphrynus* Frost et al., 2006

Duttaphrynus melanostictus (Schneider, 1799)

Bufo melanostictus Schneider, 1799. *Hist. Amph. I. Jena.*; 216 (type-locality: 'India orientali'); Ray, 1995. *Amphibia*. In: *Fauna of Western Himalaya, Part 1, Uttar Pradesh. Himalayan Ecosystem Series*: 152, fig. 7; Ray & Tilak, 1995. *Amphibia*. In: *Fauna of Rajaji National Park. Fauna of Conservation Areas* 5: 56-58, pl. 1; Ray, 1999. *Mem. zool. Surv. India*, 18(3): 61-64, pl. 21, 25 (Dehra Dun district); Husain, 2003. *Wetland Ecosystem Series* 5: 27-28 (Asan Wetland); Mehta & Uniyal, 2007. *Amphibia*. In: *Faunal Diversity Western Doon Shiwaliks*: 63.

Bufo bengalensiss Daudin, 1802 'An. XI', *Hist. Nat. Rain. Gren. Crap., Quarto*: 96 (type-locality: 'Bengale').

Bufo chlorogaster Daudin, 1802 'An. XI', *Hist. Nat. Rain. Gren. Crap., Quarto*: 74 (type-locality: 'sur une montagne de l'ile Java', Indonesia).

Rana dubia Shaw, 1802. *Gen. Zool.*, 3(1): 157 (type-locality: not designated; Neotype from 'India orientali').

Bufo flaviventris Daudin, 1802. *Hist. Nat. Rain. Gren. Crap., Quarto*: 74. pl. 74 (alternative name for *Bufo chlorogaster* Daudin, 1802).

Rana melanosticta Shaw, 1802. *Gen. Zool.*, 3(1): 174.

Bufo scaber Daudin, 1802 'An. XI', *Hist. Nat. Rain. Gren. Crap., Quarto*: 94 (type-locality: 'India orientali').

Bufo carinatus Gray, 1830. *Ill. Indian Zool.*, Part 1: pl. 83 (Type-locality: 'Bengal').

Bufo dubius Gray, 1830. *Ill. Indian Zool.*, Part 1: 8, pl. 83.

Bufo isos Lesson, 1834. In: Belanger (ed.). *Vov. Indes-Orientales N. Eur. Caucase Georgie Perse*, *Zool.*: 333 (type-locality: 'Bengale').

Bufo gymnauchen Bleeker, 1858. *Nat. tijdschr. Nedrel. Ind*., 16: 46 (type-locality: Indischen archipel, corrected to Bintang).

Bufo spinipes Fitzinger, 1861. *Sitz. Akad. Wien*., 42: 415.

Docidophryne isos Fitzinger, 1861 (1860). *Sitzungsber. Akad. Wiss. Wien, Phys. Math. Naturwiss, Kl*., 42: 415.

Docidophryne spinipes Fitzinger, 1861 (1860). *Sitzungsber. Akad. Wiss. Wien, Phys. Math. Naturwiss, Kl*., 42: 415 (type-locality: Nicobaren). *Nomen nudem*.

Phrynoidis melanostictus Cope, 1862. *Proc. Acad. Nat. Sci. Philadelphia*, 14: 358.

Bufo spinipes Steindachner, 1867. *Reise Osterreichischen Fregatte Novara, Zool., Amph*.: 42 (type-locality: Nikobaren).

Bufo longecristatus Werner, 1903. *Zool. Anz*., 26: 252 (type-locality: inneres von Borneo).

Bufo tienhoensis Bourret, 1937. *Annexe Bull. Gen. Instr. Publique, Hanoi*, 1937: 6, 11 (type-locality: col de Tien-Ho, Viet Nam).

Docidophryne melanostictus Bourret, 1942. *Batr. Indochine*: 173.

Bufo camortensis Mansukhani & Sarkar, 1980. *Bull. Zool. Surv. India*, 3: 97 (type-locality: Camorta, Andaman & Nicobar Islands).

Ansonia kamblei Ravichandran & Pillai, 1990. *Rec. zool. Surv. India*, 86: 506 (Karnala, Dist. Sholapur, Maharashtra)

Bufo melanostictus hazarensis Khan, 2001. *Pakistan J. Zool*., 33: 297 (type-localities: Ooghi, Manshera and Data, Hazara Division, eastern NWFP, Pakistan)

Bufo melanostictus melanostictus Khan, 2001. *Pakistan J. Zool*., 33: 297.

Duttaphrynus melanostictus Frost, Grant, Faivovich, Bain, Haas, Haddad, de Sa, Channing, Wilkinson, Donnellan, Raxworthy, Campbell, Blotto, Moler, Drewes, Nussbaum, Lynch, Green, and Wheeler, 2006. *Bull. Am. Mus. Nat. Hist*., 297: 365.

Duttaphrynus = Bufo melanostictus Bahuguna & Bhutia, 2010. *Amphibia. In: Faun. Uttarakhand, State Fauna Series*, 18(1): 507-508

English Names

Asian Black-Spotted Toad, Asian Common Toad, Asian Eye-Brow-Ridge Toad, Asian Toad, Black-Lipped Toad, Black-Spectacled Toad, Black-Spined Toad, Common Asian Toad, Common Indian Toad, Common Sunda Toad, Common Toad, Hazara Toad, House Toad, Indian Toad, Javanese Toad, Keeled-Nose Toad, Maharashtra Stream Toad, Reticulated Toad, South Asian Garden Toad, Southeast Asian Broad-Skulled Toad, Southeast Asian Toad and Spectacled Toad.

Diagnostic Characters

Adult

Head with bony ridges; tympanum distinct, equal or smaller than eye; tongue entire; parotid glands elevated; 1st finger longer than 2nd (in younger individuals 1st and 2nd almost equal in length), 3rd the longest, 2nd slightly shorter than 4th, metatarsal tubercle spiny and intermingled with spiny warts; toes less than ½ webbed, three digital phalanges of 4th free of webbing, 1st smallest and 4th the longest, 3rd longer than 5th; metatarsals distinct, outer oval, inner elongated and projecting; sub-articular tubercles small; skin rough with spiny warts, tips of glands tubercular, sometimes with black spines. Juveniles lack warts and have very inconspicuous tympanum.

Colouration: Brownish above and whitish or immaculate below or more or less black spotted or with a network of brown, sometimes limbs crossbarred. In juveniles, throat has a blackish band between chin and breast.

Sexual Dimorphism: Male smaller than female with a sub-gular vocal sac, black callosities or nuptial pads of first two (two inner) fingers cornified and covered with black spinules, tips of digits covered with black caps and turn yellowish-green with throat enriched in colour (often of bright yellow-orange hues) during the breeding season in monsoon.

Size: 16.5 cm in length from snout to vent.

Tadpole

Tail with broadly rounded tip, colour usually blackish above, translucent pink on lower half of belly.

Distribution

Localities in Doon Valley

Eastern Doon Valley: Rajaji National Park (*partim*).

Western Doon Valley: Asan Reservoir; Asan River below its barrage; Seepage nala and Badshahi Bagh road.

Uttarakhand

Dehra Dun, Tehri, Pauri, Uttarkashi, Chamoli, Nainital, Almora and Pithoraharh. Corbett Tiger Reserve, Givind Pashu Vihar, Nanda Devi Biosphere Reserve and Rajaji National Park.

India

Widely distributed from plains to 2,500 m altitude. Chandigarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Punjab and Rajasthan. Andaman and Nicobar Islands (introduced).

Elsewhere

Bangladesh, Brunei Darussalam, Cambodia, China (including Hainan, Taiwan), Hong Kong, Indonesia (Borneo, Sumatra; introduced into Bali, Irian Jaya, Jawa, Kalimantan, Maluku and Sulawesi), Indo-China, Lao People's Democratic Republic, Macao, Malaysia, Maldives, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Viet Nam. Bhutan (uncertain), Timor and Papua New Guinea (introduced).

Habitat and Ecology

Mainly a species of disturbed lowland habitats, from upper beaches and riverbanks to human-dominated agricultural and urban areas. It is uncommon in closed forests. It breeds in still and slow-flowing rivers and temporary and permanent ponds and pools. The larvae are found in still and slow-moving water bodies. Adults are terrestrial and may be found underground cover (rocks, leaf litter, logs) and are also associated with human habitations.

Conservation Status

IUCN Red List: Least Concern.

Threats

There are no major threats to this very adaptable species. It is sometimes found in the international pet trade but at levels that do not currently constitute a major threat.

Remarks

This form is probably a complex of more than one species. *Duttaphrynus tienhoensis* was synonymised with *D. melanostictus* by Dubois and Ohler (1999), Matsui et al. (2005).

***Duttaphrynus stomaticus* (Lutken, 1864)**

English Names

Assam Toad, Indo-Gangetic Marbled Toad, Indus Valley Toad, Marbled Toad.

Diagnostic Characters

Adult

Head without bony ridges; tympanum nearly equal to eye diameter; tongue entire; parotid glands flattened; 1st finger equal to 2nd or slightly longer; toes 2/3rd to 3/4th webbed; skin rough with numerous flat warts.

Colouration: Marbled above and dirty whitish below.

Sexual Dimorphism: Male smaller than female, with single external vocal sac, nuptial callosities develop on 1st finger.

Size: 9.0 cm from snout to vent in length.

Tadpole

Small with bright silvery-white and brown pigmentation on dark head and body, tail mottled with brown patches.

Distribution

Localities in Doon Valley

Eastern Doon Valley: Maldevta, Raipur road, Song River at Raiwala, Daudi, Muni-ki-Reti nr Rishikesh and Rajaji National Park (*partim*).

Western Doon Valley: Asan River at Badowala, Asan Barrage at Dhalipur, Puni Grant ne Timli, Timli Forest, Kata Pathar, Kalsi, Guchhupani (Robber's Cave) and Badshahi Bagh road.

Uttarakhand

Dehra Dun, Tehri, Pauri, Nainital, Almora and Pithoragarh. Corbett Tiger Reserve and Rajaji National Park.

India
Andhra Pradesh, Assam, Bihar, Chandigarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Western Ghats.

Elsewhere
Afghanistan (southern), Bangladesh, Bhutan, China, Iran (eastern), Myanmar, Nepal and Pakistan. Sri Lana (introduced).

There is a small disjunct population in northern Oman at Wadi Jubaitha, 20 km east of Mahdah (Theodore Papenfuss pers. comm., September 2008, vide IUCN Red List of Threatened Species, 2012.2).

Its altitudinal range is from sea level to 4,500 m asl.

Habitat and Ecology
Found in a wide variety of habitats including open plains, grasslands, scrubland, forest, suitable agricultural land and human habitations. Breeds in permanent and seasonal pools, seasonal streams and slow-flowing streams. Adults hide under rocks and in crevices. It is a very adaptable species that may be found in houses.

Conservation Status
IUCN Red List: Least Concern.

Threats
There are no major threats to this adaptable species. Localized threats over much of its range include loss of habitat to infrastructure development; intensification of agriculture; pollution of wetlands and land by agrochemicals; traffic-related mortality; and long-term drought.

Remarks
It is present in many protected areas and perhaps occurs in three protected areas in Iran.
Family: Dicroglossidae Anderson, 1871
(Fork-Tongued Frogs)
Subfamily: Dicroglossinae Anderson, 1871
Genus: *Euphlyctis* Fitzinger, 1843

***Euphlyctis cyanophlyctis* (Schneider, 1799)**

English Names
Cyan Five-Fingered Frog, Green Stream Frog, Green Wart Frog, Indian Skipper Frog, Seistan Skittering Frog, Skipper Frog, Skipping Frog, Skittering Frog, Small-Spotted Frog, Spiny Skittering Frog, Studded Frog, Water Skipper Frog and Water Skipping Frog.

Diagnostic Characters

Adult
Tympanum distinct, nearly equal to eye diameter; fingers pointed, 1st and 4th equal to 2nd, 3rd the longest, sub-articular and palmer tubercles small; toes fully webbed, 4th the longest; inner metatarsal tubercle short, pointed and digitiform; skin with fine tubercles and warts and rows of pores above (sometimes below also) and smooth below; a strong fold between eye and shoulder.

Colouration: Olive/dark brownish, marbled or dark spotted above with a creamy band on sides, speckled with black below and two blackish streaks on hinder side of thighs.

Sexual Dimorphism: Male smaller, with two blackish slitlike openings of vocal sacs.

Size: 6.4 cm in snout to vent length, male smaller.

Tadpole
Body stout with acutely pointed tail and dark blotches above.

Distribution

Localities in Doon Valley
Eastern Doon Valley: Maldevta; Muni-ki-Reti and Daudi, Rishikesh; Raipur road; Robber's Cave; Song River Raiwala and Rajaji National Park (*partim*).

Western Doon Valley: Asan Reservoir, Seepage nala, Asan River above Kunja Grant and below its barrage at Dhalipur, Asan River at village Jhivaredi (Shimla road), Badowala and Sahaspur; Kalsi; Kata Pathar, Lakhwar road; Karvapani; Robber's Cave (Guchhupani); Puni Grant nr. Timli and Timli Forest.

Uttarakhand

Dehra Dun, Tehri, Pauri, Uttarkashi, Nainital, Almora and Pithoragarh. Corbett Tiger Reserve, Gobind Pashu Vihar and Rajaji National Park.

India

Throughout. Arunachal Pradesh, Assam, Chhattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Manipur, Nagaland, Punjab, Rajasthan, Tamil Nadu (Thiruvannamalai), West Bengal and Western Ghats.

Elsewhere

Afghanistan, Bangladesh, Iran, Malaysia, Nepal, Pakistan (Baluchistan), Sri Lanka and Viet Nam. Thailand (might be introduced).

Habitat and Ecology

A very aquatic species found in marshes, pools and various other wetlands within a variety of habitat types where adults may be found basking at the edge of the water bodies and males calling from within the water. It may be found in modified habitats, usually where suitable wetland habitat is available.

Conservation Status

IUCN Red List: Least Concern.

Threats

There are no major threats to this species as a whole. The species is locally threatened by pollution of aquatic habitats (generally through the use of agrochemicals) and the drainage (wetland reclamation) and desiccation of wetlands.
Genus: *Fejervarya* Bolkay, 1915
Subgenus: *Rana* Linnaeus, 1758

Fejervarya limnocharis **(Gravenhorst, 1829)**

English Names

Asian Grass Frog, Boie's Wart Frog, Common Pond Frog, Cricket Frog, Field Frog, Grass Frog, Indian Cricket Frog, Indian Rice Frog, Marsh Frog, Paddy-Field Frog, Paddy Frog, Ricefield Frog, Rice Frog, Terrestrial Frog, Wart Frog and White-Lined Frog.

Diagnostic Characters

Adult

Tympanum distinct, shorter than eye diameter; 1st finger slightly longer than 2nd, 3rd the longest, 4th the shortest and almost equal to 2nd, sub-articular tubercle well developed; toes almost half webbed, outer metatarsal tubercle small and round, inner long; skin rough with warts and longitudinal ridges above, smooth below, anal region and posterior of thigh glandular.

Colouration: Grey, brownish or olivaceous with darker spots above, sometimes with a broad or narrow yellowish vertebral band, limbs with irregular crossbars, under surface whitish.

Sexual Dimorphism: Male smaller, throat with two dark blotches which may be connected and a pair of vocal sacs forming loose folds.

Size: 6.4 cm in snout to vent length.

Tadpole

Head and body slender or somewhat oval with a long and less pigmented tail, body cream-coloured body.

Distribution

Found from sea level up to 2,500 m asl.

Localities in Doon Valley

Eastern Doon Valley: Rajaji National Park (*partim*).

Western Doon Valley: Asan Reservoir, Seepage nala, Asan River above Kunja Grant and below its barrage at Dhalipur and Jhivaredi, Shimla road and Bhure-Shah nala, Timli.

Uttarakhand

Dehra Dun, Tehri, Pauri, Uttarkashi, Nainital and Almora. Gobind Pashu Vihar and Rajaji National Park.

India

All over the plains and Himalaya up to 2,500 m. Andaman and Nicobar Islands, Arunachal Pradesh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan and West Bengal.

Elsewhere

Afghanistan, Bangladesh, Brunei Darussalam, Cambodia; China (including Macao, Taiwan); Hong Kong; Indo-China, Indonesia (Borneo, Lombok), Japan, Korea, Lao People's Democratic Republic, Macao, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Viet Nam. Guam (introduced).

Habitat and Ecology

It inhabits most open wet habitat types, including river flood plains, wet agriculture areas such as ricefields, ditches, marshes and other habitats and in closed-canopy forests. Its breeds in various wetland habitats.

Conservation Status

IUCN Red List: Least Concern.

Threats

The main threats are the use of agrochemicals, specifically pesticide application in drainage or wetland areas. Morphological abnormalities, presumably due to chemical contamination, have been found in some frogs inhabiting agro-ecosystems.

Remarks

The *Fejervarya limnocharis* complex is certain to contain a large number of cryptic species (Zug et al. 1998). A recent study (Sumida et al. 2007) provides evidence supporting the notion that the population from Sri Lanka is a different species (possibly *Fejervarya syhadrensis*) and that populations from Thailand (Bangkok) and Japan (Hiroshima) may merit specific status.
Genus: *Hoplobatrachus* Peters, 1863

Hoplobatrachus crassus **(Jerdon, 1853)**

English Names

Carnatic Peters Frog, Jerdon's Bullfrog and South Indian Bullfrog.

Diagnostic Characters

Adult

Tympanum distinct, shorter than eye; 1st finger longer than 2nd, 3rd the longest, 4th slightly shorter than 2nd, sub-articular tubercles distinct and moderate; toes fully webbed, sub-articular tubercles prominent; inner metatarsal tubercle strong, almost equal to inner toe, shovel shaped with sharp edge; skin with 9–10 longitudinal glandular folds and warts with white-tipped spinules above, whitish below; supra-tympanic fold between eye and shoulder prominent.

Colouration: Olive brown, boldly marked with black stripes and spots, sometimes with traces of bright green along on face and sides and sometimes with a white vertebral line; juveniles with a prominent black stripe between tip of snout and eye.

Sexual Dimorphism: Male with external vocal sacs which turn black during breeding season.

Size: 13.0 cm in snout to vent length.

Tadpole

Larger, stockier and more bulged belly than that of Indian Bullfrog, tail obtusely pointed, upper side more densely spotted, a pale band between nostril and eye.

Distribution

Altitudinal range from sea level to 600 m.

Localities in Doon Valley

Eastern Doon Valley: Kansro; Lachhiwala; Motichur and Rajaji National Park (*partim*).

Uttarakhand

Dehra Dun, Pauri and Uttarkashi. Gobind Pashu Vihar and Rajaji National Park.

India

Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Kerala, Madhya Pradesh, Maharashtra, Nagaland, Odisha, Tamil Nadu (Chennai), Uttar Pradesh (Terai region) and West Bengal.

Elsewhere

Bangladesh, Nepal and Sri Lanka. Bhutan and Myanmar (possibly).

Habitat and Ecology

A species of seasonally flooded dry grasslands, open plains, cultivated fields and dry areas. Adults are often found in burrows and aestivate during dry periods. Breeding takes place in different water bodies.

Conservation Status
IUCN Red List: Least Concern.

Threats
Habitat loss through the general development of infrastructure and over collection of adults for subsistence use might also be a threat and reclamation of wet lands in some areas.

Hoplobatrachus tigerinus (Daudin, 1802)

Localities in Doon Valley
Eastern Doon Valley: Muni-ki-Reti, Rishikesh and Rajaji National Park (*partim*).

Western Doon Valley: Asan River.

Uttarakhand
Dehra Dun, Tehri, Pauri and Nainital. Corbett Tiger Reserve and Rajaji National Park.

India
From base of Himalaya to South India (except Meghalaya). Andaman and Nicobar Islands, Assam, Chhattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Manipur, Mizoram, Nagaland, Punjab, Rajasthan, Tripura, West Bengal and Western Ghats.

Elsewhere
Bangladesh, China (including Taiwan), Indo-China, Indonesia, Japan, Madagascar (including Nosy Be), Malaysia, Myanmar, Nepal (2,000 m alt.), Pakistan, Philippines, Sri Lanka and Thailand. Maldives and Madagascar (introduced).

Afghanistan (Khyber Pass) and Bhutan (need confirmation).

Habitat and Ecology
Inhabiting mostly freshwater wetlands, paddy fields etc. but rarely in forested areas. It is mostly solitary and nocturnal, inhabiting holes and bushes near permanent water bodies and pools. It feeds mostly on insets and other invertebrates. Breeding takes place during the monsoon season, when adults congregate at ephemeral rainwater pools.

Conservation Status
IUCN Red List: Least Concern.

Threats
Loss of wetland habitats through infrastructure development, water pollution by pesticides and other agrochemicals etc. are the main threats to the species. Earlier it was heavily collected for the international frog legs trade which has been banned since the mid-1990s.

Remarks
This taxon is now believed to consist of a complex of several cryptic species. Recent ongoing taxonomic research in Sri Lanka has revealed that *Hoplobatrachus tigerinus* does not occur in this country and that animals previously assigned to *H. tigerinus* are misidentifications of *H. Crassus*.
Genus: *Sphaerotheca* Gunther, 1859

Sphaerotheca breviceps (Schneider, 1799)

English Name
Band Sand Frog, Burrowing Frog, Clumsy-looking Burrowing Frog, Dharan Bullfrog, Indian Burrowing Frog, Maskey's Burrowing Frog, Olive Frog, Punjab Bullfrog and Short-Headed Burrowing Frog.

Diagnostic Characters

Adult
Tympanum distinct, oval, shorter than eye; 1st finger longer than 2nd, 3rd equal to or slightly longer than, 4th the shortest, 1st finger with a large, round sub-articular tubercle on palm, other sub-articular tubercles shorter and almost equal in size, palmer tubercle elongated; hind limbs short, toes half webbed, inner metatarsal tubercle large, shovel shaped, outer absent; skin smooth, with some scattered elongated tubercles above, abdomen, under side of thighs and anal region glandular.

Colouration: Much variable, from pale grey to dark brown with black irregular blotches on body (may be with some white or yellow spots and a pale vertebral line) and limbs above, rear surface of thighs brown with a series of yellow spots; whitish below with blackish throat.

Sexual Dimorphism: Male smaller than female, with a single external vocal sac (formed of two lobes, connected in middle) that appears like a fold of skin on dark brown throat.

Size: 6.5 cm in snout to vent length.

Tadpole

Smooth above, yellowish to deep brown with dark brown spots, a V-shaped mark between eyes and another M-shaped one on back, tail marked with brown blotches, belly densely pigmented.

Distribution

At elevations from sea level up to 1,500 m.

Localities in Doon Valley

Eastern Doon Valley: Rajpur, Rajaji National Park and Sahastradhara (*partim*).

Western Doon Valley: Dehra Dun City, Dhalipur, Sahaspur, Selakui, Jhajra, Kalsi and Karvapani.

Uttarakhand

Dehra Dun, Tehri, Pauri, Uttarkashi, Nainital and Pithoragarh. Corbett Tiger Reserve, Gobind Pashu Vihar and Rajaji National Park.

India

Gangetic Plain to southern India. Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Eastern Ghats, Gujarat, Haryana, Himachal Pradesh (Sirmour), Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh (Allahabad, Agra) and West Bengal.

Elsewhere

Myanmar, Nepal (below 3,000 m), Pakistan (Punjab and Sind) and Sri Lanka. Bangladesh and Maldives (possibly).

Habitat and Ecology

Inhabits seasonal, deciduous forest, dry plains and scrubland, grassland, plantations and temporary stagnant water bodies and areas of human habitation. Adults are often found underground cover. Breeding takes place in pools, puddles or ponds during monsoon.

Conservation Status

IUCN Red List: Least Concern.

Threats

Habitat loss as a result of infrastructure development is the main threat to this species. It is also threatened by agrochemical pollution and wetland degradation.

Remarks

This species was transferred to the genus *Sphaerotheca* by Dubois 1987. Dubois (1987) considers *Sphaerotheca strachani* as either *incertae sedis* within *Sphaerotheca* or as a synonym of *S. breviceps*. The taxonomy of *Sphaerotheca breviceps* needs further investigation.

Family: Microhylidae Gunther, 1858
(Narrow-Mouthed Frogs)
Subfamily: Microhylinae Gunther, 1858
Genus: *Microhyla* Tschudi, 1838

Microhyla ornata **(Dumeril and Bibron, 1841)**

English Names

Ant Frog, Black-Throated Frog, Narrow-Mouthed Ornate Frog, Orange-Yellow-Mouthed Frog, Ornamented Pygmy Frog, Ornate Frog, Ornate Narrow-Mouthed Frog and Ornate Rice Frog.

Diagnostic Characters

Adult

Tympanum hidden; tongue entire; 1st finger shorter than 2nd, 3rd the longest, 4th slightly longer than 2nd, sub-articular tubercles prominent; toes with a rudimentary web at base, sub-articular tubercles distinct, inner metatarsal tubercle elongated, outer small and round; skin smooth with small rounded tubercles above and on sides, limbs with tubercular glands, smooth below with densely set tubercles on anal region and posterior side of thigh.

Colouration: Greyish-olive above with large dark markings beginning between eyes and gradually widening on hinder part of body, sometimes with reddish-brown spots; dull below.

Sexual Dimorphism: Male quite smaller and slimmer than female with a sub-gular vocal sac in a transverse fold of skin on throat, ventral aspect profusely pigmented in contrast to female which exhibits much less pigmentation.

Size: 2.8 cm in length between snout and vent.

Tadpole

Body transparent, head hexagonal with a diamond-shaped golden patch; tail long, more or less transparent with acutely pointed tip, looking like a filament.

Distribution

Occurs up to 2,000 m asl.

Localities in Doon Valley

Eastern Doon Valley: Dehra Dun City; Lachhiwala; Motichur; Rajaji National Park (*partim*); Rajpur; Rishikesh and Sahastradhara.

Western Doon Valley: Premnagar, Jhajra, Selakui, Sahaspur, Asan Reservoir, Dhalipur and Dakpathar and Badshahi Bagh road.

Uttarakhand

Dehra Dun, Tehri, Pauri and Nainital. Corbett Tiger Reserve. Rajaji National Park.

India

Throughout from Cape to Himalayan foothills. Andaman and Nicobar Islands, Assam, Chhattisgarh, Delhi, Eastern Ghats, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, Rajasthan, Tripura and West Bengal.

Elsewhere

Bangladesh; Bhutan, China (Hainan, Kiangau, Sze-chwan, Taiwan), Cochin-China, Indo-China, Malaysia, Myanmar, Nepal; Pakistan, Southeast Asia, Sri Lanka, Thailand and Viet Nam (An Nam, Tonkin).

Habitat and Ecology

Found in a number of habitat types including lowland scrub forest, grassland, agricultural land, pastureland and urban areas. Being sub-fossorial in habit, it is also found in forest floor leaf litter. It is mostly a nocturnal and is only active diurnally during the rainy season. It breeds in temporary rain pools and other stagnant water bodies. It may occur in modified areas, like non-intensively farmed agricultural land.

Conservation Status

IUCN Red List: Least Concern.

Threats

There are no major threats to this species but might be locally threatened by agrochemical pollution of land and water and the conversion of habitat to intensively cultivated land.

Remarks

Matsui et al. (2005) in restricted this species to the Indian subcontinent; populations in Southeast Asia, China and Taiwan belonging to *Microhyla fissipes*; and populations in the Ryukyu Archipelago (Japan) belong to *M. okinavensis*.
Genus: *Uperodon* Dumeril and Bibron, 1841

Uperodon systoma **(Schneider, 1799)**

English Names

Balloon Frog, Globular Frog, Indistinct Frog, Lesser Balloon Frog and Marbled Balloon Frog.

Diagnostic Characters

Adult

Tympanum hidden; tongue entire; fingers free with tips simple, 1st shorter than 2nd which almost equal to 4th, 3rd the longest, sub-articular tubercles indistinct; a pair of strong shovel-shaped metatarsal tubercles, toes webbed at base with tips simple, 1st the smallest and 4th the longest; skin smoothly tubercular, throat and chest smooth except for glandular anal region; with supra-tympanic fold.

Colouration: Dark brown and marbled with a reticulation above, immaculate below.

Sexual Dimorphism: Male smaller with dark brown vocal sac.

Size: Snout to vent length 7.4 cm (female from Aurangabad, Jamdar et al. 2010).

Tadpole

Head and body blotched with brown and cream colour with whitish tail which is vertically banded with black.

Distribution

Found from sea level up to approximately 1,500 m asl.

Localities in Doon Valley

Eastern Doon Valley: Lachhiwala and Rajaji National Park (*partim*).

Western Doon Valley: Badshahi Bagh road, Jhajra and Kalsi.

Uttarakhand

Dehra Dun and Pauri. Corbett Tiger Reserve and Rajaji National Park.

India

Andhra Pradesh, Himachal Pradesh (Sirmour), Karnataka, Kerala, Maharashtra (Aurangabad), Odisha, Tamil Nadu, Uttar Pradesh (Agra, Allahabad and Saharanpur) and West Bengal.

Elsewhere

Nepal, Pakistan and Sri Lanka.

Habitat and Ecology

A completely fossorial species that buries itself in loose, moist soil, seen in dry forest areas, plains, home gardens and low-intensity agricultural areas. The adults surface only during monsoons but remain under the soil during the dry period. It feeds generally on termites. Breeding takes place during the monsoon months. Males call from the banks of the stream or paddy fields and eggs are laid in masses which float on the water surface.

Conservation Status

IUCN Red List: Least Concern.

Threats

The main threats are the loss of suitable habitat due to increase of urbanization and the pollution of both land and wetlands with agrochemicals.

Remarks

Tilak and Husain (1977) recorded it from Siwalik Hills near Badshahi Bagh on Timli-Saharanpur road (in district Saharanpur, Uttar Pradesh), nearly 5 km east of point where river Yamuna cuts through the Siwaliks. This locality is adjoining extreme point of Western Doon Valley.
Family: Rhacophoridae Hoffman, 1932
(Tree Frogs)
Subfamily: Rhacophorinae Hoffman, 1932
Genus: *Polypedates* Tschudi, 1838

Polypedates maculatus **(Gray, 1830)**

English Names

Chunam Frog, Chunam Tree Frog, Common Indian Tree Frog, Himalayan Tree Frog (as P. m. himalayensis), Indian Tree Frog, Spotted Tree Frog, Spotted Whipping Frog and Tree Frog.

Diagnostic Characters

Adult

Tympanum distinct, shorter than eye, with a fold from eye to shoulder; tongue bifid; fingers with rudimentary web and enlarged terminal discs, 1st and 2nd almost equal, 3rd the longest, 4th slightly longer than 2nd finger, sub-articular tubercles moderate, elongated; toes with discs, webbing partial except 5th toe which is webbed up to base of disc, outer metatarsals separated by webbing and inner single but distinct; skin smooth above, finely granulated on chin, chest and underside of thigh.

Colouration: Olivaceous to chestnut/brownish-yellow/greyish/whitish with scattered dark patches/spots above, rarely with an hourglass-shaped figure on back of head and front of back, loreal and temporal regions dark brown or black, a light line on upper lip, limbs with dark crossbars, hinder side of thighs may be with round yellow spots which are usually separated by a dark brown/purplish network.

Sexual Dimorphism: Male smaller in size, with single internal vocal sacs and nuptial pad on base of 1st finger (enlarged 1st metacarpal region).

Size: Male 3.4–5.7 and female 4.4–8.9 cm in snout to vent length.

Tadpole

Mouth adapted for clinging with a sucker-like disc; eyes on sides of head; tail muscular, long, acutely pointed in filament form; body brown or yellowish, irregularly mottled with dark brown pigmentation.

Distribution

South Asia from sea level up to at least 1,500 m asl.

Localities in Doon Valley

Eastern Doon Valley: Motichur forest and Rajaji National Park (*partim*).

Uttarakhand

Dehra Dun, Pauri, Uttarkashi and Almora. Gobind Pashu Vihar and Rajaji National Park.

India

All over India (except Haryana, Punjab and Rajasthan). Chhattisgarh, Eastern Ghats, Gujarat, Himachal Pradesh, Madhya Pradesh and West Bengal.

Elsewhere

Bangladesh; Bhutan; Nepal and Sri Lanka.

China and Myanmar (uncertain).

Habitat and Ecology

Found in a wide variety of habitat types including tropical dry and moist forests, grasslands and agricultural areas and close to human habitations. It is largely arboreal, although it can be found on walls and hidden under rocks and leaves. Males have been reported calling from the ground. It breeds in temporary pools and paddy fields.

Conservation Status

IUCN Red List: Least Concern.

Threats

Habitat pollution by agrochemicals is the main threat to the species. Otherwise, this species is not facing any significant threats.

Remarks

Dubois (1986/1987) considered *Polypedates himalayensis* to be a subspecies of this species.

Conclusion

A total of ten species belonging to eight genera, four families were collected from the Doon Valley and all of these are found in the eastern part while two species (*Hoplobatrachus crassus* and *Polypedates maculatus*) were not encountered in the Western Doon Valley; may be some more surveys reveal their presence in the area.

Distribution of Species in Conservation Areas of Uttarakhand

Corbett Tiger Reserve: Seven species, *Duttaphrynus melanostictus, D. stomaticus, Euphlyctis cyanophlyctis, Hoplobatrachus tigerinus, Microhyla ornata* and *Uperodon systoma*.

Gobind Pashu Vihar: Six species, *Duttaphrynus melanostictus, Euphlyctis cyanophlyctis, Fejervarya limnocharis, Hoplobatrachus crassus, Sphaerotheca breviceps* and *Polypedates maculatus*.

Nanda Devi Biosphere Reserve: One species, *Duttaphrynus melanostictus*.

Rajaji National Park: All the ten species (see text).

1. *Link with Arabia*: Occurrence of *Duttaphrynus stomaticus*, the Marbled Toad, in Oman is significant from zoogeographical point of view.

2. *Conservation Status*: All the ten species are classified under 'Least Concern' category of IUCN Red List of Threatened Species.
3. *Threats*: Habitat loss due various developmental activities, water pollution and use of agrochemicals could be some of the reasons for the depletion in population of amphibians.

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References

Bahuguna A, Bhutia PT (2010) Amphibia. In: Fauna of Uttarakhand. State Fauna Series 18(1):504–532. Zoological Survey of India Publication

Dubois A (1987) Miscellanea taxonomica batrachologica (1). Alytes. Paris 5:9–95

Dubois A, Ohler A (1999) Asian and oriental toads of the *Bufo melanostictus*, *Bufo scaber* and *Bufo stejnegeri* groups (Amphibia, Anura): list of available and valid names and redescription of some name-bearing types. J South Asian Nat Hist Colombo 4(2):133–180

Husain A (2003) Amphibia. In: Fauna of Asan Wetland. Wetland Ecosystem Series 5:27–28. Zoological Survey of India Publication

Jamdar S, Dhondge T, Hiware CJ (2010) Occurrence of Marbled balloon frog, *Uperodon systoma* (Schneider, 1799) from Aurangabad (M. S.), India. J Ecobiotechnol 2(6):4–6

Matsui M, Ito H, Tomohiko S, Ota H, Saidapur S, Khonsue W, Tanaka-Ueno T, Wu G-F (2005) Taxonomic relationships within the pan-oriental narrow-mouth toad Microhyla ornata as revealed by mtDNA analysis (Amphibia, Anura, Microhylidae). Zoolog Sci 22:489–495

Mehta HS, Uniyal DP (2007) Amphibia. In: Faunal diversity Western Doon Shiwaliks. Zoological Survey of India, Kolkata, pp 61–64

Peters WCH (1863) Bemerkungen über verschiedene Batrachier, namentlich über die Original-exemplare der von Schneider und Wiegmann beschriebenen Arten des zoologischen Museums zu Berlin. Monatsberichte der Königlichen Preussische Akademie des Wissenschaften zu Berlin 1863:76–82

Ray P (1995) Amphibia. In: Fauna of Western Himalaya, Part 1, Uttar Pradesh. Himalayan ecosystem series. Zoological Survey of India, Kolkata, pp 151–157

Ray P (1999) Systematic studies on Amphibian fauna of the district Dehra Dun, Uttar Pradesh India. Mem Zool Surv India 18(3):1–102

Ray P, Tilak R (1995) Amphibia. In: Fauna of Rajaji National Park, fauna of conservation areas, 5: Western Himalaya (Uttar Pradesh). Zoological Survey of India, Kolkata, pp 54–75

Sumida M, Kotaki M, Islam MM, Djong TH, Igawa T, Kondo Y, Matsui M, De Silva A, Khonsue W, Nishioka M (2007) Evolutionary relationships and reproductive isolating mechanisms in the Rice Frog (*Fejervarya limnocharis*) species complex from Sri Lanka, Thailand, Taiwan and Japan, inferred from mt DNA gene sequences, allozymes, and crossing experiments. Zool Sci 24:547–562

Tilak R, Husain A (1977) Extension of the range of distribution of a microhylid frog, *Uperodon systoma* (Schneider). J Bombay Nat Hist Soc 73(1):407

Waltner RC (1974) Geographical and altitudinal distribution of amphibians and reptiles in the Himalayas, Part-1. Cheetal 16(1):17–25

Zug GR, Htun WTT, Than Zaw Min, Win Zaw Lhon, Kyaw Kyaw (1998) Herpetofauna of the Chatthin W.S., North-central Myanmar with preliminary observations of their natural history. Hamadryad 23(2):111–120

14 Fish Fauna of Asan River and Its Tributaries, Western Doon Valley, Dehradun (Uttarakhand), with Conservation Status of Species and Threats

Akhlaq Husain*

Abstract

The present study deals with the fish fauna (44 species) of Asan River and its tributaries based on actual collections, with their update systematic account; distribution in Uttarakhand, rest of India and other countries; habitat and ecology; and conservation status with threats and importance in various ways (fishery, game, aquaria, etc.). The species of doubtful occurrence have also been listed.

Keywords

Fish • Asan River • Distribution • Diversity

Introduction

The fish fauna of Dehradun district has attracted the attention of various workers (Das 1960; Fowler 1924; Hora and Mukerji 1936; Lal and Chatterjee 1963; Singh 1964; Tilak and Husain 1973, 1976, 1977a, b, 1978a, b, 1990; Grover 1970; Grover et al. 1994; Singh and Gupta 1979; Husain 1995, 2003, 2010a, b, 2012; Husain and Tilak 1995; Badola 2009; Uniyal 2010, Uniyal and Kumar 2006; Uniyal and Mehta 2007) during the past, but very little attention has been paid on the fishes of Asan River, one of the major rivers of Western Doon Valley, Dehradun. Husain (2003) restricted his studies to the fauna of its reservoir and environs. In view of this, the present study was taken up, and a total of 44 species belonging to 29 genera, 11 families and 5 orders, with a new record of *Aspidoparia jaya* (Hamilton, 1822), were collected from the river between its inception and joining Yamuna. In this study, systematic account with English and local names; localities surveyed; diagnostic characters including sexual dimorphism (if any); distribution in Uttarakhand (as per Husain 1975, 1976, 1979, 1980, 1995, 2010b; Khanna and Badola 1992; Badola 2009; Kumar and Husain 2014), rest of India and elsewhere; habitat and ecology; and conservation status as per IUCN (International Union for Conservation of Nature) Red List along with threats and commercial or other importance of each species are dealt; doubtful records of species have also been listed. The species (*Schistura montana* and *S. rupecula*) not found in the main Asan

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River but in headwaters of its tributaries have also been mentioned under the relevant species.

Asan River and Its Tributaries

Asan is a major river of Western Doon Valley, draining whole of it into the Yamuna. It originates from a village Chandrabani (30° 20′ N Lat. and 77° 38′ E Long., at 704.2 m altitude) at the base of Siwalik passing through Badowala, Jhajra, Sahaspur, Sabhawala, Herbertpur and Dhalipur (30°26 N Lat. and 77° 41′ E Long., at 422.0 m altitude) where it is converted in a reservoir and then joins river Yamuna at Kulhal (near Paonta) which makes border with Himachal Pradesh. It is fed mainly by Tons nadi, Swarna nadi and Sitla rao arising from the Lesser Himalayan side and a large number of raos (seasonal streams) from Siwalik ranges draining into it from the southern side and the Tons and its tributaries from various narrow gorges in their upper course like Robber's cave or Guchhupani (Nalota nadi) from the northern side in the southern slopes of Mussoorie. The raos usually remain dry during most of the year but show marked increase in discharge and turn into torrents during the monsoon period and carry huge boulders in broad channels which are generally braided with gravel beds. In the apparently dry beds, the water generally flows under the gravel in many of them. The Asan reservoir (also called Dhalipur Lake) is situated at the confluence of the Eastern Yamuna Canal (coming from Dakpathar) and the Asan River. Directly below the barrage on its eastern flank, the water re-enters the Eastern Yamuna Canal on the west side of the Yamuna. At a distance of 4.5 km from the barrage on the canal, the water reaches the Kulhal Power Plant, once discharged from the power station; the water is conducted by the canal 13 km to the Khara Power Station in Uttar Pradesh.

Methods

The material was collected by using cast net and bag nets and diverting the water in small stream/ channels, visiting various sites of the river and its tributaries. The freshly collected specimens were preserved at first in 3–4 % formaldehyde solution in the field itself and kept for about two days as such putting locality labels with date. They were then transferred to 8–10 % solution and finally kept in alcohol for study. The larger specimens were also injected with formalin solution for preserving the internal viscera. Then the material was identified and the species were classified as per the latest literature.

Systematic Account of Species with Their Distribution and Conservation Status and Threats

Class: Actinopterygii
Order: Beloniformes
Family: Belonidae
Genus: *Xenentodon* Regan, 1911

1. *Xenentodon cancila* (Hamilton, 1822)

Esox cancila Hamilton, 1822. *Fish. Ganges*: 213–215, 380, pl. 27, fig. 70 (type locality: ponds and smaller rivers of the Gangetic provinces)

Xenentodon cancila Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, Asan River above Kunja Grant and below its barrage)

English Name
Freshwater Garfish.

Local Names
Sua, Cowa, Takla.

Localities Surveyed
Asan River above Kunja Grant and below its barrage at Dhalipur; Herbertpur, Partitpur and Bairagiwala villages near Herbertpur; Asan Reservoir.

Diagnostic Characters
D. 0/14–18, P. 0/11, V. 0/6, A. 0/15–19, C. 15.

Both jaws prolonged like a beak; dorsal fin inserted usually anterior to a vertical through origin of anal fin; caudal fin truncate; lateral line on posterior half of the body, without a keel. Body greenish silvery with a silvery lateral band edged dark and a series of 4–5 blotches (absent in young) on sides between the pectoral and anal fins; dorsal and anal fins with dark edges.

Sexual Dimorphism: In male, the dorsal side of the body just behind the head is humped in the form of a crest or ridge and lower jaw more prominent. Female lacks the hump but may be with a groove instead.

Maximum Size
40.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun and Haridwar districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Rajaji National Park.

India
Throughout. Chilka Lake; Ganges-Brahmaputra system; Kallar, Bhavani, Moyar, Tamil Nadu, Kanyakumari district; Terai and Dooars, North Bengal; Western Ghats rivers, Maharashtra.

Elsewhere
Bangladesh, Bhutan, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam and Hawaii (introduced).

Habitat and Ecology
Inhabits freshwaters, primarily rivers.

Conservation Status
IUCN Red List, least concern.

Threats
There is habitat degradation in some parts of its range in India due to siltation caused by deforestation and habitat loss and modification due to the loss of wetlands, especially the infilling of ponds.

Remarks
Of no fishery interest but sometimes considered as minor fishery. Generally consumed locally.

Order: Cypriniformes
Family: Cobitidae
Subfamily: Cobitinae
Genus: *Lepidocephalichthys* Bleeker, 1863

2. *Lepidocephalichthys caudofurcatus* (Tilak & Husain, 1978)

Lepidocephalus caudofurcatus Tilak & Husain, 1978. *Matsya*, 3: 60–63, figs. 1–3 (type locality: Kalapani nala, Rishikesh, District Dehradun; Sailani river, Biharigarh, District Saharanpur; and Gagan river near Moradabad, District Moradabad).

Lepidocephalus caudofurcatus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (seepage nala).

English Names
Gadera, Ghiwa, Nauni.

Local Name
Gadera.

Localities Surveyed
Seepage nala below the Asan reservoir.

Diagnostic Characters
D. 2/6, P. 1/7, V. 1/6, A. 3/5, C. 16 (8/8).

Origin of dorsal fin almost equidistant between the snout tip and caudal base; caudal fin forked; whole of lateral and ventral sides of the head scaled, focal area of subdorsal scale eccentric and very small, scales on ventral side of the body extend anteriorly much beyond the isthmus, 25 scales between the back and base of the anal fin. Body with rectangular blotches along its lateral sides.

Sexual Dimorphism: In male, two inner rays of pectoral get fused and form a vertical ossified crest. The pectoral fin is normal in female and comparatively loner.

Maximum Size
4.95 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun and Haridwar districts.

India

Uttar Pradesh (Saharanpur and Moradabad districts).

Elsewhere

No record.

Habitat and Ecology

Found in slow-flowing streams with sandy bed and vegetation.

Conservation Status

IUCN Red List, not evaluated.

Remarks

As per Kottelat (2012), the species is considered synonym of *Lepidocephalichthys goalparensis* (Pillai & Yazdani, 1976) but differs from it in a number of characters as mentioned by Tilak and Husain, 1981 (origin of dorsal fin equidistant between the snout tip and caudal base in *L. caudofurcatus* vs. nearer snout tip than to caudal base in *L. goalparensis*, focal area of subdorsal scale very small in *L. caudofurcatus* vs. comparatively bigger in *L. goalparensis*, body scales on ventral side extend anteriorly much beyond the isthmus in *L. caudofurcatus* vs. do not extend anteriorly beyond pectoral fin bases in *L. goalparensis*, presence of rectangular blotches along the lateral sides of the body in *L. caudofurcatus* vs. absent in *L. goalparensis*, 25 scales between the back and the base of anal fin in *L. caudofurcatus* vs. 16 scales in *L. goalparensis*).

3. *Lepidocephalichthys guntea* (Hamilton, 1822)

Cobitis guntea Hamilton, 1822. *Fish. Ganges*: 353, 394 (type locality: ponds and fresh rivers of Bengal).

Lepidocephalus guntea Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names

Guntea Loach, Peppered Loach, Scavenger Loach.

Local Name

Chatru.

Localities Surveyed

Asan River above Kunja Grant below its barrage, Dhalipur, Herbertpur, Partitpur near Herbertpur, Sabhawala, Sahaspur, Selakui, Jhajra and Chandrabani; seepage nala below Asan reservoir; small stream near Asan Barrage, Dhalipur; Asan reservoir.

Small stream, culvert No. 28/2, Ridapur near Sahaspur; Swarna nadi, Bhauwala; Naro nadi near Langha and at Bhurgaon near Bansiwala; small stream, culvert No. 19/2, Selakui; Tons nadi, Premnagar; Nimi nadi, Paundha; Nun nadi, Jaintanwala. Small stream (Manaksidh rao), Karwapani, Asarori forest.

Diagnostic Characters

D. 2–3/ 6–7, P. 1/6–7, V. 1/6–7, A. 2–3/5, C. 16.

Barbels three pairs, rostral, maxillo-mandibular and maxillary pairs, longer than the eye diameter; mental lobe well developed, produced into 1–2 projections, with a bean-shaped pad at the base; dorsal fin inserted slightly behind the pelvics; scales on the head in patches below and behind the eye and upper part of operculum, subdorsal scales oval with small eccentric focal area, 25–30 rows of scales between the back and anal base. Body with a series of about 10–12 irregular dark spots on its sides, connected with one another through a dark band which on age fuse with one another; upper part of caudal base with a white-edged black dot; pectoral and anal fins stippled with dark dots; dorsal and caudal fins with 6–7 oblique rows of dark dots.

Sexual Dimorphism: In male, two inner rays of pectoral are fused and ossified with a prominent broad dark brown or black lateral band. In female, the fin is normal and the band narrow.

Maximum Length

15.0 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Throughout India except Karnataka, Kerala and south India. Brahmaputra, Ganges and Indus drainages along the Himalayas and the drainages along the Satpura-Vindhyas.

Andhra Pradesh, Arunachal Pradesh, Assam (Dibru river, Guijam and Dibrugarh), Bihar, Chandigarh, Chhattisgarh, Dadra and Nagar Haveli, Daman, Delhi, Diu, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karaikal, Madhya Pradesh, Maharashtra, Manipur (Barak), Meghalaya, Mizoram, Nagaland, Odisha (Chilka Lake), Puducherry (Karaikal, Mahe, Yanam), Punjab, Rajasthan, Sikkim, Tripura, Uttar Pradesh, West Bengal (Darjeeling) and Western Ghats.

Elsewhere

Bangladesh, China (Yu river drainage system), Myanmar (main), Nepal, Pakistan and Thailand.

Habitat and Ecology

Found in flowing and clear standing waters.

Conservation Status

IUCN Red List, least concern.

Remarks

Of no fishery interest. Its distinctive taste makes it a preferred food by some people and is consumed fresh or dried.

Family: Cyprinidae

Subfamily: Barbinae

Genus: *Puntius* Hamilton, 1822

4. *Puntius carletoni* (Fowler, 1924)

Barbus carletoni Fowler, 1924. *Proc. Acad. Nat. Sci. Philad.*, 76: 80–90 (type locality: Dehradun).

Puntius carletoni Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River above Kunja Grant).

English Name

Fowler's Barb.

Local Name

Phuti.

Localities Surveyed

Asan River above Kunja Grant (Husain, 2003).

Diagnostic Characters

D. 2/8. P. 1/12, V. 1/8, A. 3/5, C. 19. L.l. 30.

Barbels absent; dorsal fin origin very slightly nearer the caudal base than snout tip, its spine moderately strong and finely serrated posteriorly; lateral line incomplete, ceasing after 4–5 scales. Body with a bright silvery-white lateral band between the eye and caudal base, a dusky diffusion at the base of the dorsal spine and 1st branched ray, dorsal spine blackish throughout its length; a black spot, slightly smaller than the eye diameter in front of the caudal base and another smaller one at the base of anterior few anal rays.

Maximum Size

4.8 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar and Pauri districts; Kumaon Division: Nainital district.

India

Madhya Pradesh (Hoshangabad district).

Elsewhere

No record.

Habitat and Ecology

Inhabits slow-moving streams with sandy bed.

Conservation Status

IUCN Red List, not evaluated (least concern under *P. guganio*).

Remarks

Of no fishery interest, a rare species in the area. It is considered a synonym of *Puntius guganio* (Hamilton, 1822) and *P. sophore* (Hamilton, 1822) by some workers, but it differs from these in a number of characters. Tilak (1970) differentiated it from *P. sophore* in various body proportions, dorsal spine, number of lateral line and other scales, pharyngeal teeth, size and colouration. *P. guganio* is a larger species, measuring 8.0 cm.

5. *Puntius chelynoides* (McClellannd, 1839)

Barbus chilinoides McClelland, 1839. *Asiat. Res*., 19(2): 271, 340, pl. 57, fig. 5 (type locality: Simla hills).

Tor chelynoides Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River below its barrage).

English Name
Dark Mahseer.

Local Names
Kali Machhi, Kali Mahseer, Karanchula, Telan Mahseer.

Localities Surveyed
Asan River below its barrage.

Tons nadi at villages Chandrauti and Bijapur; Bhitarli nadi at village Khera near Jaspur; Kiarkuli nadi, village Jaspur.

Diagnostic Characters
D. 3–4/8, P. 1/15–16, V. 1/8, A. 3/5, C. 18–19 (9–10/9 or 9/1/9). L.l. 32–35.

Head short, slightly depressed; snout smooth and without tubercles, mouth subterminal, lips fleshy, continuous at corners; barbels two pairs, longer than the eye diameter. Colour dark on the back, silvery below, margins of scales darkened with numerous fine dots, fins reddish.

Maximum Size
66.0 cm. 76.2 cm (Day 1878).

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
All along the Himalayas.

Elsewhere
Nepal.

Habitat and Ecology
Inhabits fast-flowing mountain streams. Feeds on diatoms, algae and insects; breeding begins from June.

Conservation Status
IUCN Red List, vulnerable.

Remarks
The generic status of *Puntius chelynoides* is under debate. Talwar and Jhingran (1991) have considered this species as *Tor chelynoides*, while Jayaram (1999) and Menon (1999) have considered it as *Naziritor chelynoides.*

One of the largest growing fishes of the area and is highly esteemed as food by local people. It is often captured in less numbers, being found in the interior of the hills. It is also an important game fish.

6. *Puntius chola* (Hamilton, 1822)

Cyprinus (*Puntius*) *chola* Hamilton, 1822. *Fish Ganges*: 312–313, 389 (type locality: ponds and stagnant waters in northeastern parts of Bengal).

Puntius chola Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River above Kunja Grant).

English Names
Chola Barb, Green Barb, Swamp Barb.

Local Names
Phuti, Ticker, Chidhu.

Localities Surveyed
Asan River above Kunja Grant and below its barrage at Dhalipur, Herbertpur, Partitpur and Bairagiwala near Herbertpur and Jhajra.

Diagnostic Characters
D. 3/8, P. 1/14, V. 1/8, A. 2/5, C. 19, L.l. 24–29.

Body deep and compressed; single pair of short maxillary barbels; last simple dorsal fin ray moderately strong and smooth; lateral line complete. A rosy spot on operculum; black spots, one each behind the gill opening, at the caudal base and on the dorsal fin.

Sexual Dimorphism: Male with orange-tinged Pelvic fins while female without such colouration.

Maximum Length
15.0 cm, commonly 8.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Throughout. Kerala, Maharashtra, Tamil Nadu (coastal belt) and Western Ghats.

Elsewhere
Bangladesh, Bhutan, Myanmar, Nepal, Pakistan and Sri Lanka.

Habitat and Ecology
Inhabits shallow streams, rivers, canals, lakes, tanks, ponds and inundated fields. Feeds on worms, crustaceans, insects and plant matter. Peaceful and active fish.

Conservation Status
IUCN Red List, least concern.

Remarks
Of no fishery interest; kept in aquaria.

7. *Puntius conchonius* (Hamilton, 1822)

Cyprinus (*Puntius*) *conchonius* Hamilton, 1822. *Fish Ganges*: 317, 389 (type locality: ponds of northeast of Bengal and rivers Kosi and Ami).

Puntius conchonius Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Red Barb, Rosy Barb.

Local Names
Chidhu, Kharauli-pothi, Phuti, Pothi, Ticker.

Localities Surveyed
Asan River above Kunja Grant, below barrage, at Dhalipur, Herbertpur, villages Fatehpur, Partitpur and Bairagiwala near Herbertpur, Sabhawala, Baronwala, Sahaspur, Bhimpur near Jhajra and Chandrabani; seepage nala below Asan Barrage; Asan reservoir.

Naro nadi, Langha; Swarna nadi, Bhauwala; Tons nadi near Premnagar and at Bijapur; Nimi nadi, Paundha; Nun nadi, Jaintanwala; Birhani nadi, Panditwari. Small stream (Manaksidh rao), Asarori forest.

Diagnostic Characters
D. 2–3/7–8, P. 1/13, V. 1/7–8, A. 2–3/5, C. 19, L.l. 22–26.

Barbels absent; dorsal fin spine strong, serrated; lateral line incomplete, mostly extending up to the 10–13th scale or up to the 18th scale. A dark spot on caudal peduncle.

Sexual Dimorphism: During breeding season, normal silvery male takes on a rich claret flush, while slightly larger female becomes more luminous.

Maximum Length
14.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora, Nainital (Nainital, Bhimtal and Naukuchiatal lakes), Pithoragarh and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Throughout. Assam, Bihar, Ganges, Brahmaputra, Mahanadi and Cauvery river systems where it is widespread in the Cauvery watershed, Maharashtra, Uttar Pradesh, Punjab, Uttar Pradesh and West Bengal. Kashmir Valley (probably introduced).

Elsewhere

Afghanistan, Bangladesh, Myanmar, Nepal and Pakistan. Colombia, Mexico, Puerto Rico and Singapore (introduced).

Habitat and Ecology

Generally inhabits lakes and streams. Feeds on worms, crustaceans, insects and plant matter. A prolific spawner that can tolerate low water temperatures.

Conservation Status

IUCN Red List, least concern.

Remarks

Being one of the hardiest barbs, undemanding and beautiful, it is very popular among aquarists. It can be kept in groups of five or more individuals with other small fishes.

Of no fishery interest; kept in aquaria.

8. *Puntius sarana sarana* (Hamilton, 1822)

Cyprinus (*Cyprinus*) *sarana* Hamilton, 1822. *Fish. Ganges*: 307–310, 388 (type locality: ponds and rivers of the Gangetic systems of Bengal).

English Names

Olive Barb, Olive Carp.

Local Names

Bhangan, Khami, Khangan, Phuta, Phutia, Pothia.

Localities Surveyed

Asan River at Herbertpur and Bairagiwala near Herbertpur.

Small stream, culvert No. 28/2, Ridapur near Sahaspur; small stream, culvert No. 19/2, Selakui.

Diagnostic Characters

D. 3–4/8, P. 1/14–16, V. 1/8, A. 2–3/5, C. 18–19, 30–33.

Body oblong; head small, barbels two pairs, rostral pair short and maxillary longer than the eye; lateral line complete. Body silvery with a prominent fingerlike dark spot over the caudal peduncle.

Maximum Length

42.0 cm; weight 1.4 kg.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Rajaji National Park.

India

Throughout north of Krishna river system.

Elsewhere

Afghanistan, Bangladesh, Bhutan, Nepal and Pakistan.

Habitat and Ecology

Adults occur in rivers, streams, lakes and backwaters and are salinity tolerant. They form schools in groups of four or five to several dozen. They feed on aquatic insects, fish, algae and shrimps. They spawn in running waters among submerged boulders and vegetation.

Conservation Status

IUCN Red List, least concern.

Remarks

The generic status of the fish is still unclear and keeps flipping between *Barbodes* and *Puntius*.

Of minor fishery interest; popular among anglers for its size; smaller ones with limited demand in aquarium trade.

9. *Puntius sophore* (Hamilton, 1822)

Cyprinus (*Puntius*) *sophore* Hamilton, 1822. *Fish. Ganges*: 310–311, pl. 119, fig. 86 (type locality: ponds and rivers of the Gangetic provinces).

Puntius sophore Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala and Asan River above Kunja Grant).

English Names

Pool Barb, Spot-Fin Swamp Barb, Stigma Barb.

Local Names

Phuti, Pothi, Potti, Potto.

Localities Surveyed

Asan River above Kunja Grant, below its barrage at Dhalipur, Herbertpur, villages Partitpur and Bairagiwala near Herbertpur, Jhajra and Chandrabani; seepage nala below Asan Barrage; Asan reservoir.

Small stream between Sahaspur and Herbertpur; ponds at Jassowala, Sahaspur, Selakui and on Langha road; Karwapani, Asarori forest.

Diagnostic Characters

D. 2/8, P. 1/14, V. 1/8, A. 2–3/5, C. 19, L.l. 22–27.

Barbels absent; dorsal spine bony, smooth; lateral line complete. Body silvery with a dark black spot each on the caudal base and another on the centre of the dorsal fin.

Sexual Dimorphism: Male with bright-coloured lateral scarlet band while female without such band.

Maximum Length

18.0 cm, commonly 13.0 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Throughout. Assam, Maharashtra (Savitri river), Odisha (Chilka Lake), Tamil Nadu, West Bengal and Western Ghats.

Elsewhere

Afghanistan, Bangladesh, Bhutan, China (Yunnan), Myanmar, Nepal, Pakistan and Thailand.

Habitat and Ecology

Inhabits rivers, streams and ponds in plains and sub-montane regions; large rivers with high turbid monsoon flow and with diverse substrate consisting of sand, mud, gravel, pebble, cobble and boulders. A shoaling fish, remaining appreciably smaller in the domestic aquarium and becoming mature at 7–8 cm.

Conservation Status

IUCN Red List, least concern.

Remarks

It is kept in aquaria and considered of some medicinal value.

10. *Puntius ticto* (Hamilton, 1822)

Cyprinus (*Puntius*) *ticto* Hamilton, 1822. *Fish. Ganges*: 314–315, 398, pl. 8, fig. 87 (type locality: south-eastern parts of Bengal).

Puntius ticto Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names

Fire-Fin Barb, Tic-Tac-Toe Barb, Ticto Barb, Two-Spot Barb.

Local Names

Bhuri, Phuti, Potto.

Localities Surveyed

Asan River above Kunja Grant, below Dhalipur Barrage, Herbertpur, villages Fatehpur, Partitpur and Bairagiwala near Herbertpur, Sabhawala, Sahaspur, Selakui and Bhurpur village near Jhajra; Asan reservoir.

Ponds at Sahaspur and Selakui; Tons nadi, Premnagar; Nimi nadi, Paundha; Nun nadi, Jaintanwala.

Diagnostic Characters

D. 2–3/8, P. 1/12–14, V. 1/8, A. 2–3/5, C. 16–19, L.l. 23–25.

Barbels absent; dorsal spine strong, serrated posteriorly; lateral line complete or incomplete, ceasing after the 6–8th scale, 15–17 scales afterwards. Silvery with a black spot on the body above the pectoral fin and another on the caudal peduncle, above the end of the anal fin.

Sexual Dimorphism: Male with black-tipped dorsal fin; female lacks this colouration.

Maximum Length

10.0 cm.

Distribution

Uttarakhand

Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora, Nainital, Pithoragarh and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Throughout except Kerala and South Tamil Nadu; Chilka Lake, Chittar river basin, Odisha; Hemavati and Yagachi rivers, Karnataka; Mondai stream and Kundalika river, Maharashtra; and Moyar river, Tamil Nadu; Western Ghats.

Elsewhere

Bangladesh, Bhutan, China, Laos, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand.

Habitat and Ecology

Found in still, shallow, marginal waters of tanks and rivers, mostly with muddy bottoms in plains and submontane regions. They browse close to the substrate in shallow water and feed on crustaceans, insects and plankton.

Conservation Status

IUCN Red List, least concern.

Remarks

It is a popular aquarium fish and can be kept in groups of five or more individuals in a medium-sized aquarium.

Genus: *Schizothorax* Heckel, 1838

11. *Schizothorax richardsonii* (Gray, 1832)

Cyprinus richardsonii Gray, 1832. *Ill. Indian Zool*., 1, pl. 94, fig. 2 (type locality: India).

Schizothorax plagiostomus Heckel, 1838. *Fish. Cashmir*: 16, pl. 1 (type locality: Kashmir); Badola, 2009. *Ichthyology of the Central Himalaya*: 43–45, text fig.

Schizothorax sinuatus Heckel, 1838. *Fish. Cashmir*: 16, pl. 1 (type locality: Kashmir); Badola, 2009. *Ichthyology of the Central Himalaya*: 44–45, text fig.; Uniyal, 2010. *Pisces.* In: *Fauna of Uttarakhand. State Fauna Series*, 18(1): 567.

Schizothorax richardsonii Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir).

English Names

Himalayan Barbel, Snow Trout.

Local Names

Asela, Sohal.

Localities Surveyed

Asan reservoir.

Diagnostic Characters

D. 2–4/8, P. 1/16, V. 1/9, A. 3/5, C. 19(10/9). L.l. 95–110.

Body subcylindrical; head oval; mouth inferior, transverse, slightly arched; lips thick, upper smooth, lower finely papillated, modified into a sucker; barbels two short pairs, rostral and maxillary; dorsal fin origin variable as regards to that of the pelvics, caudal forked; scales minute, elliptical, anal base and around covered by tiled row of enlarged scales, lateral line complete. Body silvery with fine dark dots, dorsal and caudal fins greyish, paired and anal fins yellowish.

Sexual Dimorphism: Male with snout covered with tubercles, dorsal spine weak with feeble serrations on the posterior edge and anal sheath well developed. Female with normal/smooth snout, strong dorsal spine having prominent serrations on the posterior edge and smaller anal sheath.

Maximum Size

60.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri, Haridwar, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Rajaji National Park.

India
Arunachal Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Manipur, Meghalaya, Nagaland, Punjab, Sikkim, Uttarakhand, Uttar Pradesh and West Bengal (Darjeeling).

Elsewhere
Afghanistan, Bhutan, China, Nepal and Pakistan.

Habitat and Ecology
Inhabits mountain streams and rivers, preferring to live among rocks and near big submerged stones. It is a primarily bottom feeder herbivore and feeds on algal slimes, aquatic plants, detritus and insects encrusted on the rocks. It breeds during April to May, before the monsoon floods the rivers and streams; the fry grows to such a size to bear the rigours of the flood water.

Conservation Status
IUCN Red List, vulnerable.

Remarks
Of fishery and game interest. The flesh is much relished.
Subfamily: Danioninae
Genus: *Barilius* Hamilton, 1822

12. *Barilius barna* (Hamilton, 1822)

Cyprinus (*Barilius*) *barna* Hamilton, 1822, *Fish Ganges*: 268–269, 384 (type locality: Yamuna and Brahmaputra rivers, extreme branches of Ganges).

Barilius barna Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, Asan River above Kunja Grant and below its barrage).

English Name
Barna Baril.

Local Names
Childi, Dhaur, Popta.

Localities Surveyed
Asan River above Kunja Grant, below its barrage at Dhalipur, Herbertpur, villages Fatehpur, Partitpur and Bairagiwala near Herbertpur, Bhaironwala, Sahaspur, Bhurpur near Jhajra and Chandrabani; Asan reservoir.

Diagnostic Characters
D.3/7, P. 2/12–13, V. 2/7, A.3/10–11, C.19 (10/9). L.l. 40.

Body somewhat deep, mouth moderate, snout and jaws with tubercles, barbels absent or rudimentary; dorsal fin origin in advance of anal fin. Body silvery with 7–11 vertical bars; dorsal and caudal fins edged with black.

Sexual Dimorphism: Male deep bodied, larger in size and with rough texture due to the presence of fine tubercles on the body, head and jaws; well-developed fins, outer few rays of pectoral and inner few rays of pelvic fins thickened; yellowish ventrally. Female streamlined and smooth with normal fins.

Maximum Size
15.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
Arunachal Pradesh, Assam, Bihar, Himachal Pradesh (Yamuna system), Meghalaya, Odisha, Sikkim, Uttar Pradesh and West Bengal.

Elsewhere
Bangladesh, Bhutan, Laos, Mekong basin, Myanmar and Nepal (Narayani river system, Chitwan).

Habitat and Ecology
Inhabits clear water hill streams and large rivers with gravelly substratum. It is a benthopelagic bottom feeder.

Conservation Status
IUCN Red List, least concern.

Threats
It is locally threatened by destructive fishing techniques such as dynamite fishing, overexploitation, loss of habitat and siltation.

Remarks
Of no fishery interest.

13. *Barilius bendelisis* (Hamilton, 1822)

Cyprinus bendelisis Hamilton, 1822. *Jour. Mysore*, 3: 345, pl. 32 (type locality: Vedawati system, Headwaters of Krishna river near Heriuru, Mysore).

Barilius bendelisis Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Hamilton's Barila, Hill Trout.

Local Name
Chedra, Chilwa.

Localities Surveyed
Asan River above Kunja Grant, below Dhalipur Barrage, villages Partitpur and Bairagiwala near Herbertpur, Sahaspur, Sabhawala, village Bhurpur near Jhajra and at Chandrabani; seepage nala below Asan Barrage; Asan reservoir. Swarna nadi, Bhauwala; Karwapani, Asarori; Naro nadi near village Langha and at Bhurgaon near Bansiwala; Tons nadi at Premnagar, village Chandrauti, Bijapur and Robber's cave, Birhani nadi near Panditwari; Nimi nadi, Paundha; Nun nadi, Jaintanwala; Nalota nala at village Chandrauti and village Malsi on lower Mussoorie road; Kiarkuli nadi and Bhitarli nadi near village Khera and Jaspur. Small stream (Manaksidh rao), Karwapani, Asarori forest.

Diagnostic Characters
D. 2/7, P. 1/12–14, V. 1/8, A. 2–3/7–8, C. 19, L.l. 40–45.

Snout and lower jaw with tubercles; barbels two short pairs, rostral pair often absent; dorsal fin inserted entirely in advance of anal fin. Body silvery with 8–12 vertical bands; scales with many radii, lateral line complete with double black spot.

Sexual Dimorphism: Male large and robust with paired fins enlarged and fan-like, outer few rays of pectorals strongly thickened and ossified, dorsal and anal fins well expanded; snout, lower jaw and outer branchiostegal rays covered by thorny tubercles, body roughened due to presence of tubercles, bands faded and dorsal fin margin grey-edged. Female normal without above modifications.

Maximum Length
22.7 cm.

Distribution

Uttarakhand
Garhwal Divisionn: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
Throughout except Kerala. Karnataka (Cedawati-Vedawati stream, headwaters of Krishna river near Heriuru, Mysore).

Elsewhere
Bangladesh, Bhutan, Myanmar (main), Nepal, Pakistan, Sri Lanka and Thailand.

Habitat and Ecology
Found in streams and rivers along the base of hills with sandy, pebbly and rocky bottom.

Conservation Status
IUCN Red List, least concern.

Threats
The possible threats to this species are overexploitation and habitat destruction due to natural and certain human activities.

Remarks
Of no fishery interest.

14. *Barilius vagra* (Hamilton, 1822)

Cyprinus (*Barilius*) *vagra* Hamilton, 1822. *Fish Ganges*: 269–270, 385 (type locality: Ganges about Patna).

Barilius vagra Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Name
Vagra Baril.

Local Names
Chalra, Dharu, Dhaur, Popta.

Localities Surveyed
Asan River at Herbertpur, above Kunja Grant, below its barrage, Sahaspur; Asan reservoir.

Swarna nadi, Bhauwala; Nun nadi, Jaintanwala; Naro nadi near village Langha.

Diagnostic Characters
D. 2/7, P. 1/13, V. 1/8, A. 3/10, C. 19 (10/9). L.l. 43–44.

Body shallow; mouth and jaws moderate with poorly developed tubercles; barbels two pairs, rostral and shorter maxillary; dorsal fin origin much anterior to that of anal fin. Body silvery with 10–14 bluish vertical bars, fins pinkish, dorsal and caudal fins edged with grey.

Maximum Size
12.5 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
Along the base of the Himalayas, Indus, Ganga and Brahmaputra river systems. Assam, Uttar Pradesh.

Elsewhere
Afghanistan, Bangladesh, Nepal, Pakistan and Sri Lanka.

Habitat and Ecology
Found in hill streams with gravelly and rocky bottom.

Conservation Status
IUCN Red List, least concern.

Threats
Destructive fishing may pose a threat to this species.

Remarks
Of no fishery interest.
Genus: *Danio* Hamilton, 1822

15. *Danio rerio* Hamilton, 1822

Cyprinus (*Danio*) *rerio* Hamilton, 1822. *Fish. Ganges*: 323, 390 (type locality: Kosi river).

Brachydanio rerio Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Zebra Danio, Zebrafish.

Local Names
Dharidar Salari.

Localities Surveyed
Asan River above Kunja Grant, at Dhalipur, Herbertpur, Sabhawala and Jhajra; seepage nala below barrage; Asan reservoir.

Small stream, culvert No. 28/2, Ridapur near Sahaspur; Swarna nadi, Bhauwala; Naro nadi, Langha; Kalughat khala, near village Doonga; Nimi nadi, Paundha; Nun nadi, Jaintanwala.. Small stream (Manaksidh rao), Karwapani, Asarori forest.

Diagnostic Characters
D. 2/6–7, P. 1/11, V. 1/5–6, A. 2–3/10–13, C. 18, L.l. 26–30.

Barbels two pairs, rostral extending to anterior margin of the eye and maxillary to about middle of opercle; lateral line absent, rudimentary or incomplete, extending beyond the pectoral fin or up to the base of the pelvic fins. Body sides blue, traversed with five uniformly, pigmented, horizontal golden stripes, extending to the end of caudal fin rays; anal fin also distinctively striped.

Sexual Dimorphism: In male, body slim, caudal fin typically homocercal and blunt and lighter in colour, while in female, body with bulging sides and deeper colouration.

Maximum Length

3.8 cm (standard length).

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora, Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Haryana, Gujarat, Karnataka, Kerala, Madhya Pradesh, Meghalaya, Nagaland, Punjab, Rajasthan, Odisha, Uttar Pradesh, Tripura and West Bengal.

Elsewhere

Bangladesh, Bhutan, Myanmar, Nepal and Pakistan. Colombia (presumably by escape from aquaria fish rearing facility).

Habitat and Ecology

Inhabits streams, canals, ditches, ponds and lakes. Also occurs in slow-moving to stagnant-standing water bodies, particularly ricefields, lower reaches of streams, rivulets at foothills. Feeds on worms and small crustaceans and also on insect larvae. Breeds all year round. Spawning is induced by temperature and commences at the onset of the monsoon season. Food availability also acts as cue for breeding.

Conservation Status

IUCN Red List, least concern.

Threats

Being a popular aquarium fish, it might suffer from overexploitation resulting in fluctuation of individuals.

Remarks

Of no fishery interest; kept in aquaria.
Genus: *Devario* Heckel, 1843

16. *Devario devario* (Hamilton, 1822)

Cyprinus (*Cabdio*) *devario* Hamilton, 1822. *Fish. Ganges*: 341–342, 393, pl. 6, Fig. 94 (type locality: rivers and ponds of Bengal).

Danio devario Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names

Devario Danio, Sind Danio.

Local Name

Chand.

Localities Surveyed

Asan River above Kunja Grant, below its barrage at Dhalipur, Herbertpur, villages Partitpur and Bairagiwala near Herbertpur, Bhaironwala, Sabhawala and village Bhurpur near Jhajra; seepage nala below barrage; Asan reservoir.

Swarna rao, Bhauwala; small stream, culvert No. 19/2, Selakui.

Diagnostic Characters

D. 2–3/15–17, P. 1/11–12, V. 1/7, A. 2–3/16–17, C. 19, L.l. 33–38.

Body rhomboidal; barbels absent; lateral line complete. Body greenish above, silvery on sides; three blue narrow bands divided by yellow bands extending backwards to the caudal fin with a pair of blue marks at its base.

Maximum Length

10.0 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Godavari and Krishna river systems, Gujarat, Madhya Pradesh, Meghalaya, Odisha, Rajasthan, Uttar Pradesh, Tripura and West Bengal.

Elsewhere

Afghanistan, Bangladesh, Nepal and Pakistan.

Habitat and Ecology

Inhabits rivers, canals, ponds, lakes and inundated fields in plains and submontane regions. Feeds on worms, small crustaceans and insects.

Conservation Status

IUCN Red List, least concern.

Threats

General habitat destruction may cause significant decline in its population.

Remarks

Of no fishery value; kept in aquaria.

Genus: *Esomus* Swainson, 1839

17. *Esomus danricus* (Hamilton, 1822)

Cyprinus (*Danio*) *danrica* Hamilton, 1822. *Fish. Ganges*: 325,390, pl. 16, fig. 88 (type locality: ponds and ditches of Bengal).

Esomus danricus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Name

Flying Barb.

Local Name

Chal.

Localities Surveyed

Asan River at Jhajra and Herbertpur, above Kunja Grant; seepage nala below barrage; Asan reservoir.

Pond at Selakui.

Diagnostic Characters

D. 2/6, P. 1/ 10–12, V. 1/6–7, A. 3/5, C. 18–19, L.l. 27–34.

Barbels two pairs, maxillary extremely long, extending to about middle of the body; dorsal fin inserted far back; lateral line absent or incomplete, piercing only up to the 4–6th scales. Body with a broad dark lateral band from the mouth to caudal fin which in juveniles edged by a fine golden line; pelvic fins reddish, others orangish.

Maximum Length

13.0 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Throughout northern India. Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Gujarat, Odisha (Chilka Lake), Madhya Pradesh, Maharashtra, Punjab, Uttar Pradesh, Tamil Nadu (Chittar river basin) and West Bengal (Jayanti river).

Elsewhere

Afghanistan, Bangladesh, Cambodia, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand.

Habitat and Ecology

It is a benthopelagic species, found in ponds, weedy ditches and irrigation canals.

An active fish that swims well and feeds on insects close to the surface. It prefers well-aerated waters.

Conservation Status
IUCN Red List, least concern.

Remarks
Of no fishery interest; kept in aquaria. It has been found to be of great utility for larvicidal purpose.
Genus: *Raiamas* Jordan, 1919

18. *Raiamas bola* (Hamilton, 1822)
Cyprinus (*Barilius*) *bola* Hamilton, 1822. Fish. Ganges: 274–275, 385 (type locality: Brahmaputra).

English Name
Trout Barb.

Local Names
Balala, Bhola, Gulabi-machhli, Naulia.

Localities Surveyed
Asan River at Herbertpur, villages Fatehpur and Partitpur near Herbertpur and Bhurpur near Jhajra.

Diagnostic Characters
D. 3/8, P. 1/14, V. 2/8, A. 3/10, C. 19 (10/9). L.l. 87–90.

Body compressed; cleft of mouth deep, barbels absent (rudimentary maxillary pair in juveniles); dorsal fin origin ahead to that of anal fin and nearer to the caudal base than to snout tip; scales small, lateral line complete. Body silvery with 15–17 dark spots of varying size and shapes; fins yellowish orange.

Sexual Dimorphism: In male, snout, suborbital bones and lower jaw densely covered with tubercles, few tubercles on opercular region and skin tip of lower jaw; scales on the body with tubercles; outer few rays of pelvic fin slightly shorter; upper surface of outer few rays of dorsal with fine tubercles. In female, head and body smooth; outer rays of pelvic fin slightly longer than inner rays.

Maximum Size
35.0 cm; weight 2.3 kg.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
Confined to hilly areas of the northern provinces, Arunachal Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Odisha, Punjab, Uttar Pradesh and West Bengal. Found in Kosi, Bagmati, Gandak drainages in Bihar and headwaters of Ganga river (in Uttarakhand). Introduced in Maharashtra (in Lonavla lakes, Pune district).

Elsewhere
Bangladesh, Bhutan, Myanmar, Nepal and Thailand.

Habitat and Ecology
Found in rivers in clear streams with rocky beds in submontane areas. It breeds during early monsoon season (June) in heavily inundated areas. It breeds approximately after attaining three years of age. Its wide mouth and streamlined body are well suited for a predaceous life.

Conservation Status
IUCN Red List, least concern.

Threats
The population of this species seems to be affected by destructive fishing methods.

Remarks
Of fishery and game interest.
Subfamily: Labeoninae
Genus: *Bangana* Hamilton, 1822

19. *Bangana dero* (Hamilton, 1822)
Cyprinus (*Bangana*) *dero* Hamilton, 1822. Fish. Ganges: 277–278, 385, pl. 17, fig. 78 (type locality: Brahmaputra river)

English Name
Kalabans.

Local Names
Kalabans, Karaunchar, Moli, Moili, Unera.

Localities Surveyed
Asan River below its barrage at Dhalipur, Herbertpur, Bairagiwala near Herbertpur.

Diagnostic Characters
D. 3/10, P. 1/16, V. 1/8, A. 2/5, C. 19(10/9). L.l. 41–42.

Body elongate, dorsal profile, especially predorsal part raised and bluntly edged; mouth moderately arched; lips thin, upper smooth but glandular at corners, lower finely fimbriated with inner surface studded with nodular tubercles, lower jaw with cartilaginous layer; snout blunt with horny tubercles, a pair of short maxillary barbels; dorsal origin variable, upper caudal lobe slightly longer; scales moderate to minute, lateral line complete. Body greenish grey, scales tinged with red, fins reddish, dorsal margin darkish.

Sexual Dimorphism: In male, snout with deep transverse groove and dorsolateral sides covered by greatly enlarged cornified tubercles and anterior few rays of dorsal prolonged. In female, groove less marked, tubercles rudimentary and simple dorsal fin.

Maximum Size
75.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
All along Himalaya, Arunachal Pradesh, Assam, Jammu and Kashmir, Manipur, Punjab, Uttar Pradesh and West Bengal (Adma, Buxa and Jayanti rivers). Deccan and south as far as Cauvery, Chota Nagpur, Satpura-Vindhya ranges.

Elsewhere
Afghanistan, Bangladesh, Bhutan, China, Iran, Myanmar, Nepal and Pakistan.

Habitat and Ecology
Inhabits torrential hill streams in shallow waters. They migrate to warmer regions of lakes and streams during winter. They are herbivorous.

Conservation Status
IUCN Red List, least concern.

Threats
The possible threat may be habitat degradation, dams and other human activities.

Remarks
Of commercial fishery and game interest. Commonly used as bait for *Raiamas bola* and *Tor putitora*. Highly esteemed as food.
Genus: *Crossocheilus* van Hasselt, 1823

20. *Crossocheilus latius latius* (Hamilton, 1822)
Cyprinus (*Garra*) *latius* Hamilton, 1822. *Fish. Ganges*: 345–346, 394 (type locality: Tista river).
Crossocheilus latius latius Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River above Kunja Grant and below its barrage).

English Name
Gangetic Latia.

Local Names
Dhanaura, Saknera.

Localities Surveyed
Asan River above Kunja Grant, Herbertpur and below its barrage.

Diagnostic Characters
D. 2/8, P. 1/14, V. 1/8, A. 2/5, C. 16, 20 (8/8, 11/9). L.l. 38–39.

Body elongate; head depressed, mouth inferior, barbels two pairs (short rostral and maxillary); dorsal fin origin much in advance of the pelvics; scales moderate, lateral line complete.

Body greyish brown with irregular punctuations with a faint lateral stripe, dorsal and caudal fins yellowish grey, other fins orangish.

Maximum Size

12.5 cm.

Distribution

Uttarakhand

Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India

Arunachal Pradesh, Karnataka, Kerala, Manipur, Mizoram, Meghalaya, Odisha (Chilka Lake; Mahanadi drainage) and Tripura. Drainages of Ganga and Brahmaputra in northern India.

Its occurrence south to the headwaters of Krishna river and Western Ghats is to be confirmed.

Elsewhere

Afghanistan, Bangladesh, Bhutan, China, Iran, Myanmar, Nepal and Pakistan.

Habitat and Ecology

Inhabits streams, rivers and lakes of montane and submontane regions with gravel and stony substratum in benthopelagic environment.

Conservation Status

IUCN Red List, least concern.

Remarks

Of no fishery interest.
Genus: Garra Hamilton, 1822

21. *Garra gotyla gotyla* (Gray, 1830)

Garra gotyla Gray, 1830. *Ill. Indian Zool.*, 1, pl. 88, fig. 3 (type locality: not mentioned).

Garra gotyla gotyla Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir).

English Names

Sucker Head, Stonefish.

Local Names

Bhangnera, Budna, Dhanaura, Gotyla, Gotla.

Localities Surveyed

Asan River below Dhalipur Barrage, Herbertpur and Sabhawala; Asan reservoir.

Small stream, culvert No. 28/2 at Ridapur; Swarna nadi, Bhauwala; small stream, culvert No. 19/2 at Selakui; pond at Sahaspur.

Diagnostic Characters

D. 3/7–8, P. 1/16, V. 1/8, A. 3/5, C. 17. L.l. 33.

Body elongate; head depressed, snout with a median proboscis with spiny tubercles; mouth ventral, arched and with a mental disc; barbels two short pairs; dorsal origin in advance of the pelvis; scales moderate, lateral line complete. Body greenish brown with a dusky spot behind the gill opening and a row of dark spots along the base of dorsal fin, gins greyish.

Maximum Size

15.5 cm.

Distribution

Uttarakhand

Garhwal Division: Chamoli, Dehradun, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India

All along the Himalayas, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal (Adma, Buxa and Jayanti rivers). Chota Nagpur plateau and the Vindhya-Satpura mountains of the Indian peninsula.

Elsewhere

Afghanistan, Bangladesh, Bhutan, Myanmar, Nepal and Pakistan.

Habitat and Ecology
Inhabits fast-flowing streams with boulders and rocks and lakes along the Himalayan ranges. Feeds on algae, plants and detritus.

Conservation Status
IUCN Red List, least concern.

Threats
It is a substrate specialist species. Throughout its range, the boulders and gobbles are removed leading to habitat loss accompanied by other threats due to deforestation, damming and siltation.

Remarks
Of no fishery interest but a highly valuable food fish of the Himalayan region.
Genus: *Labeo* Cuvier, 1817

22. *Labeo dyocheilus* (McClelland, 1839)
Cyprinus (*Labeo*) *dyocheilus* McClelland, 1839. *Asiat. Res*., 19(2): 268, 330, pl. 37, Fig. 1 (type locality: Brahmaputra river).

English Name
Brahmaputra Labeo.

Local Names
Boalla, Doongri, Kali.

Localities Surveyed
Asan River, Herbertpur.

Diagnostic Characters
D. 2–3/8–11, P. 1/14–16, V. 1/8, A. 2/5, C. 19, L.l. 43.

Head comparatively longer, snout conical projecting beyond the mouth and with a distinct lateral lobe, lips thick (not fringed) inside of the lower lip with striations; one short maxillary barbel pair. Body dull greenish brown laterally, darker above; fins dark in the centre.

Maximum Length
90.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri and districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Rajaji National Park.

India
All along Himalaya. Assam, Bihar, Sikkim, Uttar Pradesh and West Bengal. Damodar and Mahanadi rivers.

Elsewhere
Afghanistan, Bangladesh, Bhutan, Cambodia, Laos, Myanmar, Nepal, Pakistan, Thailand and Vietnam (uncertain).

Habitat and Ecology
Inhabits clear active currents of large rivers. Increasing day length and water temperature are favourable for ovarian development in female under both captive and wild conditions, and it breeds during monsoon season.

Conservation Status
IUCN Red List, least concern.

Remarks
Commercially important food fish.
Subfamily: Rasborinae
Genus: *Aspidoparia* Heckel, 1847

23. *Aspidoparia jaya* (Hamilton, 1822)
Cyprinus (*Cabdio*) *jaya* Hamilton, 1822. *Fish. Ganges*: 383–384, 392 (type locality: rivers of northern Bengal).

English Names
Carplet, Jaya.

Local Names
Chal, Chilwa.

Localities Surveyed
Asan River, Herbertpur.

Diagnostic Characters
D. 3/7. P. 1/12–13, V. 1/7–8, A. 3/7, C. 19. L.l. 46–53.

Body subcylindrical; mouth inferior, jaws short; pharyngeal teeth in two rows, barbels absent; dorsal fin origin above insertion of the pelvic fins; scales deciduous, lateral line almost straight. Body silvery.

Maximum Length
15.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun and Hardwar districts; Kumaon Division: Nainital district. Rajaji National Park.

India
Assam and Uttar Pradesh.

Elsewhere
Afghanistan, Bangladesh, Nepal.

Habitat and Ecology
Inhabits streams and ponds in plains and mountainous regions. It is rare in the catches. Typically found at an altitude of 0–1,769 m.

Conservation Status
IUCN Red List, least concern.

Threats
Harvested for its ornamental value and indiscriminately for its food value by use of destructive fishing.

Remarks
This is the new record from Asan River.

Of no fishery interest. Considered a tasty food fish, though rare in the catches.
Genus: *Cabdio* Hamilton, 1822

24. *Cabdio morar* (Hamilton, 1822)

Cyprinus (*Chela*) *morar* Hamilton, 1822. *Fish. Ganges*: 264, 384. Pl. 31, fig. 75 (type locality: rivers Yamuna and Tista).

Aspidoparia morar Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River above Kunja Grant and below its barrage).

English Name
Morari.

Local Names
Chal, Chilwa.

Localities Surveyed
Asan River above Kunja Grant and below its barrage.

Diagnostic Characters
D. 2/7, P. 1/12–13, V. 1/7–8, A. 3/9, C. 19 (10/9). L.l. 36–38.

Body subcylindrical; mouth inferior, jaws short, pharyngeal teeth in three rows, barbels absent; scales deciduous, lateral line slightly curved. Body yellowish silvery with a burnished lateral band.

Maximum Size
17.5 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun district; Kumaon Division: Nainital district.

India
Throughout northern India.

Elsewhere
Afghanistan, Bangladesh, China, Iran, Myanmar, Nepal, Pakistan and Thailand. Vietnam (introduced). The taxonomic identity of the records in Iran, Myanmar, Pakistan and Thailand needs to be confirmed.

Habitat and Ecology
Found in streams, rivers and ponds in plains and mountainous regions. This is an oviparous species; they scatter their eggs after spawning.

Conservation Status
IUCN Red List, least concern.

Threats
Harvested for its ornamental value and for its food value, using destructive fishing methods. The area is also affected by habitat degradation due to deforestation.

Remarks
Of no fishery interest.
Genus: *Rasbora* Bleeker, 1859

25. *Rasbora daniconius* (Hamilton, 1822)
Cyprinus (*Danio*) *daniconius* Hamilton, 1822. *Fish. Ganges*: 327–328, 391, pl. 15, fig. 89 (type locality: rivers of southern Bengal).
Parluciosoma daniconius Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Black-Line Rasbora, Common Rasbora, Slender Barb, Slender Rasbora, Striped Rasbora.

Local Name
Bhuri.

Localities Surveyed
Asan River above Kunja Grant, below its barrage at Dhalipur, Herbertpur, villages Partitpur and Bairagiwala near Herbertpur, Sabhawala and village Bhurpur near Jhajra; seepage nala below barrage; small stream near Asan Barrage, Dhalipur; Asan reservoir.

Small stream between Sahaspur and Herbertpur; Swarna rao, Bhauwala; ponds at village Jassowala near Sahaspur and Selakui.

Diagnostic Characters
D. 2/7, P. 1/11–13, V. 2/8, A. 3/5–7, C. 19, L.l. 27–34.

Lateral line nearly complete, with only the last few scales lacking pores. Body silvery on sides with a distinct blue-black mid-lateral stripe from the eye to the base of caudal fin, edged with gold; a narrow dark stripe above the anal fin; fins tinged with yellow, caudal fin lobes often tipped grey.

Maximum Length
15.0 cm, commonly 8.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora, Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Andaman Islands, Andhra Pradesh, Assam, Bihar, Gujarat, Madhya Pradesh, Odisha, Punjab, Uttar Pradesh, Tamil Nadu and West Bengal.

Elsewhere
Afghanistan, Bangladesh, Bhutan, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam.

Habitat and Ecology
It is a benthopelagic and potamodromous species. Found in a variety of habitats, ditches, ponds, canals, sandy streams and rivers and inundated fields. Sometimes forms large schools. A surface feeder, feeding mainly on aquatic insects and detritus. Its spawning sites are found in rivers and ponds; mature adults probably breed during the rainy season.

Conservation Status
IUCN Red List, least concern.

Threats
Threats to this species and its habitat are not evident at present, although it is collected for the aquarium trade and for poultry food but the scale does not appear to be causing a decline in the population.

Remarks
Of no fishery interest; kept in aquaria being hardy and adaptable fish. It may prove very useful for destroying mosquito larvae.

Subfamily: Incertae (uncertain)
Genus: *Chagunius* Smith, 1938

26. *Chagunius chagunio* (Hamilton, 1822)

Cyprinus (*Cyprinus*) *chagunio* Hamilton, 1822. *Fish. Ganges*: 295–297, 387 (type locality: Yamuna and in the northern rivers of Behar and Bengal).

Chagunius chagunio Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (seepage nala).

English Name

Chaguni.

Local Names

Chhibban, Pathal, Pathali, Pithari.

Localities Surveyed

Asan River at Dhalipur, Herbertpur, Fatehpur and Bairagiwala villages near Herbertpur and Chandrabani; seepage nala below Asan Barrage.

Diagnostic Characters

D. 4/8, P. 1/14, V. 1/8, A. 3/5, C. 19. L.l. 40–46.

Body depth slightly more than the head length; mouth narrow and subterminal, tubercles on snout, 2 pairs barbels, longer than orbit; dorsal spine strong and serrated, denticles recurved; scales small. Body silvery with few black dots.

Sexual Dimorphism: Tubercles on snout and cheeks of females smaller than those of males.

Maximum Size

50.0 cm.

Distribution

Uttarakhand

Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India

Northern India: Brahmaputra and Ganga drainages along the base of Himalaya. Assam, Bihar, Delhi, Madhya Pradesh, Manipur, Odisha, Punjab, Uttar Pradesh and West Bengal (Adma, Buxa and Jayanti rivers). Chota Nagpur, Damodar drainage.

Elsewhere

Bangladesh and Nepal.

Habitat and Ecology

Inhabits large rivers with rocky substratum, clear and fast water and little or no vegetation. Adults prefer stronger current than juveniles.

Conservation Status

IUCN Red List, least concern.

Threats

Habitat of this species is being degraded due to deforestation and illegal fishing techniques, dams, sand quarry and mining.

Remarks

Of commercial and game value.

Genus: *Tor* Gray, 1833

27. *Tor putitora* (Hamilton, 1822)

Cyprinus (*Cyprinus*) *putitora* Hamilton, 1822. *Fish. Ganges*: 303–305, 388 (type locality: eastern parts of Bengal).

Tor putitora Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River above Kunja Grant and below its barrage).

English Names

Common Himalayan Mahseer, Golden Mahseer, Putitor Mahseer.

Local Names

Mahseer, Mahsir, Pila-par Mahseer, Pili Mahseer.

Localities Surveyed

Asan River above Kunja Grant, below its barrage at Dhalipur, Herbertpur, Partitpur and Bairagiwala near Herbertpur, Sabhawala and Bhurpur near Jhajra.

Diagnostic Characters

D. 4/8, P. 1/15, V. 1/8, A. 2–3/5, C. 19, L.l. 22–28.

Body streamlined; lips thick, continuous at angles of the mouth, often hypertrophied; barbels two pairs; head longer than depth of the body in adult. Body greenish above, light pinkish yellow on sides with a broad, light greenish blue lateral band and silvery below.

Maximum Length
2.75 m, commonly 1.83 m; weight 54 kg.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
All along the Himalayas including Assam, Bihar, Jammu and Kashmir, Himachal Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Uttar Pradesh (Ramganga) and West Bengal (Darjeeling).

Elsewhere
Afghanistan, Bhutan, China, Iran, Myanmar, Nepal, Pakistan and Thailand. Introduced in Bangladesh.

Habitat and Ecology
Inhabits rapid streams with rocky bed, rivers, riverine pools and lakes in montane and submontane regions in pH ranges 7.4–7.9 and 13–30 °C temperature. It is a column feeder, omnivorous in nature, feeding on fish, zooplankton, dipteran larvae and plant matter; juveniles subsist on plankton while fingerlings feed mainly on periphytic algae and diatoms. Ascend streams to breed over gravel and stones and returns to perennial ponds after breeding.

Conservation Status
IUCN Red List, endangered.

Threats
Threatened due to overharvesting and feeding and breeding habitat loss throughout its range due to many anthropogenic stresses.

Remarks
Commercial fishery, game/sport and of food value. Presently, specimens over 30 cm and 5 kg in weight are rarely caught due to overexploitation of resources.

28. *Tor tor* (Hamilton, 1822)

Cyprinus (*Cyprinus*) *tor* Hamilton, 1822. *Fish. Ganges*: 305–306, 388 (type locality: Mahananda river).

Tor tor Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River below its barrage).

English Names
Deep-Bodied Mahseer, Large-Scaled Barb, Red-Finned Mahseer, Tor Barb, Tor Mahseer.

Local Names
Ladhar, Lal-machhli, Lal Mahseer, Machiyari, Mahseer, Mahasher, Makhni, Mashir.

Localities Surveyed
Asan River below its barrage at Dhalipur, Herbertpur, Bairagiwala near Herbertpur and Bhurpur near Jhajra.

Diagnostic Characters
D. 3–4/8–9, P. 1/14–17, V. 1/8, A. 3/5, C. 19(10/9). L.l. 24–26.

Body stoutly built, somewhat compressed; head bluntly point, its length shorter than the depth of the body; mouth somewhat inferior, short; lips fleshy, upper sometimes greatly enlarged and produced, median lobe of lower lip invariably produced backwards into a long fleshy and pointed appendage; barbels two pairs, short rostral and maxillary; eyes large, mostly in anterior half of the head; dorsal fin origin variable, its spine osseous, strong, groove behind, much shorter than body depth, pelvics with scaly appendage at its axil, caudal fin forked with its upper lobe slightly longer; scales large, dorsal and anal fins in a sheath of scales, lateral line complete. Colour silvery with pinkish tinge, dorsal and caudal fins greyish with a tinge of pink, other fins reddish or orange; fry with a black spot at the caudal base.

Maximum Size

2.0 m, commonly 17.5 cm; weight 9.0 kg. Reported to reach 150 cm in total length and gain a maximum weight of 68 kg (Thomas 1897 vide Talwar and Jhingran 1991). Considered a long-living species for 10 years (Desai 2003).

Distribution

Uttarakhand

Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India

Sub-Himalayan range, Ganges and Narmada river systems; Assam and all along the foothills of the Eastern and Central Himalayas as far as Yamuna system, higher reaches of the Mahanadi in Odisha and Vindhya and Satpura ranges (Madhya Pradesh). Buxa, Adma and Jayanti rivers (West Bengal) and Tungabhadra river (Karnataka/Andhra Pradesh).

Elsewhere

Bangladesh, Bhutan, Myanmar, Nepal and Pakistan.

Habitat and Ecology

Inhabits rivers and lakes, also in rapid streams with rocky bottom. Grows better in a river with a rocky bottom. Omnivorous feeds on filamentous algae, chironomid larvae, water beetles and crustaceans. Travels towards headwaters at the start of the rainy season for breeding and downstream at the end of the rainy season. Spawns from March to September, over stones and gravel.

Conservation Status

IUCN Red List, near threatened.

Threats

Destruction of habitat due to various developmental projects.

Remarks

Of commercial, aquaculture and game interest.

Family: Nemacheilidae

Genus: *Acanthocobitis* Peters, 1861

29. *Acanthocobitis botia* (Hamilton, 1822)

Cobitis botia Hamilton, 1822. *Fish. Ganges*: 350–351, 394 (type locality: rivers of the northeastern parts of Bengal).

Nemacheilus botia Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names

Mottled Loach, Sand Loach, Striped Loach.

Local Names

Baktia, Gadera, Ghiwa, Nauni.

Localities Surveyed

Asan River above Kunja Grant below Asan Barrage at Dhalipur, Herbertpur, villages Fatehpur and Partitpur near Herbertpur, Sabhawala, Bhaironwala, Sahaspur, Selakui, Bhurpur near Jhajra and Chandrabani; seepage nala below barrage; small stream near Asan Barrage, Dhalipur; Asan reservoir.

Small stream, culvert No. 28/2, Ridapur near Sahaspur; Bhur nadi, Bhurgaon; Naro nadi, Langha; Tons nadi near Premnagar and Robber's cave; Nimi nadi, Paundha; Nun nadi, Jaintanwala.

Diagnostic Characters

D. 3/9–11, P. 1/11, V. 1/7, A. 2–3/5, C. 19.

Nostrils close to each other, anterior nostril simple, not tubular; lips papillose; caudal fin emarginated; scales conspicuous, reduced on chest; lateral line complete or if incomplete reaching to anal opening or little beyond. Body pale with 10–12 short, blackish twisted bands on lateral sides, descending to below the lateral line, interrupted in young, broken up into patches in adults and scattered irregularly; dorsal fin orange, with row of black spots; dorsal fin with 5–6 oblique zigzag narrow bands; a black ocellus, encircled with white, on upper half of the caudal fin base; caudal fin with 5–7 posteriorly directed V-shaped dark bands.

Sexual Dimorphism: In male, a deep slitlike groove in front of the lower edge of the eye below the nostrils, turning round a small knob-like fleshy appendage of preorbital below the anterior 1/3rd of the eye; upper surface of pectoral fins finely tuberculated. Female lacks these modifications.

Maximum Length
11.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital, Pithoragarh and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Northern India in Brahmaputra and Ganges; Assam, Bihar, Haryana, Himachal Pradesh, Maharashtra, Punjab, Uttar Pradesh and Western Ghats rivers.

Elsewhere
Bangladesh, Bhutan, China, Myanmar, Nepal, Pakistan (Indus basin), Sri Lanka and Thailand.

Habitat and Ecology
Demersal inhabiting clear water, swift-flowing streams with rocky, pebbly and sandy bed. It is omnivorous. It spawns with about 100–150 eggs.

Conservation Status
IUCN Red List, least concern.

Threats
In hilly areas, the habitat quality is declining as a result of deforestation, leading to siltation. Furthermore, drought has led to a loss of suitable habitat.

Remarks
Of no fishery interest. Distinguished from its congeners by the absence of a suborbital flap in male, the flap being replaced by a suborbital groove.
Genus: *Nemacheilus* van Hasselt, 1822.

30. '*Nemacheilus*' *corica* (Hamilton, 1822)

Cobitis corica Hamilton, 1822. *Fish. Ganges*: 359, 395 (type locality: Kosi river).

Nemacheilus corica Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River below its barrage).

English Name
Polka-Dotted Loach.

Local Names
Gadera, Nauni.

Localities Surveyed
Asan reservoir; seepage nala and Asan River below its barrage.

Description
D. 2–4/8, P. 1/10, V. 1/7, A. 2–3/5, C. 17 (9/8).

Body cylindrical anteriorly, moderately compressed posteriorly; head oval, granulated; barbels covered with fine nodules; dorsal fin origin slightly ahead of the pelvics, 2nd branched ray of pectoral produced, caudal peduncle narrow, caudal fin forked to halfway; scales on the predorsal region of the ventral side absent, a few scales before the pelvics, lateral line complete, ridged anteriorly, grooved in the caudal region. Body pale with 12–13 brownish oval blotches, a fine black line below the lateral line in caudal area, a broad band on the dorsal fin nearer its base, two V-shaped bands on the caudal fin.

Sexual Dimorphism: In male, preorbital projects in the form of a club-shaped movable fleshy process directed postero-ventrally below the anterior margin of the eye; upper surface of the pectoral fin covered with minute tubercles. Female lacks these characters.

Maximum Size
5.0 cm, 4.2 cm (standard length).

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Nainital

and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Himalayan foothills. Assam (Numaligarh), Bihar, Himachal Pradesh, Odisha (Salane river), Punjab (Sutlej basin), Uttar Pradesh and West Bengal (Darjeeling).

Elsewhere
Afghanistan, Bangladesh (Padma river), Nepal and Pakistan.

Habitat and Ecology
Inhabits clear waters and hill streams with sandy bottom, also collected in a large river with high, turbid monsoon flow and with diverse substrate consisting of sand, mud, gravel, pebble, cobble and boulders.

Conservation Status
IUCN Red List, least concern.

Threats
Damming and destructive fishing.

Remarks
Kullander et al. (1999) placed the species under *Schistura*, but very recently, Kottelat (2012) mentioned it under taxonomic notes 'Generic position requires investigation' and hence followed the same treatment here.

Of no fishery interest.

Genus: *Schistura* McClelland, 1838

31. *Schistura beavani* (Gunther, 1868)

Nemachilus beavani Gunther, 1868. Cat. Fish. Brit. Mus., 7: 350 (type locality: Kosi river).

Nemacheilus beavani Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant).

English Name
Creek Loach.

Local Name
Gadera.

Localities Surveyed
Asan reservoir; seepage nala and Asan River above Kunja Grant.

Diagnostic Characters
D. 3/8, P. 1/10, V. 1/7, A. 2/5.

Body elongated, nostrils close to each other, mouth semicircular, lips fleshy and furrowed, barbels longer than the eye; dorsal fin origin midway between the snout tip and caudal base, caudal fin forked; scales minute, inconspicuous, more prominent posteriorly, absent on ventral side, lateral line complete. Body pale with about nine vertical bars, wider than interspaces, dorsal fin with a row of dark spots, a dark band at the caudal base.

Maximum Length
8.0 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri and Tehri districts; Kumaon Division: Nainital district. Corbett Tiger Reserve and Rajaji National Park.

India
West Bengal (north). Reports of its occurrence in parts of the Brahmaputra river drainage in Meghalaya need to be verified.

Elsewhere
Bangladesh and Nepal.

Reports of its occurrence in Pakistan, Myanmar and Pakistan need to be verified.

Habitat and Ecology
Occurs in shallow and swift clear hill streams with sandy, gravely and pebbly bed, preferring pools and riffle areas of creek, also collected in large rivers with high, turbid monsoon flow and with diverse substrate consisting of sand, mud, gravel, pebble, cobble and boulders

Conservation Status
IUCN Red List, least concern.

Threats
At least in some parts of its range, facing threats from habitat loss caused by natural calamities and human interferences.

Remarks
Banarescu and Nalbant (1995) treat the species under the genus *Schistura* McClelland.

32. *Schistura doonensis* (Tilak & Husain, 1977)

Noemacheilus doonensis Tilak & Husain, 1977. *Sci. & Cult*., 43(3): 133–135, figs. 1a, b, c (type locality: a small stream near village Kandholi on the way to Doonga; Soor Sahab wali Khal, a stream near Asarori, District Dehradun).

Nemacheilus doonensis Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (seepage nala).

English Name
Doon Loach

Local Names
Gadera, Nauni.

Localities Surveyed
Seepage nala below Asan Barrage.

Small stream near village Kandholi on way to Doonga.

Diagnostic Characters
D. 3/7, P. 1/8, V. 1/6–7, A. 3/5, C. 16.

Small-sized loach, subcylindrical and slightly curved downwards anteriorly; area in front of the pelvic fins flattened, head depressed, nostrils close together, membranous flap of anterior nostril produced in the form of nasal barbel, barbels longer than the eye, lips fleshy and continuous, upper jaw produced into beak-like truncated process while lower notched, eyes almost in anterior half of the head, dorsal origin variable and its 2nd branched ray longest (not produced), caudal fin slightly emarginated and shorter than the head; scales minute, body mostly devoid of scales, lateral line incomplete. Body pale with 22–23 dark vertical bars on lateral side and a darker one at the caudal base, a few anterior rays of dorsal fin with a dark spot and a faint band across its middle.

Maximum Size
3.4 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun and Pauri districts; Kumaon Division: Nainital and Pithoragarh districts.

India
No other record.

Elsewhere
No record.

Habitat and Ecology
Inhabits clear, swift streams with pebbly bottom.

Conservation Status
IUCN Red List, not evaluated.

Remarks
Of no fishery value.

33. *Schistura montana* (McClelland, 1838)

Schistura montana McClelland, 1838. *J. Asiat. Soc. Beng*., 7: 947, pl. 55, fig. 1 (type locality: mountain stream at Simla).

English Name
Shimla Loach.

Local Name
Gadera.

Localities Surveyed
Small stream, Dehradun-Mussoorie road (head-water of the tributary of Tons nadi – tributary of Asan River).

Diagnostic Characters
D. 3/7–8, P. 1/8–10, V. 1/7, A. 3/5, C. 17–18 (8–9/9).

Body slightly compressed, head narrow, barbels longer than the eye which is slightly in the anterior half of the head, dorsal origin variable, 2nd branched ray of paired fins longest (not produced) while two outer ones thickened, 1st branched ray of anal longest (not produced), anterior part of dorsal and anal base sometimes swollen, caudal deeply emarginated, lateral line complete, major part of the predorsal area naked. Body pale, colour highly variable with 3–13 (normally 10–12) bars on the lateral side which on caudal peduncle may encircle it, an oblique dark band across the middle of the dorsal fin with tips and base of the anterior few rays sometimes blackish, paired fins blackish on the upper side, caudal fin marked with 'W-shaped' diffused bands.

Sexual Dimorphism: In male, the preorbital is produced into a movable posteriorly directed obtuse projection, upper surface of pectoral fin finely tuberculated, urinogenital papilla prominent. Female lacks these characters.

Maximum Size
9.2 cm.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts.

India
Assam (Kaziranga), Himachal Pradesh (Kangra, Shimla).

Elsewhere
No record.

Habitat and Ecology
Inhabits small hill streams with gravelly bottom. Feeds on microorganisms, small insects and their larvae and algal matter. Breeds during monsoon months.

Conservation Status
IUCN Red List, not evaluated.

Remarks
Record of this species from the main Asan River (Uniyal 2010; Uniyal and Kumar 2006; Uniyal and Mehta 2007) is doubtful as being a fish of torrents.

34. *Schistura rupecula* McClelland, 1838

Schistura rupecula McClelland, 1838. *J. Asiat. Soc. Beng*., 7: 948, pl. 55, fig. 3 (type locality: mountain streams at Simla).

English Name
Stonefish.

Local Name
Gadera.

Localities Surveyed
Naro nadi, Bhurgaon near Bansiwala; Tons nadi, Bijapur; Nun nadi, Jaintanwala; Nalota nala at Chandrauti near Robber's cave; Kiarkuli nadi and Bhitarli nadi at village Khera near Jaspur; Birhani nadi near Panditwari (headwaters of Asan).

Diagnostic Characters
D. 2–3/7–8. P. 1/10, V. 1/7, A. 3/5, C. 18(9/9).

Body elongated, stoutly built, predorsal profile slightly arched, ventral in front of the anal fin flattened; head broad, depressed; barbels longer than the eye; nasal flap may reach the eye; upper jaw produced into a beak-like process, lower with a slight concavity; dorsal origin variable, 2nd branched ray longest; base of the anterior few rays of dorsal and anal swollen; paired fins broad and horizontal with outer 3–4 rays thickened and padded, 3rd outer branched ray of pectoral and 2nd outer branched ray of pelvic longest (not produced), 2nd branched ray of anal longest, upper and lower edges of the caudal peduncle keeled, caudal fin emarginated; posterior half of the body scaled and a few scales in front of the dorsal fin, lateral line complete. Body pale with 10–13 dark brown vertical bars, broader than pale interspaces; dorsal fin marked with 2–3 oblique rows of dark dots, caudal fin with two dusky 'V-shaped' vertical bands.

Sexual Dimorphism: In adult males, upper surface of pectoral fin finely tuberculated, urinogenital papilla narrow. In female, pectorals smooth and papilla thickened.

Maximum Size
6.7 cm (standard length), 10.2 cm (Hora 1935).

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Corbett Tiger Reserve and Rajaji National Park.

India
Bihar, Himachal Pradesh (Satluj and Beas drainages; Shimla), Jammu and Kashmir (Poonch Valley), Nagaland (Naga hills) and West Bengal (Adma and Jayanti rivers).

Elsewhere
Nepal.

Habitat and Ecology
Inhabits shallow-water riffles, spring pools and small hill streams with pebbly bottom.

Conservation Status
IUCN Red List, least concern.

Remarks
Of no fishery interest. Record of this species from the main Asan River (Uniyal 2010; Uniyal and Kumar, 2006; Uniyal and Mehta 2007) is doubtful as being a fish of torrents.
Order: Perciformes
Family: Badidae
Genus: *Badis* Bleeker, 1853

35. *Badis badis* (Hamilton, 1822)

Labrus badis Hamilton, 1822. *Fish. Ganges*: 70–72, 368 (type locality: ponds and ditches throughout the Gangetic provinces).

Badis badis Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Badis, Dwarf Chameleon Fish.

Local Name
Chiri.

Localities Surveyed
Small stream near Asan Barrage at Dhalipur; Asan River above Kunja Grant, below barrage, at Herbertpur, Sabhawala, Selakui and Jhajra villages; seepage nala below barrage; Asan reservoir.

Small stream at Karwapani, Asarori forest.

Diagnostic Characters
D. 15–18/7–10, P. 0/12, V. 1/5, A. 3/6–8, C., L.l. 25–30.

Body ovate, compressed; dorsal spines slender; anal spines short; caudal fin rounded; scales ctenoid; lateral line interrupted, sometimes absent. Body reddish brown with a series of alternate obliquely vertical black and greenish or dirty red bands and blackish spots, opercles also with such spots; a conspicuous bluish-black spot (covering superficial part of cleithrum above the pectoral fin base) behind the gill opening; fins yellowish green or bluish, dorsal base and fin with a series of prominent dark spots/blotches, caudal peduncle without a dark blotch, body with indistinct bars on sides.

Maximum Size
8.9 cm (Day, 1875), commonly much less.

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar and Pauri districts; Kumaon Division: Nainital district. Rajaji National Park.

India
Throughout. Mahanadi river drainage; Yamuna, Ganges and Brahmaputra river systems. Assam (Brahmaputra, Guwahati, Kaziranga and Dibru river), Himachal Pradesh and Western Ghats.

Elsewhere
Bangladesh, Bhutan, Nepal and Pakistan.

Myanmar (misidentification) and Thailand (doubtful).

Habitat and Ecology
Occurs solitarily in rivers, ponds, swamps and ditches. Feeds on worms, crustaceans and insects.

Conservation Status
IUCN Red List, least concern.

Remarks
Of no fishery interest; aquarium. It is used for aquarium purposes.
Family: Channidae
Genus: *Channa* Scopoli, 1777

36. *Channa gachua* (Hamilton, 1822)

Ophicephalus gachua Hamilton, 1822. *Fish. Ganges*: 68, 367, pl. 21, fig. 21. (type locality: ponds and ditches of Bengal).

Ophiocephalus gachua Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Asiatic Snakehead, Dwarf Snakehead.

Local Names
Dawla, Dorrah

Localities Surveyed
Asan River above Kunja Grant, below barrage, at Dhalipur; Herbertpur, Sabhawala, Sahaspur, Jhajra; stream near Asan Barrage at Dhalipur; seepage nala below barrage; Asan reservoir.

Swarna nadi, Bhauwala; stream at culvert No. 28/2, Ridapur near Sahaspur; Naugaon nala at village Naugaon near Bhauwala; pond on Langha road; Naro nadi at Bhurgaon near Bansiwala via Jhajra; Kalughat khala near village Doonga; Nimi nadi, Paundha; Nun nadi, Jaintanwala; Tons nadi, Robber's cave; Birhani nadi near Panditwari. Small stream at Karwapani, Asarori forest.

Diagnostic Characters
D. 0/ 34–36, P. 0/15–17, V. 1/5, A. 0/21–22, C. 13–14, L.l. 40–50.

Body small; rosette of cephalic shields circular, postorbital touching basal, consisting of a median shield surrounded by six marginals, frontal shield touching single inter-nasal anteriorly and the rosette posteriorly; dorsal fin long, low, inserted slightly ahead of the pelvics; pectoral fins fan-like, extending to anal fin; pelvic fins short; anal fin also long, low, inserted under about the 13th dorsal ray; caudal fan-like; lateral line, curving down after about the 12–14th scale. Body above and on lateral greenish grey, ventral side pale with a blush of pink; a row each of dark bands above and below the lateral line; dorsal, anal and caudal fins dark, edged with orange; pectoral fin with 5–7 dark-grey vertical bands.

Maximum Length
20.0 cm (standard length).

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora, Nainital, Pithoragarh and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Throughout. Andaman and Nicobar Islands and Maharashtra.

Elsewhere
Afghanistan, Bangladesh, Bhutan, Cambodia, China, Indonesia, Iran, Laos, Malaysia, Myanmar, Pakistan, Singapore, Sri Lanka, Thailand and Vietnam.

Nepal and Taiwan (doubtful).

Habitat and Ecology
Found in hill streams, adults inhabit medium to large rivers, rapid-running mountain streams and stagnant water bodies including sluggish-flowing canals. Feed at night on small fish, insects and crustaceans. Exhibit parental care, with the male breeding eggs and fry in his mouth.

Conservation Status
IUCN Red List, least concern.

Remarks
Kept in aquaria. Of no fishery interest.

37. *Channa punctata* (Bloch, 1793)

Ophiocephalus punctatus Bloch, 1793. *Naturges, Ausland*, *Fische*, **8**: 139, pl. 358 (type locality: rivers and lakes of Coromandel coast).

Ophiocephalus punctatus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan River below its barrage).

English Name
Spotted Snakehead.

Local Names
Sauli, Sewal.

Localities Surveyed
Asan River below barrage, at Dhalipur; Herbertpur, villages Partitpur and Bairagiwala near Herbertpur; small stream near Asan Barrage, Dhalipur.

Ponds at Jassowala near Sahaspur and Selakui.

Diagnostic Characters
D. 0/29–30, P. 0/16–17, V. 1/5, A. 0/20–21, C. 12, L.l. 36–39.

Body cylindrical; rosette of cephalic shields elliptical and inter-orbital with two transverse rows of shields between it and basal shield, frontal shield separated from single inter-nasal, lie in the centre; dorsal fin long, low, origin in relation to the pelvics variable; pectorals ovate; pelvic fins shorter with obliquely convex margin; anal fin also long, low, inserted under about the 9th or 10th dorsal ray; caudal fin almost rounded; lateral line, curving down after about the 13–16th scale. Body olive green above, becoming yellowish on sides and paler below, about 7–8 dark, almost triangular bands on upper half and about 9–11 same-type bands below on the lateral sides of the body; three dark stripes behind the eye; a black spot behind the operculum; ventral side marked with blackish dots; dorsal, anal and caudal fins darker, edged with white; paired fins pale.

Sexual Dimorphism: In male, urinogenital opening elongated, ventral side of the body profusely dotted with black and abdomen not distended, whereas in female, the urinogenital opening circular and suffused with blood, ventral side of the body marked with diffused black blotches and abdomen distended during breeding season.

Maximum Length
31.0 cm, commonly 15.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar and Pauri districts. Kumaon Division: Nainital district. Rajaji National Park.

India
Throughout plains, Terai and Duars, up to an altitude of 600 m. Kerala (Wayanad), Maharashtra, Odisha (Chilka Lake), Tamil Nadu (Bhavani river) and West Bengal.

Elsewhere
Afghanistan, Bangladesh, China (Yunnan), Myanmar, Nepal, Pakistan and Sri Lanka. Malaysia and Thailand (doubtful).

Habitat and Ecology
Found in ponds, swamps, brackish water, ditches and lakes. Adults prefer stagnant waters in muddy streams. Feed on worms, insects and small fish. Breed throughout the year.

Conservation Status
IUCN Red List, least concern.

Remarks
Of minor fishery interest. Commonly used as food by the locals. Kept in aquaria and occasionally used as bait (used as live bait for angling larger snakeheads; accepts chopped fish and shrimp in the aquarium).

Order: Siluriformes
Family: Amblycipitidae
Genus: *Amblyceps* Blyth, 1858

38. *Amblyceps mangois* (Hamilton, 1822)

Pimelodus mangois Hamilton, 1822. *Fish. Ganges*: 199–201, 379 (type locality: tanks of northern Bihar).

Amblyceps mangois, Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala, Asan River above Kunja Grant and below its barrage).

English Name
Torrent Catfish.

Local Names
Billi, Chhoti-singhi, Sudaal.

Localities Surveyed
Asan River above Kunja Grant, below barrage at Dhalipur; Herbertpur, Sabhawala, village Bhurpur near Jhajra and Selakui; seepage nala below barrage; Asan reservoir.

Diagnostic Characters
D. 1/6, P. 1/5–7, V. 1/5–6, A. 5/8–11, C. 17.

Dorsal fin far forward being inserted above the middle or first quarter of the pectoral fin and with weak spine and concealed; pectoral fin with a short, concealed, smooth and pointed spine; anal fin large, fan-like; dorsal, paired and fins are enveloped in thick skin with their bases swollen; caudal fin deeply forked, with longer upper lobe; lateral line absent. Body olive brown.

Maximum Length
12.5 cm (standard length).

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar, Pauri and Tehri districts; Kumaon Division: Almora and Nainital districts. Corbett Tiger Reserve and Rajaji National Park.

India
Himalayan foothills from Kangra Valley in Himachal Pradesh, Punjab to Assam and also Krishna system (Andhra Pradesh, Karnataka and Maharashtra) and Madhya Pradesh.

Elsewhere
Bangladesh, Cambodia, Laos, Myanmar, Nepal, Pakistan and Thailand.

Habitat and Ecology
Occurs in pebbly beds in swift currents at the base of the hills. Found among rocks and boulders on the substratum of fast-flowing upland streams. Feeds on aquatic insects.

Conservation Status
IUCN Red List, least concern.

Remarks
Of no fishery/food interest.
Family: Bagridae
Genus: *Mystus* Scopoli, 1777

39. *Mystus bleekeri* (Day, 1877)

Bagrus keletius Bleeker (*nec*. Valenciennes), 1849. *Nat. Gen. Arch. Ned. Ind.*, 3(2): 135 (type locality: Bengal).

Macrones bleekeri Day, 1877. *Fish. India*: 451, pl. 101, fig. 1 (type locality: Sind, Jumna, upper waters of Ganges and Burma, Bengal).

Mystus bleekeri Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (seepage nala).

English Name
Day's Mystus.

Local Name
Kater.

Localities Surveyed
Asan River below barrage at Dhalipur, Herbertpur and Bairagiwala near Herbertpur; seepage nala below barrage.

Diagnostic Characters
D. 1/7, P. 1/8–9, V. 1/5, A. 2/7–8, C. 15–17.

Body elongate, compressed behind; head somewhat depressed, occipital process long and extend to the basal bone of dorsal fin, median longitudinal groove shallow; mouth terminal, teeth in bands on jaws, barbels four pairs, maxillary long reaching the anal fin; dorsal fin spine smooth, rarely finely serrated; adipose fin large starting from just behind rayed; caudal fin forked. Body brownish with two pale longitudinal bands on sides, often with a dark shoulder spot; fins greyish with dark edges.

Sexual Dimorphism: Male with a well-developed elongated urinogenital papilla which in female is very small.

Maximum Size
15.5 cm (20.0 cm, Soni and Srivastava 1979).

Distribution

Uttarakhand
Garhwal Division: Dehradun district; Kumaon Division: Nainital district. Rajaji National Park.

India
Generally confined to northern India. Also found in Andhra Pradesh (Godavari estuary), Chhattisgarh (Mahanadi headwaters), Karnataka (Ombatta swamp), Kerala, Maharashtra, Tamil Nadu (Moyar and Bhavani rivers) and West Bengal.

Elsewhere
Bangladesh, Bhutan, Indonesia, Myanmar, Nepal, Pakistan and Thailand.

Habitat and Ecology
Found in lakes, tanks, ponds, rivers and canals. Oviparous, distinct pairing, possibly like other members of the same family.

Conservation Status
IUCN Red List, least concern.

Remarks
Of minor fishery and aquarium interest. Generally caught with other fishes from fishing operations.

40. *Mystus vittatus* (Bloch, 1794)

Silurus vittatus Bloch, 1794. *Ichthyol. Hist. nat.*, **11**: 40, pl. 371, fig. 2 (type locality: Tranquebar, Tamil Nadu).

Mystus vittatus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (seepage nala, Asan River above Kunja Grant and below its barrage).

English Names
Asian Striped Catfish, Striped Dwarf Catfish, Tengara Mystus.

Local Names
Kattarah, Tengan, Tengra, Tengar, Tengara.

Localities Surveyed
Asan River above Kunja Grant, below its barrage at Dhalipur; Herbertpur, Bairagiwala and Partitpur villages near Herbertpur; seepage nala below barrage.

Diagnostic Characters
D. 1/7, P. 1/7–9, V. 1/5, A. 2–3/7–10, C. 15–17.

Maxillary barbels extending beyond the pelvic fins, often to the end of the anal fin; occipital process reaching the basal bone of dorsal fin; median longitudinal groove on the head may or may not be extending the base of occipital process; dorsal spine weak, finely serrated on its inner edge, also sometimes slightly serrated on its anterior upper edge; adipose fin short, inserted much behind the rayed dorsal fin but anterior to the anal fin; pectoral fin spine strong with about 16 coarse teeth. Body grey silvery, its lateral side with 4–5 pale blue or dark brown to black longitudinal bands.

Sexual Dimorphism: Male with a well-developed urinogenital papilla and a spear-shaped thickening at the base of the caudal fin. Female with normal papilla but with spheroidal swelling between the pelvic and anal fins.

Maximum Size
21.0 cm (standard length).

Distribution

Uttarakhand
Garhwal Division: Dehradun, Haridwar and Pauri districts; Kumaon Division: Nainital district. Corbett Tiger Reserve and Rajaji National Park.

India
Throughout. Assam, Bihar, Madhya Pradesh, Odisha (Chilka Lake), Punjab, Tamil Nadu, Uttar Pradesh, West Bengal and Western Ghats.

Elsewhere
Bangladesh, Bhutan, Myanmar, Nepal, Pakistan and Sri Lanka.

Cambodia, Laos, Malaysia and Vietnam (doubtful). Thailand (misidentification).

Conservation Status
IUCN Red List, least concern.

Remarks
M. tengara (Hamilton, 1822) is considered synonym of this species by various workers. It is of minor commercial value and is also kept in aquaria.
Family: Heteropneustidae
Genus: *Heteropneustes* Muller, 1840

41. *Heteropneustes fossilis* (Bloch, 1794)
Silurus fossilis Bloch, 1794. *Naturg. Ausland. Fische*, 8: 46, pl. 370, fig. 2 (type locality: Tranquebar).
Heteropneustes fossilis Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir and seepage nala).

Localities Surveyed
Asan River, Herbertpur and Bairagiwala near Herbertpur; Asan reservoir; seepage nala.

English Name
Stinging Catfish.

Local Name
Singhi.

Diagnostic Characters
D. 0/7, P. 1/7, V. 1/5, A. 2/58–61, C. 15.

Body subcylindrical anteriorly, compressed behind, head depressed, occipital process not reaching the base of dorsal fin; mouth small, terminal; barbels four pairs; dorsal fin short, slightly ahead of the pelvics; pectoral fin with a strong spine, serrated behind and with a few serrations anteriorly, shorter than the head; anal fin long, separated by a notch from the caudal fin. Body purplish brown, juveniles reddish brown.

Sexual Dimorphism: Male lean and agile with an elongated urinogenital papilla. Female little heavy but with small papilla.

Maximum Size
30 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun district; Kumaon Division: Nainital district. Rajaji National Park.

India
Throughout Indian plains and Andaman and Nicobar Islands, Kerala, Karnataka, Maharashtra, Odisha (Chilka Lake), Tamil Nadu (Ombatta stream, Mudumalai and Tharangambadi/Tranquebar) and West Bengal (Adma, Buxa and Jayanti rivers) and Western Ghats.

Elsewhere
Bangladesh, Iran, Myanmar, Nepal, Pakistan and Sri Lanka. Iraq and Turkey (introduced). Cambodia, Laos and Thailand (doubtful).

Habitat and Ecology
Found mainly in ponds, ditches, swamps and marshes but sometimes occurs in muddy rivers. Can tolerate slightly brackish water. Omnivorous. Breeds in confined waters during the monsoon months but can breed in ponds, derelict ponds and ditches when sufficient rainwater accumulates. Oviparous, distinct pairing possibly like other members of the same family.

Conservation Status
IUCN Red List, least concern.

Remarks
It is in great demand due to its medicinal value. Highly commercial in fishery, aquaculture and aquaria.
Family: Sisoridae
Subfamily: Glyptosterninae
Genus: *Glyptothorax* Blyth, 1860

42. *Glyptothorax pectinopterus* (McClelland, 1842)
Glyptosternon pectinopterus McClelland, 1860. *Calcutta J. Nat. Hist.*, 2: 587 (type locality: Simla).
Glyptothorax pectinopterus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir and Asan River above Kunja Grant).

English Name
River Cat.

Local Names
Katharua, Pathr-chat, Pathar-chatti, Patthar-chatti.

Localities Surveyed
Asan River above Kunja Grant, at Selakui and Herbertpur; Asan reservoir.

Diagnostic Characters
D. 1/6, P. 1/8, V. 1/5, A. 4/7, C. 17.

Head greatly depressed; occipital process opposed to basal bone of the dorsal fin; mouth inferior; lips papillated; barbels four pairs; adhesive thoracic apparatus well developed, as long as broad and without central pit; dorsal fin origin nearer adipose fin than snout tip and its spine weak and smooth; paired fins plaited below; caudal fin forked; skin granulated. Body dark brown, dorsal and caudal fins greyish with tips yellowish.

Sexual Dimorphism: In male, the urinogenital papilla is elongated, wide and bulbous at base and much narrow at its tip while it is smaller, narrow at base and bulbous at the tip in female.

Maximum Size
17.8 cm (standard length).

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital and Pithoragarh districts. Rajaji National Park.

India
Himachal Pradesh (Kangra Valley; Shimla hills) and Punjab.

Elsewhere
Nepal (Pokhara lake; Baghmati, Madi and Seti rivers) and Pakistan.

Reports from Myanmar not considered valid.

Habitat and Ecology
Small benthic species, inhabiting pools and run areas of streams/mountain rapids.

Conservation Status
IUCN Red List, least concern.

Remarks
Used as ornamental fish by Buddhists. Of no fishery interest, consumed locally.
Order: Synbranchiformes
Family: Mastacembelidae
Genus: *Macrognathus* Lacepede, 1800

43. *Macrognathus pancalus* (Hamilton, 1822)

Macrognathus pancalus Hamilton, 1822. *Fish. Ganges*: 30, 364, pl. 17, fig. 7 (type locality: tanks, place not mentioned).

Macrognathus pancalus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, seepage nala and Asan River below its barrage).

English Names
Barred Spiny Eel, Spiny Eel, Striped Spiny Eel.

Local Name
Baam.

Localities Surveyed
Asan River at Jhajra, Sahaspur, Herbertpur, below barrage, Dhalipur and near Kulhal; seepage nala below barrage; Asan reservoir.

Diagnostic Characters
D. 23–26/30–42, P. 0/17–19, A. 3/31–46, C. 10–12.

Body eel-like; snout produced into a fleshy appendage; preopercle with 2–5 spines; preorbital spine strong, piercing the skin; dorsal fin long, inserted above the middle of the pectoral fin, with free stumpy spines; ventral fins absent; anal fin also long, with three spines; caudal fin slightly convex with rounded corners; body and preoperculum with minute scales, vertex naked; lateral line complete, arched anteriorly. Body olive green above, yellowish below, with several pale spots.

Sexual Dimorphism: Female larger and stouter with prominent urinogenital papilla and dull in colouration, while male smaller and lean with feebly developed papilla and bright in colour.

Maximum Size
18.0 cm.

Distribution

Uttarakhand
Garhwal Division: Dehradun and Haridwar districts; Kumaon Division: Nainital district.

India
Throughout. Peninsular India, Odisha (Chilka Lake), Maharashtra, West Bengal and Western Ghats.

Elsewhere
Bangladesh, Nepal and Pakistan.

Habitat and Ecology
Inhabits slow and shallow waters of rivers of plains and estuaries; never available above an altitude of 366 m. Also found in canals, streams, lakes, ponds and inundated fields. It stays on bottom and spawns in the upper water level. The more slender and generally smaller males pursue the female in courtship; several males may join in.

Conservation Status
IUCN Red List, least concern.

Remarks
Of minor fishery value, also kept in aquaria by hobbyists.
Genus: *Mastacembelus* Scopoli, 1777

44. *Mastacembelus armatus* (Lacepede, 1800)

Macrognathus armatus Lacepede, 1800. *Hist. Nat. Poiss*., 2: 286 (type locality: not known).

Mastacembelus armatus Husain, 2003. *Faun. Asan Wetland, Wetland Ecosystem Series 5*: 23–26 (Asan reservoir, Asan River above Kunja Grant and below its barrage).

English Names
Tire-Track Spiny Eel, Zigzag Eel.

Local Names
Bam, Baam, Guj.

Localities Surveyed
Asan River above Kunja Grant, below barrage, at Bairagiwala and near Herbertpur; small stream near Asan Barrage, Dhalipur; Asan reservoir.

Tons nadi, Premnagar; Nimi nadi, Paundha.

Diagnostic Characters
D. 33–40/67–82, P. 0/24, A, 3/67–83, C. 17.

Body eel-like, preopercle with 2–3 spines, preorbital spine strong, mouth small with sharp teeth on both jaws, spinous dorsal fin origin above the pectoral fin, dorsal and anal fins continuous with caudal fin; body greenish brown with zigzag markings, a row of black spots along the base of the soft dorsal fin, dorsal and anal fins banded or spotted, pectoral fin spotted.

Maximum Size
90.0 cm; weight 500 g.

Distribution

Uttarakhand
Garhwal Division: Chamoli, Dehradun, Haridwar, Pauri, Tehri and Uttarkashi districts; Kumaon Division: Almora, Nainital, Pithoragarh and Udham Singh Nagar districts. Corbett Tiger Reserve and Rajaji National Park.

India
Jammu and Kashmir (Tawi river and its tributaries), Kerala (Arikayam puzha, Karimpuzha, Kabani and Kallar rivers), Maharashtra (Vashishti river and Dhom reservoir), Odisha (Chilka Lake), Tamil Nadu (Moyar, Chammanaar, Tamiraparani and Bhavani rivers) and West Bengal (Adma, Buxa and Jayanti rivers).

Elsewhere
Bangladesh, Bhutan, Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam.

Habitat and Ecology

Inhabits in highland streams to lowland wetlands, usually in streams and rivers with sand, pebble or boulder substrate, seldom leaving bottom except when disturbed. Also occurs in still waters, marshes and dry zone tanks, sometimes stays partially buried in fine substrate. Feeds at night on benthic insect larvae, worms and some submerged plant material.

Conservation Status

IUCN Red List, least concern.

Remarks

Economically important species, both for food and aquarium trade. Marketed fresh and frequently seen in the aquarium trade. A popular food fish especially when freshly caught in West Bengal.

Doubtful Records of Species from Asan River/Dehradun

1. *Botia dario* (Hamilton, 1822): from Dehradun (Badola 2009) and as *Botia geto* from tributaries of Asan (Singh 1964) – needs confirmation for identity.
2. *Puntius phutunio* (Hamilton, 1822): from Dehradun (Badola 2009) – needs confirmation for identity as also doubted by Singh 1964.
3. *Schizothorax progastus* (McClelland, 1839): Asan and its tributaries (Singh 1964).
4. *Amblypharyngodon mola* (Hamilton, 1822): from Asan River and its tributaries (Singh,1964).
5. *Barilius barila* (Hamilton, 1822): from Dehradun (Badola 2009), Asan River, village Jhiva Redi and other localities (Uniyal 2010) – needs confirmation for identity.
6. *Devario aequipinnatus* (McClelland, 1839): as *Danio aequipinnatus* from Dehradun (Badola 2009).
7. *Labeo boga* (Hamilton, 1822): from Dehradun (Badola 2009).
8. *Labeo calbasu* (Hamilton, 1822): Asan and Yamuna in the west Doon (Singh 1964).
9. *Labeo pangusia* (Hamilton, 1822): Asan River, Herbertpur (Singh 1964).
10. *Catla catla* (Hamilton, 1822): from Asan River, Jhajra (Uniya 2010).
11. *Schistura savona* (Hamilton, 1822): as *Nemacheilus savona* from Timli Forest (Uniyal and Mehta 2007; Uniyal 2010) – needs confirmation for identity.
12. *Gambusia holbrooki* (Girard, 1859): as *Gambusia affinis holbrooki* from Asan River, Kunja Grant (Uniyal 2010) – exotic species.
13. *Sicamugil cascasia* (Hamilton, 1822): from Timli Forest (Uniyal 2010).
14. *Channa marulius* (Hamilton, 1822): from Asan River at Badowala and Sabhawala, stream near Timli Forest and Karwapani nala.
15. *Channa striatus* (Bloch, 1793): as *Channa striatus* from Asan River, Sabhawala; stream near Timli Forest and Karwapani nala.
16. *Nandus nandus* (Hamilton, 1822): from the confluence of Asan and Yamuna rivers (Uniyal and Kumar 2006), Karwapani nala, Asarori and Timli Forest (Uniyal 2010).
17. *Osphronenus goramy* (Lacepede, 1801): from a stream near Bhatta fall, Mussoorie road (Uniyal 2010) – exotic species.
18. *Trichogaster fasciata* (Bloch & Schneider, 1801): as *Colisa fasciatus* from the foothills of Dehradun (Badola 2009), confluence of Asan and Yamuna rivers (Uniyal 2010; Uniyal and Kumar 2006).
19. *Mystus cavasius* (Hamilton, 1822): from Mothrowala near Herbertpur (Singh 1954).
20. *Mystus gulio* (Hamilton, 1822): from Asan River, Herbertpur (Singh 1964) – primarily a brackish water species.
21. *Rita rita* (Hamilton, 1822): from Dehradun (Badola 2009).
22. *Sperata seenghala* (Sykes, 1839): as *Mystus seenghala* from west Dehradun (Singh and Gupta 1979).
23. *Clupisoma garua* (Hamilton, 1822): from Dehradun (Badola 2009).
24. *Ompok pabda* (Hamilton, 1822): from the confluence of Asan and Yamuna rivers (Uniyal and Kumar 2006).

25. *Wallago attu* (Bloch & Schneider, 1801): from Asan River, Jhajra (Uniyal and Kumar 2006).
26. *Glyptothorax dakpathari* Tilak & Husain, 1976: from Asan River, Kunja Grant (Uniyal 2010) – needs confirmation for identity.

Conclusion

1. *Fauna*: 44 species belonging to 29 genera, 11 families and 5 orders from Asan River and its tributaries; *Aspidoparia jaya* (Hamilton, 1822) is recorded for the first time from the river. Of these, *Schistura montana* and *S. rupecula*, being species of torrents, are not found in the main Asan River but in tributaries joining from the Himalayan side. *Puntius chelynoides*, *Bangana dero*, *Labeo dyocheilus*, *Tor* spp., *Schizothorax richardsonii*, *Amblyceps mangois* and *Glyptothorax pectinopterus*, also species of torrents, have probably been washed down from tributaries/ ascended from Yamuna into Asan during the rainy season.
2. *IUCN Red List Conservation Status*: *Tor putitora* 'Endangered', *Puntius chelynoides* and *Schizothorax richardsonii* 'Vulnerable', *Tor tor* 'Near Threatened' and 36 species 'Least Concern' category. *Lepidocephalichthys caudofurcatus, Puntius carletoni, Schistura doonensis and S. montana* are not evaluated for their status.
3. *Doubtful Records*: Records of *Botia dario*, *Puntius phutunio*, *Schizothorax progastus*, *Amblypharyngodon mola*, *Barilius barila*, *Devario aequipinnatus*, *Labeo boga*, *L. calbasu*, *L. pangusia, Catla catla*, *Schistura savona*, *Gambusia holbrooki*, *Sicamugil cascasia*, *Channa marulius*, *C. striata*, *Nandus nandus*, *Osphronemus goramy*, *Trichogaster fasciata*, *Mystus cavasius*, *M. gulio*, *Rita rita*, *Sperata seenghala*, *Clupisoma garua*, *Ompok pabda*, *Wallago attu* and *Glyptothorax dakpathari* by some workers (*op. cit.*) in the river/ area are doubtful.
4. *Commercial Importance*: *Puntius chelynoides*, *Bangana dero*, *Labeo dyocheilus*, *Raiamas bola*, *Chagunius chagunio*, *Tor putitora*, *T. tor*, *Schizothorax richardsonii*, *Channa punctata* and *Mastacembelus armatus* are commercially important food fishes, some of offer good game. *Puntius* spp., *Aspidoparia jaya*, *Cabdio morar*, *Danio rerio*, *Devario devario*, *Esomus danricus*, *Rasbora daniconius*, *Lepidocephalichthys guntea* and *Acanthocobitis botia*, *Badis badis*, *Channa* spp., *Mystus* spp., *Macrognathus pancalus* and *Mastacembelus armatus* are generally popular among aquarists. Rest of the species are of not much value except as food by local people. To some extent, *Puntius sarana sarana* is also popular among anglers.
5. *Larcicidal Species*: Species like *Esomus danricus* and *Rasbora daniconius* are considered useful in mosquito eradication.

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References

Badola SP (2009) Ichthyofauna of the Central Himalaya. TransMedia Publication, Srinagar (Garhwal), p 206

Banarescu P, Nalbant TT (1995) A generical classification of Nemacheilinae with description of two new genera (Teleostei: Cypriniformes: Cobitidae). Travaux du Museum d'Histoire Naturelle "Grigore Antipa" 35:429–495

Das SM (1960) The remarks of the Doon Valley. Uttara Bharti:11–17

Day F (1875) The fishes of India, being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. Bernard Quaritch, London, pp 553–778 (vide Menon and Rao, 1974)

Day F (1878) The fishes of India, being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. Bernard Quaritch, London, pp 553–778

Desai VR (2003) Synopsis of biological data on the tor mahseer *Tor tor* (Hamilton, 1822). FAO Fish. Synopsis no. 158:36 p

Fowler HW (1924) Notes and description of Indian freshwater fishes. Proc Acad Nat Sci Phila 76:67–101

Grover SP (1970) On a collection of fishes of Song river in Doon Valley, Uttar Pradesh. G Vishwa J Sci Res 2:115–118

Grover SP, Agarwal BS, Rauthan JVS (1994) Ichthyofauna of Doon Valley. J Environ Zool 38(2):133–136

Hora SL (1935) Notes on fishes in the Indian Museum XXIV. Loaches of the genus *Nemacheilus* from Eastern Himalayas, with the description of a new species from Burma and Siam. Rec Ind Mus 37(1):49–67

Hora SL, Mukerji DD (1936) Fish of Eastern Doon, United Provinces. Rec Ind Mus 38(2):133–146

Husain A (1975) Fauna of Rajaji Sanctuary (District Saharanpur), Uttar Pradesh 2. Fish. Cheetal 16(4):55–57

Husain A (1976) Fish fauna of Corbett National Park, Uttar Pradesh. Cheetal 17(2):39–42

Husain A (1979) Fish fauna of Corbett National Park. 5. Fish. Cheetal 21(1):31–32 (contd. 21(2–3: 43, 1979–80)

Husain A (1980) Fauna of Corbett National Park. 5. Fish. Cheetal, 21(2–3):43

Husain A (1995) Pisces. In: Fauna of Western Himalaya (U. P.), Himalayan ecosystem series, Part I: 117–150, figs. 1–63. Zoological Survey of India Publication

Husain A (2003) Pisces. In: Fauna of Asan Wetland, Wetland ecosystem series 5:23–26. Survey of India Publication

Husain A (2010a) A description of a new Baril Carp, Barilius lanceolatus (Cypriniformes, Cyprinidae, Danioninae) from Dehra Dun, Uttarakhand, India. J Res Dev 10:3–8

Husain A (2010b) A comparative study on fish fauna of Thar Desert and Western Himalaya with conservation status of species. In: Proceedings of national seminar on impact of climate changes on biodiversity and challenges in Thar Desert, pp 96–117

Husain A (2012) Description of a new species of fish, *Barilius pectoralis* (Cypriniformes: Cyprinidae: Danininae) from Uttarakhand. J New Biol Rep 1(1):21–24. ISSN 2319-1104

Husain A, Tilak R (1995) Fishes (Pisces). In: Fauna of Rajaji National Park. Fauna of conservation area 5:115–193, figs. 1–49. Zoological Survey of India Publication

Jayaram KC (1999) The Freshwater Fishes of Indian Region. Narender Publication House, Delhi, pp 1–551

Khanna DR, Badola SP (1992) Fish fauna of the river Ganga at Hardwar. In: Gautam A (ed) Aquatic environment. Ashish Publishing House, New Delhi, pp 90–94

Kottelat M (2012) Conspectus cobitidum: an inventory of the loaches of the world (Teleostei: Cypriniformes: Cobitoidei). Raffles Bull Zool Supplement no. 26:1–199

Kullander SO, Fang F, Delling F, Ahlander E (1999) The fishes of the Kashmir Valley. River Jhelum, Kashmir Valley. In: Impacts on the aquatic environment. Swedmar, Goteborg

Kumar P, Husain A (2014) Pisces. In: Fauna of Jhilmil Jheel conservation reserve, Conservation area series 50. Zoological Survey of India, Kolkata, pp 93–125

Lal MB, Chatterjee P (1963) Survey of Eastern Doon fishes with certain notes on their habitat & ecology. J Zool Soc India 14(2):230–243

Menon AGK (1999) Checklist Freshwater Fishes of India. Rec Zool Surv India Occas Pap no. 175:1–366

Singh PP (1964) Fishes of the doon valley. Ichthyologica 3(1–2):86–92

Singh KN, Gupta PN (1979) Working plan for the West Dehra Dun Forest Division, Uttar Pradesh (1979–1980 to 1988–1989) 1:64, Nainital

Soni DD, Srivastava BK (1979) Ecological study on predatory fishes of Sagar lake. Geobios 6(6):269–271

Talwar PK, Jhingran AG (1991) Inland fishes of India and adjacent countries 1:541 p (:159). Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi/Bombay/Calcutta

Thomas HS (1897) The rod in India. London, 435 pp

Tilak R, Husain A (1973) Notes on fishes of Doon Valley, Uttar Pradesh. 1. Distributional and morphological studies on some glyptothoracid fishes (Sisoridae). Rec Zool Surv India 67(1–4):391–399

Tilak R, Husain A (1976) Description o a new species of the genus *Glyptothorax* Blyth from river Yamuna, India (Pisces, Siluriformes, Sisoridae). Ann Zool Warszwa 33(14):229–234

Tilak R, Husain A (1977a) Description of a new species of the genus *Noemacheilus* from District Dehra Dun (U.P.). Sci Cult 43(3):133–135

Tilak R, Husain A (1977b) On the systematic status and distribution of *Lepidocephalus annandalei* Chaudhuri in Uttar Pradesh. Newsl Zool Surv India 3(6):408–410

Tilak R, Husain A (1978a) Redescription of *Glyptothorax saisii* (Jenkins) (Sisoridae: Siluriformes) with remarks on its discontinuous distribution. Ann Zool 14(1):33–40, figs. 18–22

Tilak R, Husain A (1978b). Description of a new species of the genus *Lepidocephalus* Bleeker from Uttar Pradesh (Cobitidae: Cypriniformes). Matsya 3:60–63, figs. 1–3

Tilak R, Husain A (1981) On the systematics of the Indian fishes of the genus *Lepidocephalus* Bleeker with keys to the species of the genus and genera of the subfamilies Botiinae and Cobitinae (Cobitidae: Cypriniformes). Records of Zoological Survey of India, Occasional Paper No. 32, pp 1–42

Tilak R, Husain A (1990) Description of a new cyprinid, *Barilius dimorphicus* (Subfamily: Rasborinae) from Rajaji National Park, Uttar Pradesh. J Bombay Nat Hist Soc 87(1):102–105

Uniyal DP (2010) Fauna of Uttarakhand, state fauna series 18(Part-1):533–621. ZSI Publication

Uniyal DP, Kumar A (2006) Fish diversity in the selected streams of Chakrata and Shiwalik hills (District Dehradun), India. Rec Zool Surv India Occas Pap no. 253:1–120

Uniyal DP, Mehta HS (2007) Fishes (Pisces). In: Faunal diversity of Western Doon Shiwaliks. Zoological Survey of India Publication, Kolkata, pp 41–59

Fish Diversity of Chambal River, Rajasthan State

15

Harinder Singh Banyal and Sanjeev Kumar

Abstract

The Chambal is the only perennial river which flows through Rajasthan. The Chambal River rises in the hills of Vindhya Range at Madhya Pradesh and flows downstream in south to north through Rajasthan. It enters ahead of Gandhi Sagar Dam in Chittorgarh District of Rajasthan and then forms the boundary between Rajasthan and Madhya Pradesh before turning southeast to join the Yamuna River in Uttar Pradesh. The fish fauna of the Chambal River is rich and diverse. Various types of carps, catfish, and mullet reside in the river waters. Fifty-four species of fishes were reported from the Rajasthan part of the Chambal River. To conserve the critically endangered gharials and other aquatic fauna, a stretch of more than 640 km of the Chambal River in the states of Rajasthan, Madhya Pradesh, and Uttar Pradesh has been jointly declared as the National Chambal Sanctuary. Present studies deal with fish fauna from the Rajasthan part of the Chambal River and various other factors governing their diversity and distribution.

Keywords

Chambal • Distribution • Fish diversity • Rajasthan

Introduction

Fish diversity is an integral part of a riverine ecosystem. Most of the higher vertebrates residing in riverine ecosystem are dependent on fishes. Fish diversity is an indicator of the health of a river wetland and foretells its ability to sustain life in the future. Conservation of biodiversity is especially crucial in developing countries where people's livelihoods are directly dependent on natural resources such as forests and fisheries. Habitat loss is a serious threat to biodiversity, and establishment of protected areas for biota conservation is critical to ensure species survival and ecosystem balance.

Understanding of fish fauna of Rajasthan is mainly based on the work of Mathur (1952),

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Hora and Mathur (1952), Datta and Majumdar (1970), Johal (1982), Sharma and Johal (1984), Johal and Sharma (1986), Johal et al. (1993), Yazdani (1996), Mohan and Singh (2004), and Hussain (2010). Not much information regarding consolidated list of the fish fauna from Rajasthan portion of Chambal River is available. Dubey and Mehra (1962) described 71 species of fish from Madhya Pradesh portion of Chambal River.

The entire Chambal River basin extends over Madhya Pradesh, Rajasthan, and Uttar Pradesh covering around 93 tehsils and 24 districts (Hussain and Badola 2001). The Chambal River is also utilized for hydropower generation at Gandhi Sagar Dam, Rana Pratap Sagar Dam, and Jawahar Sagar Dam and for annual irrigation of 5,668.01 km^2 in the commands of the right main canal and the left main canal of the Kota Barrage. The river flows in a generally north-easterly direction for a length of 225 km through Rajasthan. The Chambal flows for another 217 km between Madhya Pradesh and Rajasthan and further 145 km between Madhya Pradesh and Uttar Pradesh. It enters Uttar Pradesh and flows for about 32 km before joining the Yamuna River in Etawah District at an elevation of 122 m, to form a part of the greater Gangetic drainage system (Jain et al. 2007). A 600 km stretch of the Chambal River between Kota Barrage and Chambal-Yamuna confluence has been protected as the tristate National Chambal Sanctuary. The National Chambal Sanctuary lies between 24° 55′ to 26° 50′ N and 75° 34′ to 79° 18′ E. It consists of the big arc described by the Chambal between Jawahar Sagar Dam in Rajasthan and the Chambal-Yamuna confluence in Uttar Pradesh. Over this arc, two stretches of the Chambal are protected as the National Chambal Sanctuary status – the upper segment, extending from Jawahar Sagar Dam to Kota Barrage, and the lower segment, expanding from Keshoraipatan in Rajasthan to the Chambal-Yamuna confluence in Uttar Pradesh. The sanctuary was formed in order to facilitate the restoration of "ecological health" of this riverine system and provide full protection for the endangered gharial (*Gavialis gangeticus*). This river harbors unique faunal diversity such as Deccan Mahseer (*Tor khudree*), giant freshwater ray (*Himantura chaophraya*), narrow-headed giant soft-shelled turtle (*Chitra indica*), three-striped roofed turtle (*Batagur dhongoka*), gharial (*Gavialis gangeticus*), mugger crocodile (*Crocodylus palustris*), Indian skimmer (*Rynchops albicollis*), black-bellied tern (*Sterna acuticauda*), sarus crane (*Grus antigone*), Gangetic dolphin (*Platanista gangetica gangetica*), and smooth-coated otter (*Lutrogale perspicillata*). Most of the aforementioned higher vertebrates are dependent on the fishes as their food; an alteration in fish community structure will have direct impact on their survival. Therefore, present studies are undertaken to explore fish diversity of Chambal River besides challenges and threats faced by fisheries in this river. This will help fishery managers and administrators to design conservation strategies in proper perspective.

Importance of the Chambal River

Chambal River extends over Madhya Pradesh, Rajasthan, and Uttar Pradesh. The Chambal River, a principal tributary of Yamuna River, originates from the Singar Chouri peak at an elevation of about 843 m in the Vindhya Range near Mhow in Indore District of Madhya Pradesh. The Chambal River basin lies between latitudes 22° 27′ N and 27° 20′ N and longitudes 73° 20′ E and 79° 15′ E. The geographic location of Chambal River being at the inter junction of the Aravalli, Vindhyan hill ranges, and Malwa Plateau makes it zoo-geographically important. In its topography, the deep and fast flowing Chambal River varies considerably. The substrate ranges from mud and silt to sand and rock. This river harbors unique faunal diversity such as Deccan Mahseer (*Tor khudree*), giant freshwater ray (*Himantura chaophraya*), narrow-headed giant soft-shelled turtle (*Chitra indica*), three-striped roofed turtle (*Batagur dhongoka*), gharial (*Gavialis gangeticus*), mugger crocodile (*Crocodylus palustris*), Indian skimmer (*Rynchops albicollis*), black-bellied tern (*Sterna acuticauda*), sarus crane (*Grus antigone*), Gangetic dolphin (*Platanista gangetica gangetica*), and smooth-coated otter (*Lutrogale perspicillata*). Most of these animals are scheduled species. A 600 km stretch of the Chambal River between Kota Barrage and Chambal-Yamuna confluence has been protected as the tristate National Chambal Sanctuary. The National Chambal Sanctuary lies between 24°55′ to 26°50′ N and 75°34′ to 79°18′ E. The sanctuary was formed in order to facilitate the restoration of "ecological health" of this riverine system and provide full protection for the endangered gharial (*Gavialis gangeticus*). Since, most of the protected higher animals are dependent on the fishes as their food. Therefore, present studies are undertaken to know details of the fish community from the Rajasthan part of the Chambal River besides challenges and threats faced by them. Fish collection was done only from the unprotected parts of the Chambal River.

Study Area

Entire area along the length of the river bed was surveyed from ahead of Gandhi Sagar Dam (from where the river enters in the territory of Rajasthan state) up to Rajghat in Dholpur District. The Chambal is a rain fed catchment and the total area drained up to its confluence with the Yamuna is 1, 43,219 km^2. The 960 km long Chambal River, a principal tributary of river Yamuna, originates from the Singar Chouri peak at an elevation of about 843 m the Vindhya Range near Mhow in Indore District of Madhya Pradesh, at an elevation of 354 m, at latitude 22° 27′ and longitude 73° 20′. The Chambal basin lies between latitudes 22° 27′ N and 27° 20′ N and longitudes 73° 20′ E and 79° 15′ E. On its south, east and west, the basin is bounded by the Vindhyan mountain ranges and on the northwest by the Aravallis. Below the confluence of the Parvathi and Banas, the catchment becomes narrower and elongated. In this reach, it is bounded by the Aravalli mountain ranges on the North and the Vindhyan hill range on the south (Jain et al. 2007). The Chambal drainage area resembles a rectangle up to the junction of the Parvathi and Banas Rivers with the Chambal flowing along its major axis. The National Chambal Gharial Sanctuary in Rajasthan extends along the Chambal River from Jawahar Sagar Dam to Kota Barrage and again, after a gap of 18 km of free zone, from Keshoraipatan to Pachnada at the confluence of Chambal and Yamuna rivers. Badland topography is a characteristic feature of the Chambal valley, whereas kankar has extensively developed in the older alluvium (Heron 1953).

The Chambal basin is characterized by an undulating floodplain, gullies, and ravines (Gopal and Srivastava 2008). The area lies within the semi-arid zone of northwestern India at the border of Madhya Pradesh, Rajasthan, and Uttar Pradesh states (Hussain 2009), and the vegetation consists of ravine, thorn forest, a subtype of the northern tropical forests (Champion and Seth 1968). Chambal River was studied at Singhadia, Rodi bandi, and Rawatbhata; all of these locations are part of Rana Pratap Sagar Dam (Chittorgarh dist.), Jawahar Sagar Dam, upstream and downstream to Kota Barrage, Keshoraipatan, Gainta, confluence point of Kalisindh and Chambal at Batawada in Etawah, at confluence points of the Parbati and Banas with Chambal near Palighat (Sawai Madhopur) Mandrel, (Karauli dist.), and downstream and upstream to Rajghat (Dholpur dist.) (Figs. 15.1, 15.2, and 15.3).

Methods

Fishes were collected mainly by using cast and gill nets. Hand net, scoop net, drag net, and baited hooks were also used. The fishes were also collected from fishermen's catch at many landing sites located in the vicinity of Chambal River. The fishes were preserved in 10 % formalin for further studies. The fishes were identified following Day (1878), Johal and Tandon (1979, 1980), Talwar and Jhingran (1991), Menon (1992), Jayaram (1999), and www.fishbase.org, version (02/2014) Editors, Froese and Pauly (2014). Fishes were collected from the unprotected portions of the river besides from the tributaries of the Chambal River.

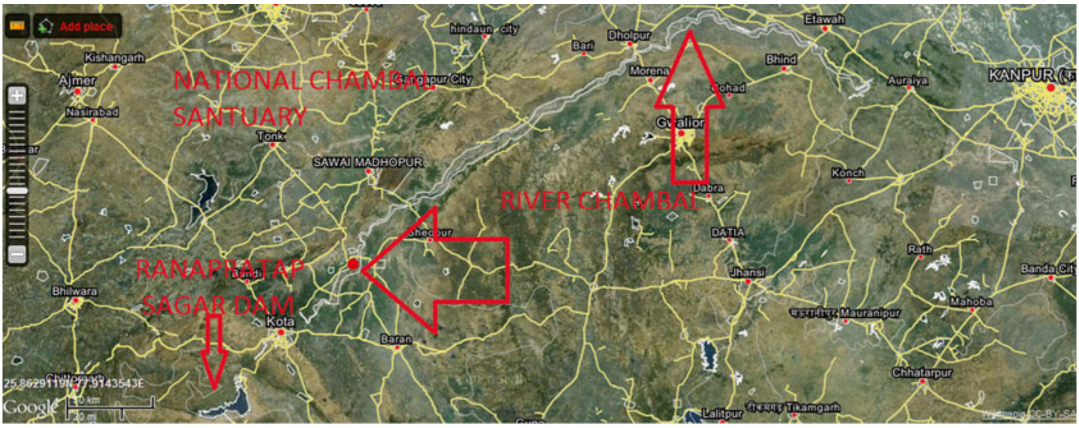

Fig. 15.1 Satellite view of Chambal River

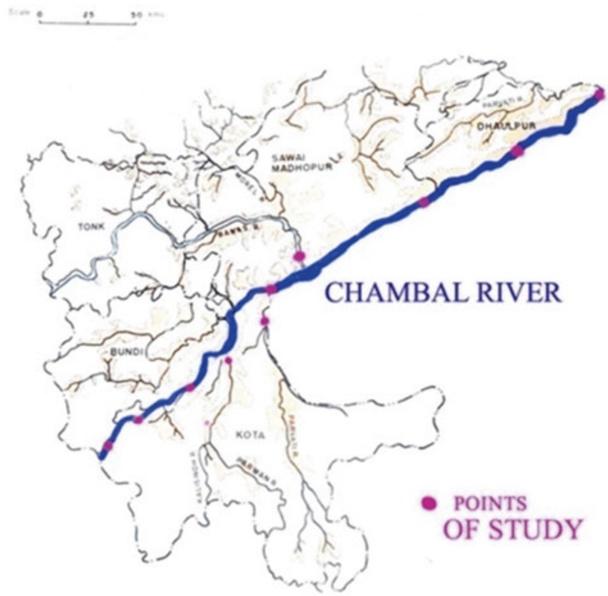

Fig. 15.2 Chambal River and its tributaries

Results and Discussion

The geographic location of Chambal River being at the inter junction of the Aravalli, Vindhyan hill ranges, and Malwa Plateau makes it zoo-geographically important, and more unique as floral and faunal elements of both ranges could occur. The climate is subtropical characterized by distinct winter, summer, and monsoon season. It has been observed that the fish fauna of the Chambal River is rich, and a variety of carps, catfishes, and mullet inhabit the river waters. The carps and the catfishes prefer the deeper waters as also the gharial and the Gangetic dolphin. Carps and catfishes were dominant in total fish

Fig. 15.3 View of Chambal River

catch followed by other types of fishes. Among cyprinids *Catla catla* (Hamilton) and *Labeo rohita* (Hamilton) were dominant in fish catch, whereas *Sperata seenghala* (Hamilton) and *Silonia silondia* (Hamilton) were dominant among catfishes. A mullet (*Rhinomugil corsula*) locally known as natera is a fish of shallow, clean water, which was common around Kota, but the pollution of the river between Kota Barrage and Keshoraipatan probably has forced its distribution downstream. This fish is observed in good numbers along the banks of the river. Hussain (1992) refers to this fish as a preferred food species of the smooth-coated otter. Though fishing is banned within the sanctuary limits, it was observed to be frequent at a number of places and was reportedly rampant outside the protected areas. Fish diversity was fair in Rana Pratap Sagar Reservoir. Fish diversity was less in downstream to Kota Barrage up to Keshoraipatan due to low level of water and pollution. The substrate of the river ranges from mud and silt to sand and rock. The Chambal River has very little amount of water in most of the parts between Kota and Palighat. The river is very deep at the confluence point of Kali Sindh at Batawada and Parbati River at Palighat. Fish diversity was fair at these points. Fifty-four species of fishes were reported from the Chambal River. Cypriniformes (27 spp.) was the dominant order of fishes followed by Siluriformes (12 spp.) and Perciformes (5 spp.). List of the fishes with classification is given below:

Class: Actinopterygii
Order: Osteoglossiformes
Family: Notopteridae
Genus: *Notopterus* Lacepede

1. *Notopterus notopterus* (Pallas, 1769)

Genus: *Chitala* Fowler

2. *Chitala chitala* (Hamilton, 1822)

Order: Cypriniformes
Family: Cyprinidae
Genus: *Barilius* Hamilton

3. *Barilius bendelisis* (Hamilton, 1807)

Genus: *Salmophasia* Swainson

4. *Salmophasia bacaila* (Hamilton, 1822)
5. *Salmophasia balookee* (Sykes, 1839)
6. *Salmophasia phulo* (Hamilton, 1822)

Genus: *Rasbora* Bleeker

7. *Rasbora daniconius* (Hamilton, 1822)

Genus: *Tor* Gray

8. *Tor khudree* (Sykes, 1839)

Genus: *Osteobrama* Heckel

9. *Osteobrama cotio cotio* (Hamilton, 1822)

Genus: *Puntius* Hamilton

10. *Puntius sophore* (Hamilton, 1822)
11. *Puntius vittatus* Day, 1865

Genus: *Pethia* Pethiyagoda et al.

12. *Pethia ticto* (Hamilton, 1822)

Genus: *Systomus* McClelland

13. *Systomus sarana* (Hamilton, 1822)

Genus: Catla Valenciennes

14. *Catla catla* (Hamilton, 1822)

Genus: *Cirrhinus* Cuvier

15. *Cirrhinus mrigala* (Hamilton, 1822)
16. *Cirrhinus reba* (Hamilton, 1822)

Genus: *Labeo* Cuvier

17. *Labeo pangusia* (Hamilton, 1822)
18. *Labeo boggut* (Sykes, 1839)
19. *Labeo calbasu* (Hamilton, 1822)
20. *Labeo dyocheilus* (McClelland, 1839)
21. *Labeo gonius* (Hamilton, 1822)
22. *Labeo rohita* (Hamilton, 1822)
23. *Labeo bata* (Hamilton, 1822)

Genus: *Bangana* Hamilton

24. *Bangana dero* (Hamilton, 1822)
25. Hybrid fish of Catla and Rohu

Genus: *Cyprinus* Linnaeus

26. *Cyprinus carpio* Linnaeus, 1758

Genus: *Hypophthalmichthys* Bleeker

27. *Hypophthalmichthys molitrix* (Val., 1844)

Genus: *Garra* Hamilton

28. *Garra gotyla gotyla* (Gray, 1830)

Genus: *Devario* Heckel

29. *Devario devario* (Hamilton, 1822)

Order: Siluriformes

Family: Bagridae

Genus: *Sperata* Holly

30. *Sperata seenghala* (Sykes, 1839)

Genus: *Mystus* Scopoli

31. *Mystus bleekeri* (Day, 1877)
32. *Mystus gulio* (Hamilton, 1822)

Family: Siluridae

Genus: *Ompok* Lacepede

33. *Ompok bimaculatus* (Bloch, 1794)
34. *Ompok pabda* (Hamilton, 1822)

Genus: *Wallago* Bleeker

35. *Wallago attu* (Bloch and Schneider, 1801)

Family: Schilbeidae

Genus: *Clupisoma* Swainson

36. *Clupisoma garua* (Hamilton, 1822)

Genus: *Eutropiichthys* Bleeker

37. *Eutropiichthys murius* (Hamilton, 1822)
38. *Eutropiichthys vacha* (Hamilton, 1822)

Genus : *Silonia* Swainson

39. *Silonia silondia* (Hamilton, 1822)

Genus : *Ailiichthys* Day

40. *Ailiichthys punctata* Day, 1872

Family: Heteropneustidae

Genus: *Heteropneustes* Muller

41. *Heteropneustes fossilis* (Bloch, 1794)

Order: Beloniformes

Family: Belonidae

Genus: *Xenentodon* Regan

42. *Xenentodon cancila* (Hamilton, 1822)

Order: Cyprinodontiformes

Family: **Poeciliidae**

Genus: *Gambusia* Poey

43. *Gambusia affinis* (Baird and Girard, 1853)

Order: Synbranchiformes

Family: Mastacembelidae

Genus: *Macrognathus* Lacepede

44. *Macrognathus pancalus* Hamilton, 1822

Genus: *Mastacembelus* Scopoli

45. *Mastacembelus armatus* (Lacepede, 1800)

Order: Perciformes

Family: Nandidae

Genus: *Nandus* Valenciennes

46. *Nandus nandus* (Hamilton, 1822)

Family: Channidae

Genus: *Channa* Scopoli

47. *Channa punctata* (Bloch, 1793)
48. *Channa striata* (Bloch, 1793)
49. *Channa marulius* (Hamilton, 1822)
50. *Channa orientalis* Bloch and Schneider, 1801

Family: Ambassidae

Genus: *Chanda* Hamilton

51. *Chanda nama* Hamilton, 1822

Family: Cichlidae

Genus: *Oreochromis* Gunther

52. *Oreochromis mossambicus* (Peters, 1852)

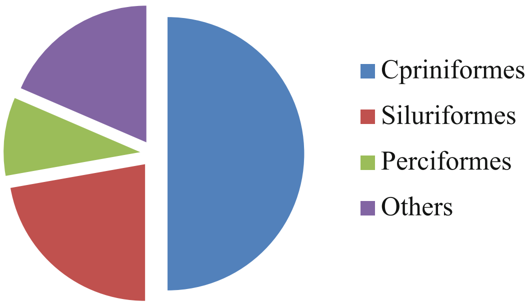

Fig. 15.4 Composition of different orders of fishes in Chambal River

Order: **Clupeiformes**
Family: Clupeidae
Genus: *Gonialosa* Regan

53. *Gonialosa manmina* (Hamilton, 1822)

Order: Mugiliformes
Family: Mugilidae
Genus: *Rhinomugil Gill*

54. *Rhinomugil corsula* (Hamilton, 1822) (Figs. 15.4 and 15.5)

Threats to the Fish Diversity and Other Fauna

Human impacts have now elevated the natural rate of species extinction by at least a thousand times (Pimm et al. 1995). Human beings presence near to the waterbodies severely affects their biota. Main threat for most of the terrestrial and freshwater species is the destruction of their habitats (Baillie et al. 2004).

Protected areas have become world's most important areas from biodiversity conservation perspective (Burner et al. 2001).

The Chambal is very important from conservation point of view due to presence of diverse biota (Hussain and Badola 2001). However, this river is affected severely from hydrological modifications due to dams and from the diversion of river water for irrigation and from anthropogenic activities like sand mining, fishing, and human presence (Hussain 2009; Nair 2010). Aforementioned findings are in conformity of the present findings as almost in entire stretch of the river, widespread anthropogenic activities were noted such as channelization and lift irrigation (at many places) of the river water for agriculture (particularly around the banks of the river), illegal fishing, mining of rocks, and sand. The presence of over 200 irrigation projects and 4 major dams on the Chambal River has severely reduced water levels, and the river does not flow below the Kota Barrage (left), for most of the year. The Chambal on average is 400 m wide, but several sections shrink to less than 20 m. This situation has increased anthropogenic threats to the river several fold, and such areas are no longer viable fish habitat. Low water flow induces habitat fragmentation and changes in the assemblage structure of river fishes. Isolated pools are also resulted due to low water flows which are vulnerable to anthropogenic activities, e.g., netting and dynamiting. Hence, it is very important to maintain minimum critical water level particularly during the breeding period of the fishes. Besides, regular monitoring and frequent ecological studies related to this reservoir is required. Dams obstruct the dispersal and migration of organisms, and these and other effects have been directly linked to loss of populations and entire species of freshwater fish (Nilsson et al. 2005). This fact is accounting for decrease in number of those fish species which migrate upstream, i.e., Deccan Mahseer (*Tor khudree*). Chambal River provides a large number of fish fingerlings and fries to other parts of the Chambal River where fishing is allowed. Besides, numerous endangered animals are also dependent on fishes as food. Therefore, it is necessary to increase security of this riverine ecosystem (Figs. 15.6, 15.7, and 15.8).

Recommendations

1. It is necessary to increase security to this riverine ecosystem in general and its biota in particular.
2. Illegal fishing must be stopped particularly during breeding period of fishes.
3. The adverse effects of dam construction on a river can be surmounted by providing timber chute and fish ladders or lifts.

Fig. 15.5 (**a** and **b**) Fishes of the Chambal River

4. All commercial activity must be immediately stopped within the periphery of the sanctuary.
5. Anthrpogenic activities around banks should be completely stopped as these activities are adversely affecting the physiochemical characteristics such as water temperature.
6. Plantation of native flora around banks will stabilize the banks.
7. Removal of bed material should be stopped.
8. Forest guards and other frontline staff should be posted in sufficient numbers at vulnerable places.

Fig. 15.6 Sand mining

Fig. 15.7 Encroachments of the banks

Fig. 15.8 Illegal use of the river water

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References

Baillie JEM, Hilton TC, Stuart SN (2004) 2004 IUCN red list of threatened species: a global species assessment. IUCN, Gland/Cambridge, Xxiv+191 pp

Burner AG, Gullison RE, Rice RE, Fonseca GAB (2001) Effectiveness of parks in protecting tropical biodiversity. Science 291:125–128

Champion HG, Seth SK (1968) A revised survey of the forest types of India. Manager of Publication, Delhi, 404 p

Datta AK, Majumdar N (1970) Fauna of Rajasthan, India, Part 7 Fishes. Rec Zool Surv India 62(1&2):36–100

Day F (1878) The fishes of India: being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. Text and Atlas (4th Indian Reprint 1994) Jagdamba Book Agency (formerly Today and tomorrows Book Agency) New Delhi, 778 pp

Dubey GP, Mehra RK (1962) Fish and fisheries of Chambal River. Proc 1st All India Congr Zool 1(2):647–665

Froese R, Pauly D (eds) (2014) Fish Base. World Wide Web electronic publication www.fishbase.org Version (02/2014).

Gopal L, Srivastava VC (2008) History of agriculture in India (up to c. 1200 A. D.). In: History of science, philosophy and culture in Indian civilization. Project of History of Indian Science, Philosophy and Culture. Centre for Studies in Civilizations, New Delhi, India, xxxiv+912 pp

Heron AM (1953) The geology of Central Rajaputana. Mem Geol Surv India 79:389

Hora SL, Mathur BBL (1952) On certain palaeographical features of Rajasthan as evidenced by distribution of fishes. Bull Nat Inst Sci India 1:32–36

Hussain SA (1992) The wild otters of the Chambal. Sanctuary Asia 12(5):25–31

Hussain SA (2009) Basking site and water depth selection by gharial *Gavialis gangeticus* Gmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation. Aquat Conserv Mar Freshw Ecosyst 19:127–133

Hussain SA (2010) A comparative study of fish fauna of Thar desert and western Himalaya with conservation status of species. In: Ramakrishna CK, Bohra P, Sharma G (eds) Proceeding of National seminar on impact of climate change on biodiversity and challenges in Thar Desert, Organized on July 9, 2010 at DRC, ZSI, Jodhpur

Hussain SA, Badola R (2001) Integrated Conservation planning for Chambal River Basin. Paper presented in the National workshop on Regional Planning for Wildlife Protected Areas held at India Habitat Centre, New Delhi, from August 6–8, 2001. Wildlife Institute of India, Dehra Dun, pp 1–20

Jain SK, Agarwal PK, Singh VP (2007) Hydrology and water resources of India, vol 57 of Water science and technology library – Tributaries of Yamuna River. Springer, 350 p

Jayaram KC (1999) The freshwater fishes of the Indian region. Narendra Publishing House, Delhi
Johal MS (1982) Field key to the fishes of Ganganagar district, Rajasthan. Res Bull Punjab Univ 33:43–49
Johal MS, Sharma KP (1986) Fish Fauna of Sawai Madhopur district, Rajasthan State, India. Vest cs Spolec Zool 50:112–119
Johal MS, Tandon KK (1979) Monograph on the fishes of reorganized Punjab. Part I. Punjab Fish Bull 3(2):1–44
Johal MS, Tandon KK (1980) Monograph on the fishes of reorganized Punjab. Part II. Punjab Fish Bull 4(1):39–112
Johal MS, Chahal IS, Tandon KK (1993) Ichthyofauna of Rajasthan State. J Bombay Nat Hist Soc 90:404–411
Mathur BBL (1952) Notes on the fishes of Rajasthan. Rec Indian Mus 50(1):105–110
Menon AGK (1992) The Fauna of India and the adjacent countries Pisces, vol IV Cobitidae. Zoological Survey of India, Calcutta
Mohan D, Singh S (2004) Impact of IGNP lift canal on fish fauna of Kailana Lake. Fish diversity in protected habitats. Nature Conservators, Publication 8, India, pp 255–257
Nair T (2010) Ecological and anthropogenic covariates influencing gharial *Gavialis gangeticus* distribution and habitat use in Chambal River, India. Unpublished master's thesis, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore
Nilsson C, Reidy CA, Dynesius M, Revenga C (2005) Fragmentation and flow regulation of the world's large river systems. Science 308:405–408
Pimm SL, Russel GJ, Gittleman JL, Brooks TM (1995) The future of biodiversity. Science 269:347–350
Sharma KP, Johal MS (1984) Fish and fisheries of Kota district, Rajasthan. Res Bull Punjab Univ 35(3&4):29–38
Talwar PK, Jhingran AG (1991) Inland fishes, vols 1 and 2. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi
Yazdani GM (1996) Fish diversity in Thar Desert. In: Ghosh AK, Baquri QH, Prakash I (eds) Faunal diversity in the Thar desert: gaps in research. Scientific Publishers, Jodhpur, pp 285–295

Length–Weight Relationship and Condition Factor in *Channa punctatus* (Bloch) from Hussainsagar Lake, Hyderabad, Andhra Pradesh, India

16

S. Anitha Kumari and N. Sree Ram Kumar

Abstract

The present study describes the length–weight relationship and condition factor in *Channa punctatus* (Bloch) from Hussainsagar lake, Hyderabad A.P. The work was carried out on 200 fishes ranging from 15 to 30 cm in length. The value of correlation coefficient was calculated to be 0.991 indicating a high degree of correlation between the length and the weight. The parabolic and regression equations were found to be $w = 0.03273\,L^{2.621}$ and log $W = -1.485 + 2.621$ log L, respectively. Deviation in the cube law was observed, and the condition factor showed continuous decrease with increase in length indicating a physiological response of the fishes to different environmental conditions of the lake waters.

Keywords

Length–weight • *Channa punctatus* • Fish • Hussainsagar lake

Introduction

The study of length–weight relationship is an important tool in fishery biology, and according to Lecren (1951), it is pursued with two objectives: firstly, to describe the mathematical model between the length and the weight so as to derive one from the other (Beverton and Holt 1957; Wooton 1990) and, secondly, to compute the departure from the expected weight for length of the individual fish or a group of fishes as an indicator of fatness or degree of well-being of fish. This relationship is called the condition factor (Wooton 1990). Further, the length–weight relationship finds significance in the assessment of the growth of fish in different environments (Mirza et al. 1988). Many reports are available on the study of length–weight relationship of fishes subjected to pollution stress. Hence, the present study was undertaken to estimate the length–weight relationship and condition factor so as to

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have the specific knowledge of the growth pattern of a freshwater teleost fish, *Channa punctatus* (Bloch), inhabiting the polluted waters of Hussainsagar lake, which is situated in between the twin cities of Hyderabad and Secunderabad in Andhra Pradesh, India.

Methods

The present study was conducted on nearly 200 specimens of *Channa punctatus* (Bloch) ranging from 15 to 30 cm in length. For convenience the fishes were divided into eight groups according to their length. The fishes were collected from five different stations of Hussainsagar lake using a cast net. The fishes were then brought to the laboratory where they were weighed after soaking water with the help of a blotting paper. Then the statistical relationship between length and weight of fishes was established using the following formula:

$$W = aL^b \quad (\text{Lecren } 1951)$$

where W = weight of the fish, L = length of the fish,

a = constant, and b = regression coefficient.

The length–weight relationship is usually expressed in its logarithmic form as

$$\text{Log}\,W = \log a + b \log L \quad (\text{Lecren } 1951).$$

The correlation coefficient (r) was calculated by using the following formula:

$$r = \frac{\sum XY}{\sqrt{\sum X^2 \cdot \sum Y^2}}$$

where X = log length and Y = log weight.

The condition factor (K) was determined by using the following formula:

$$K = \frac{W \times 100}{L^3}$$

where L = length in cm and W = weight in gm.

Results and Discussion

The parabolic and logarithmic relationship between length and weight of *Channa punctatus* from Hussainsagar lake is shown in Figs. 16.1 and 16.2. When the observed length (cm) was plotted against the observed weight (gm), an exponential curve was obtained as seen in Fig. 16.1, but when both the variables were plotted against each other in their logarithmic forms, a straight line was obtained. The value of the correlation coefficient (r) was calculated to be 0.991 indicating a high degree of correlation between the length and the weight. The regression equation derived using the recorded data is represented by log $W = -1.485 + 2.621 \log L$, and its arithmetic transformation is $W = -0.03273\, L^{2.621}$.

Since the value of regression coefficient ($b = 2.621$) is less than "3" and not equal to 3, this indicates that the fish from the Hussainsagar water body shows deviations from the cube law. Spencer (1871) and Allen (1938) have suggested that for an ideal fish following the cube law, the value of "b" remains constant at "3," but Hile (1936) and Martin (1949) advocated that the value of "b" usually ranges between 2.5 and 4.0, and in a majority of cases, "b" is not equal to 3 as the fish normally do not retain the same shape or body pattern throughout their life span (Lecren 1951; Rounsefell and Everhart 1953; Ali et al. 2000). The value of $b < 3$ represents that the fish

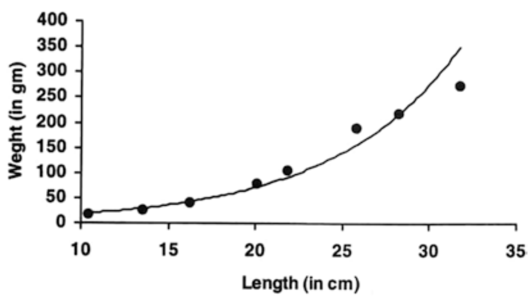

Fig. 16.1 Parabolic relationship between the length and weight of *Channa punctatus* from Hussainsagar lake

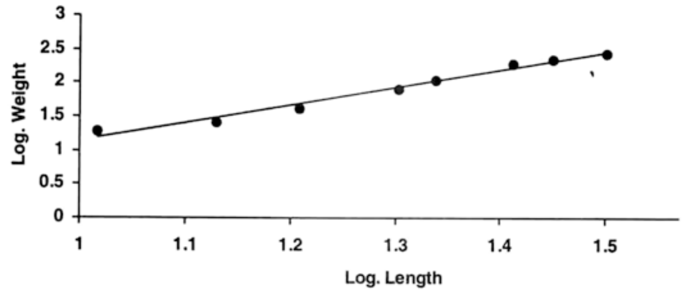

Fig. 16.2 Logarithmic relationship between the length and weight of *Channa punctatus* from Hussainsagar lake

Table 16.1 Average log length, average log weight, and condition factor for various length groups of fishes from Hussainsagar lake

Length group (cm)	Average log length (*L*)	Average log weight (*w*)	Condition factor (*K*)
15–16	1.01703	1.27438	1.67220
17–18	1.13033	1.41229	1.09834
19–20	1.2 0951	1.60831	0.95448
21–22	1.30319	1.90374	0.98662
23–24	1.33845	2.02734	1.02796
25–26	1.41161	2.27943	1.10810
27–28	1.45024	2.34076	0.97726
29–30	1.50105	2.43697	0.85860

becomes less rotund as the length increases, and the value of $b>3$ represents that the fish becomes more rotund as the length increases. In both the cases, the dimensions of the fish change with growth. Further, if "*b*" equals 3, growth may be isometric (Allen 1938) meaning that the fish grows equally in all directions in the form of cube, whereas if $b>3$ or $b<3$, growth may be allometric (Grover and Juliano 1976; Bagenal and Tesch 1978) meaning that the fish grows unequally.

Condition factor (*K*) is an indicator of the general well-being of the fish. In the present study the condition factor showed continuous declining values, i.e., from 1.67220 to 0.85860 in successive length groups as seen from Table 16.1. Similar results were drawn by MacGregor (1959) and Johal and Tandon (1983). MacGregor suggested that if the value of exponent "*b*" is less than 3, then the condition factor should decrease with increase in size/age of fish. Further low value of a condition factor is a definite sign of allometric growth (Kumar et al. 2006).

In the present investigation too, the experimental fish disobeyed the cube law showing allometric growth pattern. Several authors have assigned various factors to be responsible for influencing the value of "*b*" and condition factor (*K*) in any water body. These generally include nutritional and biological factors like intensity of feeding, state of maturity, sex, taxonomic differences, competition for food and space, etc. (Srivastava and Pandey 1981; Zafar et al. 2003). However, since the present study was carried out in a heavily polluted water body, i.e., Hussainsagar lake, the fishes inhabiting in this lake are exposed to frequent stresses caused by changes in temperature, salinity, pH water velocity, sediment loads, hypoxia, eutrophication, sewage, industrial effluents, etc. The cumulative or synergistic effect of these factors or stresses might have led to the changes in the length–weight relationship and condition factor of the fishes resulting in abnormal growth pattern. The observed changes may thus be attributed to the physiological response of the fishes to different environmental conditions of the lake waters.

References

Ali M, Salam A, Iqbal F (2000) Weight-length relationship and condition factor of wild *Channa punctata* from Multan. Punjab Univ J Zool 15:183–189

Allen KR (1938) Some observations on the biology of the trout (Salmo trutta) in Windermere. J Anim Ecol 7:333–349

Bagenal TB, Tesch FW (1978) Age & growth. In: Bagenal TB (ed) Methods for assessment of fish production in freshwaters, 3rd edn, IBP handbook No. 3. Blackwell Scientific Publications, Oxford

Beverton RJH, Holt SJ (1957) On the dynamics of exploited fish population. Fisheries Investigations. London. Series 2(9):533

Grover HJ, Juliano RO (1976) Length- weight relationship of pond raised milk fish in Philippines. Aquaculture 7:339–746

Hile R (1936) Age and growth of Cisco *Leucichthys artedi* (Le sueur) in the lake of the north eastern highlands, Wisconsin. US Bur Fish Bull 48:211–317

Johal MS, Tandon KK (1983) Age, growth & length-weight relationship of Catla catla and Cirrhina mrigala (pisces) from sukhna lake. Chandigarh. (India). Vestrik Ceskoslovenske Spolecnosti Zoologicke 47:87–98

Kumar R, Sharma BK, Sharma LL, Upadhyay B (2006) Length- weight relationship and condition factor of Catla catla (Hamilton) and Labeo rohita (Hamilton) from Daya reservoir, Udaipur (Rajasthan). J Int Fish Soc India 38(1):72–76

Lecren ED (1951) The length – weight relationship and seasonal cycle in the age and growth of the perch (Perca fluviatilis) from the opercular bone. J Anim Ecol 20:201–219

MacGregor JS (1959) Relationship between fish condition and population size in the Sardine (*Sardinops caeruleus*). U.S. Fish & Wildlife Service Fish Bulletin 60:216–230

Martin WR (1949) The mechanism of environmental control of body form of fishes. Univ Toronto Stud Biol 58 Publ Fish Res Lab 78:1–91

Mirza AM, Ahmad I, Mirza MR (1988) Biologia 34:201–207. Cited by Muhammad Z, Yasmin M, Shamim A, Aneesa S (2003) Weight length and condition factor relationship of Thaila, Catla catla from Rawal Dam, Islamabad. Pak J Biol Sci 6(17):1532–1534

Rounsefell GA, Everhart WH (1953) Fishery science, its methods and applications. Publication Wiley, Inc/ Chapman & Hall Ltd., New York/London, 444

Spencer H (1871) The population of Biology – vider Jhingran, V.G. (1952) General length – weight relationship of three major carps of India. Proc Nat Sci India 18(5):449–460

Srivastava S, Pandey AK (1981) Length- weight relationship and condition factor of three Indian major carps in composite fish farming. Matsya 7:70–74

Wooton RJ (1990) Ecology of teleost fishes. Chapman & Hall, London

Zafar M, Mussaddaq Y, Akhter S, Sultan A (2003) Weight – length and condition factor relationship of thaila, *Catla catla* from Rawal Dam, Islamabad Pakistan. J Biol Sci 6(17):1532–1534

17 Avian Diversity of Wetlands in and Around Jodhpur, Western Rajasthan

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Abstract

Jodhpur is one of the erstwhile princely states of Marwar, Rajasthan, considered as a "door" to The Great Indian *Thar* Desert. The ecological conditions of this district have in the recent past been due to several anthropogenic changes. Jodhpur exhibits wide variety of avian fauna native as well as migratory. There has been a continuous increase in aggravation of bird species which has increased from 125 species to 278. An ample water supply in this area have changed overall ecological scenario of wetland birds also, inflow of water through Indira Gandhi Canal have created several wetlands from seasonal to perennial which in turn have attracted several wetland species to this area. Urbanization changed the scrublands into residential areas and gardens. Increase in mining activities has showed negative impact on the diversity of species and their replacement. The well-managed gardens have attracted several species, as a result of which there is a considerable change in species composition of species. The native fauna is declining and facing pressure of aggravation of sympatric species competition.

Keywords

Biodiversity • Wetland • Species richness • Alpha diversity

Introduction

Situated in extreme western part of India between 26° 00′ to 27° 37′ N and 72° 55′ to 73° 52′ E, Jodhpur is second largest city in the Indian state of Rajasthan spreading around 22,850 km^2. Jodhpur was once capital of erstwhile state of western *Marwar* is a *door* to the Great Indian Thar Desert and contributes a considerable part about 11.6 % of total area of arid zone of the state. This region receives scanty rainfall between 103 and 640 mm averaging up to 279.40 mm per annum with high temperature variation from 49 °C in summer to 2 °C in winters, very low relative humidity and high wind velocity throughout

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the year. Jodhpur is blessed with a wide variety of flora and fauna. The natural vegetation composed of trees are *Prosopis cineraria, Salvadora oleoides, S. persica, Acacia senegal,* and *Dactyloctenium aegyptium*, whereas among shrubs *Capparis decidua, Calligonum polygonoides, Ziziphus nummularia, Euphorbia caducifolia, Calotropis procera,* etc. Some recently planted trees are *Azadirachta indica, Mangifera indica*, *Ficus religiosa*, *F. bengalensis*, *Delonix regia*, *Pongamia pinnata*, and *Dalbergia sisoo* on roadsides, gardens, resorts, and official campuses; in addition to this, *Prosopis juliflora* has invaded each possible place since it was introduced and inside wetland vegeteation like *Typha latifolia, Vallisneria* spp. *Eichhornia crassipes, Phragmites karka, Hydrilla verticillata Chata* spp. *and Green algae are found growing*.

This part of western India is famous for its forts, cultural heritages, and handicrafts, and these are major tourist's attraction of this city. The famous fort Mehrangarh was founded in 1459 AD, since then up to five decades back, most of the population of Jodhpur was restricted inside the old city wall and Mahamandir area outside city wall; the rest of the present Jodhpur was sparsely populated. Kaylana and Balsamand Lake and Jaswant Sagar and Umed Sagar dam are important water bodies of the district. Total 1,934 wetlands are mapped including 1,673 small wetlands (<2.25 ha) with 17,032 ha area. The river/streams with 8,284 ha. contributed 48.64 % to the total wetland area. The salt pans with 4,471 ha (26.25 %) is the second major wetland category, followed by tanks/ponds with 1,798 ha area, i.e., 10.56 %. The district is dominated by man-made wetlands. Open water spread of the wetlands is significantly higher in post-monsoon (1,381 ha) than during pre-monsoon (254 ha), indicating the rainfall dependence of the wetlands in the state. The qualitative turbidity of water is low in both the seasons (National Wetland Atlas 2010).

Almost all villages of Jodhpur had their village pond or *naadi* which were locally conserved and properly harvested; there was proper management of water due paucity of water and rain dependence of pond. These were shelter to several wetland birds. Migratory waterfowls use to appear seasonally in these ponds. Migratory birds like ducks, coots, and waders were common visitor to these water bodies. Due to increase in population of city and villages and with the increase in need of water, the village ponds are now neglected as villages have alternate source of water supply through the government. As a result of which, several water bodies have diminished and mismanaged as they are out of use. On the other hand, fewer of them are still well managed like Barli, Gudha, and Kherjarli ponds.

In Jodhpur City, Kaylana Lake has become the only source of water supply to the city; it gets regular water recharge from Indira Gandhi Canal, and water level does not fluctuate much throughout the year. The regular supply of water have increased plantation of trees and gardens. The population of Jodhpur has increased about 27.73 % from 28.81 lac in year 2001 to 36.87 lac in 2011 (Census of India 2011). Urbanization of the city is progressing very fast, and several surrounding villages are now merged in the main city. Plantation of trees like neem (*Azadirachta indica*), gulmohar (*Delonix regia*), mango (*Mangifera indica*), karanj (*Pongamia pinnata*), sheesham (*Dalbergia sisoo*), and keekar (*Prosopis juliflora*) has been undertaken. There is an impact on diversity of wetland birds due to changed profile of the district which is enumerated in the present communication.

Past Studies on Bird Community in Jodhpur

The old records of studies on birds were carried out way back by Adams (1899), Hume (1873, 1878) Barnes (1886, 1891), and Whistler (1938) and the comprehensive study by Ali (1975). Thereafter extensive surveys conducted by Roberts (1991) in western Rajasthan and Pakistan documented several endemic bird species and there distribution. The erstwhile princely state Jodhpur contributes about 11 % of total *Thar* desert in India. The diversity of birds was very less, almost 100–125 species, but in fair density which was documented by Prakash and Ghosh (1964). These species included native species, those adapted for xeric environment, like larks, peafowl, wheatear, pigeons, partridges, sandgrouses, coursers, and demoiselle cranes, and certain rare birds like great Indian bustard, lesser florican, and houbara bustard were also observed. A large number of scavengers including six species of vultures were in fair numbers. There are several notes on wintering birds around Jodhpur by Agoramoorthy and Mohnot (1986, 1989), Rana and Rana (1985), Bohra and Goyal (1992), and Katju and Mohnot (1995).

In past decade, the change in bird community of western Rajasthan is well documented in the studies by Rahmani (1997) and Rahmani and Soni 1997). Few research contributions after year 2000 were conducted on the birds of Jodhpur by Dookia (2001), Dookia and Pandey (2004) Chhangani (2002, 2004, 2005a, b, 2008), Singh (2002, 2005, 2009, 2010), Sivaperuman et al. (2004), and Idris et al. (2009). In addition to the wetland species, several other aspects of ground birds and raptors were also studied by several researchers during the period of 2000–2013.

Hence the present study is a continuation of all the basic studies conducted in the past. A trend of increase in biodiversity in overall basis of the birds is from 123 species of almost 40 families (Bohra and Goyal 1992), 158 species (Chhangani 2002), and 166 species (Dookia and Pandey 2004) to 232 species of 58 families in 2006 (Singh 2009) and about 278 species in 2010 (Singh 2010) which is considerably high (Table 17.1).

Study Area

The study was undertaken on wetlands, areas of Jodhpur. Nine wetlands around Jodhpur were selected for the present study, i.e., Balsamand Lake (1 km × 200 m, rocky banks with depth 30 ft, perennial water body with check dam), Gudha village pond (300 m × 200 m, sandy banks with depth 10 ft, perennial shallow water body but during summer water level down water restricted to ditches), Khejarli village pond (50 m × 200 m, sandy banks with depth 20 ft, perennial water body is village pond), Akheraj ji pond (500 m × 500 m, rocky and muddy mixed banks with depth 25 ft), perennial water body adjoining to Kaylana Lake with vegetations on the banks), Umed Sagar (700 m × 650 m, rocky and muddy banks with depth 30–35 ft, perennial water body with a check dam the muddy banks are croplands), Soor Sagar (700 m × 300 m, rocky and muddy banks with depth 20–30 ft, perennial water body, located near the residential area), Kaylana Lake (3 km × 300 m, rocky banks with depth 30–40 ft, perennial water body is major source of water for Jodhpur and acquires water from Indira Gandhi Canal and rains), Barli pond (500 m × 30 m, rocky and shallow banks with depth 10–30 ft, perennial water body is a village pond have a temple at check dam side), and Umed Bhawan pond (200 m × 50 m, rocky banks with depth 20–40 ft), perennial water body with check dam and banks have *Acacia juliflora* scrubs. Data analysis was done using standard statistical tools for estimation of diversity (Fig. 17.1).

Methods

Observations were made with a 10 × 50 binocular. The wetlands were covered walking on the banks. Birds around wetland areas were also recorded for their number and species. Observations were also made in nearby scrublands and the gardens up to about 100 m from the study ponds/lakes. All observations were taken in the morning hours from 6 to 9 am. From year 2008 to 2012, the observations were taken in winter season from November to February. Identification of birds was done using standard pictorial bird guides (Ali and Ripley 1983; Grimmett et al. 1998). The data were collected in periodical manner at the same time, i.e., between 6 and 9 am in the morning, to avoid any bias and repeated twice in a month. Standard nomenclature of birds was followed using list by Manakadan and Pittie (2001).

Table 17.1 Check list of Jodhpur birds (2012)

Sl. No.	Family	Common name	Scientific name	Status
1	Podicipedidae	Great crested grebe	*Podiceps cristatus*	RM
2		Little grebe	*Podiceps ruficollis*	C
3	Pelecanidae	Dalmatian pelican	*Pelicanus crispus*	CM
4		Great white pelican	*Pelicanus onocrotalus*	O+
5		Spot-billed pelican	*Pelicanus philipensis*	O+
6	Phalacrocoracidae	Great cormorant	*Phalacrocorax carbo*	C
7		Little cormorant	*Phalacrocorax niger*	C
8		Indian shag	*Phalacrocorax fuscicollis*	R
9	Anhingidae	Oriental darter	*Anhinga melanogaster*	C
10	Ardeidae	Cattle egret	*Bubucus ibis*	C
11		Grey heron	*Ardea cinerea*	O
12		Great egret	*Casmerodius albus*	O
13		Little egret	*Egretta garzetta*	O
14		Striated heron	*Butorides striatus*	R
15		Black-crowned night heron	*Nycticorax nycticorax*	O
16		Indian pond heron	*Ardea grayii*	C
17		Purple heron	*Ardea purpurea*	O
18		Little bittern	*Ixobrychus minutus*	C
19		Intermediate egret	*Mesophoyx intermedia*	C
20	Ciconiidae	Open-billed stork	*Mycteria oscitans*	O
21		Painted stork	*Mycteria leucocephalus*	O
22		Wooly necked stork	*Ciconia episcopus*	O
23	Threskiornithidae	Indian black ibis	*Pesudibis papillosa*	R
24		Glossy ibis	*Plegadis falcinellus*	O+
25		Eurasian spoon bill	*Platalea leucordia*	C+
26		Black-headed ibis	*Threskiornis aethiopica*	C
27		Greater flamingo	*Phoenicopterus ruber*	RM+
28		Lesser flamingo	*Phoenicopterus minor*	RM+
29	Anatidae	Bar-headed goose	*Anser indicus*	OM+
30		Ruddy shell duck	*Tadorna ferruginea*	RM
31		Common pochard	*Anas ferina*	CM
32		Blue winged teal	*Anas crecca*	O
33		Eurasian wigeon	*Anas penelope*	CM
34		Gadwall	*Anas strepera*	CM
35		Garganey	*Anas querquedula*	RM
36		Grey teal	*Anas gibberifrons*	RM
37		Lesser whistling teal	*Dendrocygna javanica*	CM
38		Red-crested pochard	*Netta rufina*	RM
39		Northern shoveler	*Anas clypeata*	CM+
40		Indian spot-billed duck	*Anas poecilorhyncha*	C+
41		Tufted duck	*Aythya fuligulanyroca*	CM
42		Ferruginous duck	*Aythya nyroca*	RM
43		Cotton teal	*Nettapus coromandelianus*	R
44		Grey lag geese	*Anser anser*	M
45		Northern pintail duck	*Anse acuta*	M
46		Comb duck	*Sarkidiornis melanotos*	M
47		Marbled teal	*Marmaronetta angustirostris*	R ?

(continued)

Table 17.1 (continued)

Sl. No.	Family	Common name	Scientific name	Status
48		Common Shelduck	*Tadorna tadorna*	R
49	Accipitridae	Black vulture	*Sarcogyps calvus*	R
50		Black-shouldered kite	*Elanus caeruleus*	R
51		Bonelli's hawk eagle	*Hieraaetus fasciatus*	R
52		Cinereous vulture	*Gyps fulvus*	RM
53		Griffon vulture	*Aegypius monachus*	RM
54		Himalayan griffon	*Gyps himalayensis*	RM
55		Indian long-billed vulture	*Gyps indicus*	O–
56		Marsh harrier	*Circus aeruginosus*	R
57		Pale harrier	*Circus macrourus*	R
58		Pariah kite	*Milvus migrans*	C+
59		Scavenger vulture	*Neophron percnopterous*	C
60		Shikra	*Accipiter badius*	C+
61		Short-toed eagle	*Circus gallicus*	R
62		Sparrow hawk	*Accipiter nisus*	R
63		Steppy eagle	*Rapax nipalensis*	R
64		Tawny eagle	*Aquila rapax*	
65		White-rumped vulture	*Gyps bengalensis*	O–
66		Crested serpent eagle	*Spilornis cheela*	R
67		Greater spotted eagle	*Aquila clanga*	M
68		Indian spotted eagle	*Aquila pomarina*	O–
69		Eastern imperial eagle	*Aquila heliaca*	O–
70		Common buzzard	*Buteo buteo*	R
71	Pandionidae	Osprey	*Pandion haliaetus*	R
72	Falconidae	Kestrel	*Falco tinnunculus*	OM
73		Laggar falcon	*Biarmicus jugger*	R
74		Redheaded falcon	*Falco chicquera*	RM
75		Peregrine falcon	*Falco peregrinus*	RM
76	Phasianidae	Grey partridge	*Francolinus francolinus*	C
77		Grey quail	*Coturnix coturnix*	O
78		Indian peafowl	*Pavo cristatus*	A
79		Rain quail	*Cotunix coromandelianus*	C
80	Gruidae	Common crane	*Grus grus*	R
81		Demoiselle crane	*Anthropoides virgo*	C+
82		Sarus crane	*Grus antigone*	R
83	Rallidae	White-breasted waterhen	*Amaurornis phoenicurus*	C
84		Coot	*Fulica atra*	CM
85		Indian moorhen	*Gallinula chloropus*	C
86		Purple moorhen	*Porphyrio porphyrio*	R
87		Baillon's crake	*Porzana pusilla*	R
88	Jacanidae	Bronze-winged jacana	*Metopidius indicus*	O
89		Pheasant-tailed jacana	*Hydrophasianus chirurgus*	O
90	Rostratulidae	Painted snipe	*Rostratula benghalensis*	CM
91	Charadriidae	Kentish plover	*Charadrius mongolus*	RM
92		Little-ringed plover	*Charadrius dubius*	OM
93		Red-wattled lapwing	*Vanellus indicus*	A
94		Sociable lapwing	*Vanellus gregarious*	R

(continued)

Table 17.1 (continued)

Sl. No.	Family	Common name	Scientific name	Status
95		Eurasian curlew	*Numenius arquata*	R
96		Yellow-wattled lapwing	*Vanellus leucurus*	O
97		European golden plover	*Pluvialis apricaria*	M
98		Lesser sand plover	*Charadrius mongolus*	M
99	Scolopacidae	Black-tailed godwit	*Limosa limosa*	OM
100		Spotted green shank	*Tringa nebularia*	M
101		Common sandpiper	*Tringa hypoleucos*	C
102		Fantailed snipe	*Gallinago gallinago*	RM
103		Green sandpiper	*Tringa ochropus*	RM
104		Little stint	*Calionis minuta*	CM
105		Marsh sandpiper	*Tringa stagnatilis*	M
106		Ruff	*Philomachus pugnax*	C
107		Spotted red shank	*Tringa erythropus*	OM
108		Temminick's stint	*Calidris temminickii*	RM
109		Common red shank	*Tringa totanus*	M
110		Green shank	*Tringa guttifer*	M
111		Terek sandpiper	*Xenus cinereus*	M
112		Wood sand piper	*Tringa glareola*	M
113		Dunlin	*Calidris alpina*	M
114		Jack snipe	*Lymnocryptes minimus*	M
115		Bar-tailed godwit	*Limosa lapponica*	OM
116	Recurvirostridae	Black-winged plover	*Himantopus himantopus*	C
117		Pied avocet	*Recurvirostra avosetta*	CM
118	Bruhinidae	Beach stone plover	*Burhinus magnirostris*	CM
119		Stone-curlew	*Burhinus oedicnemus*	CM
120		Great stone plover	*Esacus recurvirostris*	C
121	Glareolidae	Cream-colored courser	*Cursorius cursor*	RM
122		Indian courser	*Cursorius coromandelicus*	R
123		Small pratincole	*Glareola pratincola*	RM
124	Laridae	Brown-headed gull	*Larus brunicephalus*	M
125		Gull-billed tern	*Gelochelidon nilotica*	RM
126		Herring gull	*Larus argentatus*	RM
127		Indian river tern	*Sterna aurantia*	C
128		Little tern	*Sterna albifrons*	C
129		Pallas's gull	*Larus ichthyaetus*	CM
130		Whiskered tern	*Chidonias hybridus*	M
131		Black-headed gull	*Larus ridibundus*	RM
132	Pteroclididae	Imperial sandgrouse	*Pterocles orientalis*	M–
133		Spotted sandgrouse	*Pterocles senegallus*	R
134		Indian sandgrouse	*Pterocles exustus*	C
135	Rynchopidae	Indian skimmer	*Rynchops albicollis*	R
136	Columbidae	Blue rock pigeon	*Columba livia*	A
137		Little brown dove	*Streptopelia senegalensis*	C
138		Red turtle dove	*Streptopelia tranquebarica*	R
139		Ring dove	*Streptopelia decaocto*	C
140		Yellow-footed green pigeon	*Treron phoenicoptera*	R+
141		Oriental turtle dove	*Streptopelia orientalis*	R

(continued)

Table 17.1 (continued)

Sl. No.	Family	Common name	Scientific name	Status
142		Spotted dove	*Streptopelia chinensis*	C
143	Psittacidae	Alexandrine parakeet	*Psittacula eupatria*	R
144		Rose-ringed parakeet	*Psittacula krameri*	A
145		Plum-headed parakeet	*Piittacula cyanocephala*	R
146	Cuculidae	Common cuckoo	*Cuculus micropterus*	R
147		Brain fever bird	*Hieococcyx various*	R
148		Crow pheasant	*Centropus sinensis*	C
149		Koel	*Eudynamus scolopacea*	A
150		Pied-crested cuckoo	*Clamator jcobinus*	RM
151		Sireer malkoha	*Phaenicophaeus leschenaultii*	R
152	Tytonidae	Barn owl	*Tyto alba*	C
153	Strigidae	Eurasian eagle owl	*Bubo bubo*	R
154		Short-eared owl	*Asio flammeus*	R
155		Spotted owlet	*Athene brama*	C
156		Tawny wood owl	*Strix aluco*	R
157		Mottled wood owl	*Strix ocellata*	R
158	Caprimulgidae	Long-tailed nightjar	*Caprimulus macurus*	O+
159		Franklin's nightjar	*Caprimulus affinis*	O+
160		Common nightjar	*Caprimulus asiaticus*	O+
161	Apodidae	House swift	*Apus affinis*	C
162		White-rumped needle swift	*Zoonavena sylvatica*	C
163	Alcedinidae	Common kingfisher	*Alcedo attis*	O–
164		Lesser pied kingfisher	*Cryel rudius*	R
165		White-breasted kingfisher	*Halcyon smyrnensis*	C
166	Meropidae	Blue-cheeked bee-eater	*Merops superciliosus*	C
167		Blue-tailed bee-eater	*Merops philippinus*	R
168		Chestnut-headed bee-eater	*Merops leschenaulti*	R
169		Green bee-eater	*Merops orientalis*	C
170	Coraciidae	Indian roller	*Coracias benghalensis*	CM
171		Eurasian roller	*Coracias garrulus*	M
172	Upupidae	Hoopoe	*Upupa epops*	O-
173	Bucerotidae	Grey hornbill	*Ocyceros birostris*	O
174	Capitonidae	Blue-throated barbet	*Megalaima asiatica*	R
175		Coppersmith barbet	*Megalaima rubicapilla*	O
176	Picidae	Yellow-crowned woodpecker	*Dendrocopos mahrattensis*	R
177		Grey-capped pygmy woodpecker	*Dendrocopos canicapillus*	R
178		Black-rumped flame back	*Dinopium bengalensis*	R
179		Eurasian wryneck	*Jynx torquilla*	R
180		Indian pitta	*Pitta nipalensis*	R
181	Alaudidae	Singing bush lark	*Mirafra cantillans*	R
182		Greater hoopoe-lark	*Alaemon alaudipes*	R
183		Eastern skylark	*Alauda gulgula*	R
184		Ashy-crowned sparrow-lark	*Eremopterix grisea*	C
185		Crested lark	*Galerida cristata*	R
186		Eastern calandra lark	*Melanocorypha bimaculata*	C
187		Horned lark	*Eremophila alpestris*	R

(continued)

Table 17.1 (continued)

Sl. No.	Family	Common name	Scientific name	Status
188		Rufous-tailed finch-lark	*Ammomanes phoenicurus*	O
189		Short-toed lark	*Calandrella cinerea*	C−
190		Sykes's crested lark	*Galerida deva*	R
191		Eurasian sky lark	*Alauda arvensis*	C
192		Indian bush lark	*Mirafra erythroptera*	O
193	Hirundinidae	Dusky crag martin	*Hirundo concolor*	C
194		Plain sand martin	*Riparia paludicola*	C
195		Wire-tailed swallow	*Hirundo smithii*	C
196		Streak-throated swallow	*Hirundo fluvicola*	C
197		Barn swallow	*Hirundo rustica*	C
198	Motacillidae	Long-billed pipit	*Anthus similes*	R
199		Grey wagtail	*Motacilla cinerea*	CM
200		Large pied wagtail	*Motacilla maderaspatensis*	R+
201		Tawny pipit	*Anthus campestris*	R
202		Yellow wagtail	*Motacilla flava*	OM
203		Yellow-headed wagtail	*Motacilla melanogrisea*	OM
204		Masked wagtail	*Motacilla alba*	M
205		Citrine wagtail	*Motacilla citreola*	M
206		Water pipit	*Anthus spinoletta*	M
207		Paddyfield pipit	*Anthus rufulus*	R
208	Campehagidae	Common wood shrike	*Tephrodornis pondicerianus*	O+
209		Grey minivet	*Pericrocotus cinnamomeus*	R
210	Pycnonotidae	Red-vented bulbul	*Pycnonotus leucogenys*	A+
211		White-cheeked bulbul	*Pycnonotus cafer*	C+
212	Irenidae	Common iora	*Aegithina tiphia*	R
213		Marsall's iora	*Aegithina nigrolutea*	R
214	Laniidae	Grey shrike	*Lanius excubitor*	O+
215		Long-tailed shrike	*Lanius schach*	O+
216		Pale brown shrike	*Lanius collurio*	R
217		Bay-backed shrike	*Lanius vittatus*	O
218	Turdinae	Black redstart	*Phoenicurus ochruros*	O
219		Bluethroat	*Erithacus svecicus*	O
220		Brown rock chat	*Cercomela fusca*	O
221		Desert wheatear	*Oenanthe deserti*	O+
222		Indian robin	*Saxicoloides fulicata*	C+
223		Isabelline chat	*Oenanthe isabellina*	R+
224		Pied bush chat	*Saxicola caprata*	R
225		Pied wheatear	*Oenanthe pleschanka*	M
226		Rufous chat	*Erythropygia galactotes*	O
227		Kurdish wheatear	*Oenanthe xanthoprymna*	R
228		Stolizka's bush chat	*Saxicola macrorhyncha*	R−
229		Variable wheatear	*Oenanthe picata*	O+
230		Common stone chat	*Saxicola torquata*	O
231	Timillidae	Common babbler	*Turdoides malcolmi*	A+
232		Jungle babbler	*Turdoides striatus*	VR
233		Large grey babbler	*Turdoides caudatus*	A+

(continued)

Table 17.1 (continued)

Sl. No.	Family	Common name	Scientific name	Status
234		Striated babbler	*Turdoides earlei*	R
235		Streaked wren-warbler	*Napothera brevicaudata*	R
236	Sylviinae	Ashy wren-warbler	*Prinia socialis*	C
237		European chiffchaff	*Phylloscops collybita*	CM
238		Indian great reed warbler	*Acrocephalus stentoreus*	R
239		Lesser white throat	*Sylvia curruca*	OM
240		Orphean warbler	*Sylvia hortensis*	O
241		Plain wren-warbler	*Prinia subflava*	C+
242		Tailor bird	*Orthotomus sutorius*	C+
243		Graceful prinia	*Prinia gracilis*	OM
244		Plain prinia	*Prinia inornata*	OM
245		Franklin's prinia	*Prinia hodgsonii*	OM
246		Booted warbler	*Hilppolais caligata*	OM
247		Blyth's reed warbler	*Acrocephalus dumetorum*	OM
248		Plain leaf warbler	*Phylloscopus neglectus*	OM
249		Desert warbler	*Sylvia nana*	OM
250		Greater white throat	*Sylvia communis*	OM
251	Rhipidurinae	Whitebrowed fantailed flycatcher	*Rhipidura aureola*	R+
252		Grey-headed flycatcher	*Culicicapa ceylonensis*	R+
253	Paridae	White-naped tit	*Parus xanthogenys*	R
254	Nectariniidae	Purple sunbird	*Nectarinia asiatica*	A
255	Zosteropidae	Oriental white eye	*Zosterops palpebrosus*	R
256	Emberizidae	Grey-necked bunting	*Emberiza buchanani*	RM
257		Striolated bunting	*Emberiza striolata*	RM
258	Fringillidae	Common rose finch	*Carpodacus erythrinus*	R
259	Estrildidae	Spotted munia	*Lonchura punctulata*	R
260		Green munia	*Amandava formosa*	R
261		White-throated munia	*Lonchura malabarica*	C+
262	Passerinae	House sparrow	*Passer domesticus*	A
263		Sind sparrow	*Passer pyrrhonotus*	R
264		Spanish sparrow	*Passer hispaniolensis*	RM
265		Yellow-throated sparrow	*Petronia xanthcollis*	R
266	Ploceinae	Baya weaver	*Ploceus philippinus*	C+
267		Streaked weaver	*Ploceus manyar*	R
268	Sturnidae	Bank myna	*Acridotheres ginginianus*	C+
269		Brahminy starling	*Sturnus pagodarum*	C
270		Asian pied starling	*Gracupica contra*	A
271		Common myna	*Acridotheres tristis*	A
272		Jungle myna	*Acridotheres fuscus*	R
273		Rosy starling	*Sturnus roseus*	AM
274		Common starling	*Sturnus vulgaris*	RM
275	Oriolidae	Golden oriole	*Oriolus oriolus*	R+
276	Dicruridae	Black drongo	*Dicrurus adsimilis*	O+
277	Corvidae	House crow	*Crovus splendens*	A
278		Raven	*Crovus corax*	R+

A abundant, *C* common, *O* occasional, *R* rare, *M* migratory, + number likely to increase, – number likely to decrease, ? species not confirmed

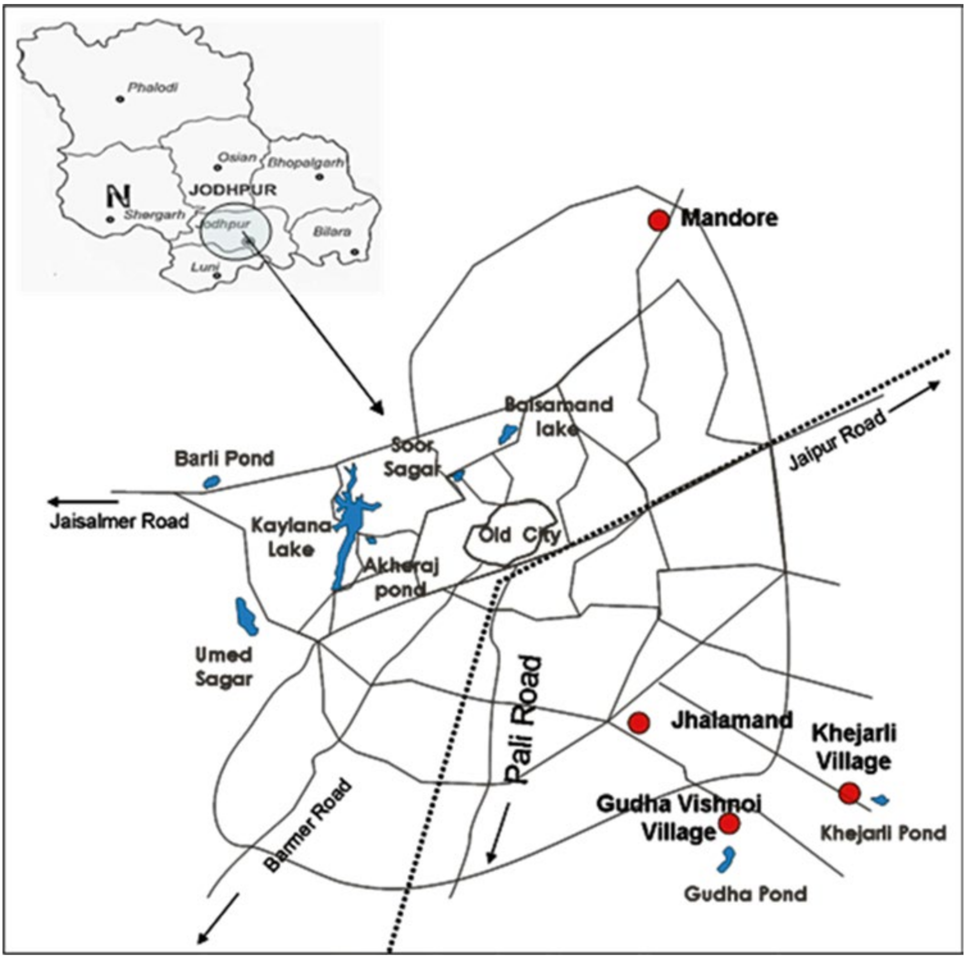

Fig. 17.1 Location of various wetlands in and around Jodhpur City

Data Collection For each study site, the vegetation condition of wetland was recorded before the collection of bird data. For each wetland, number of species and number of individuals were recorded in separate data sheets thereafter. The collected data were entered in the computer and pooled for data analysis.

Data Analysis Alpha (α) diversity was calculated for each study site, i.e., wetland, using Shannon–Wiener diversity index on the records of individual study site using the following formula (Shannon 1948):

$$H = -\sum\left[\left(p_i\right)\times \ln\left(p_i\right)\right], \quad (\text{Pielou}\,1966)$$

where

p_i = proportion of total sample represented by species i.

Divide the no. of individuals of species i by the total number of samples

S = number of species, = species richness.

Maximum diversity possible diversity and evenness were calculated using formula

$$H_{\max} = \ln\left(S\right) \text{and}\, E = \text{Evenness}\, e = H / \text{In}\, S \,\text{used by Pielou}\left(1966\right),$$

where

H = Shannon–Wiener diversity index,

S = total number of species in the sample.

For assessment of similarity among the sites, beta diversity was calculated using the following formula (Sorenson 1948):

$$\text{Sorenson's index}\left(C_s\right) = \frac{2j}{(a+b)},$$

where a = richness in first site, b = richness in second site, j = shared species.

The analysis for the diversity was carried out only for the wetlands.

Results

Out of a total record of 278 species belonging to 63 families in and around Jodhpur, about 205 species of 58 families were recorded from 9 wetlands of Jodhpur, out of which 111 were wetland species. Total diversity in the wetlands of study area was found to be alpha diversity (α) = 3.82 (205 species). Among the individual wetlands, the highest species count was found in Kaylana Lake (170 species of 53 families) followed by Barli pond (132 species of 48 families), whereas the lowest species count was observed in Umed Bhawan pond (64 species of 28 families) (Table 17.2).

Though the Kaylana Lake was found to be the most species rich (170 species), yet the alpha diversity (H' Shannon Index) of Balsamand Lake was found to be highest (α = 4.08) due to high evenness (E) in the distribution of species (E = 0.86) followed by Akheraj pond (α = 3.79; E = 0.81) and Soor Sagar pond (α = 3.76; E = 0.76), and the lowest diversity was found to be of Umed Bhawan pond (α = 1.16; E = 0.28) (Table 17.2).

Out of 205 species recorded during the study period, 111 species were wetland dependent species; maximum wetland dependent were species from Gudha tank and Khejarli pond (69 species each) (Table 17.2). There is increasing trend shown in the number of wetland species form 49 species (11 families) in year 1992 to 111 species (23 families) observed during the present study in 2012.

Diversity of Individual Wetlands

Kaylana Lake

The lake is spread over 84 km^2 located (26° 17′ N; 72° 58′ E) 8 km west of Jodhpur in Rajasthan, India. It is an artificial lake, built in 1872. Kaylana Lake is situated in a rocky bed and receives water from *Hati Nehar* (Elephant-sized canal) which is now connected with the main canal irrigation system of Indira Gandhi Canal (IG Canal), a major water resource of Jodhpur. Kaylana is spread over 84 km^2 with length of about 4 km, 100–250 m wide, and about 35–40 ft deep. The vegetation composition is dominated by *Acacia nilotica* and *Euphorbia caducifolia*.

Kaylana Lake is rich in its avian diversity study conducted in by Bohra and Goyal (1992) and showed about 123 species of 40 families which has increased gradually to about 156 species of 51 families (Singh 2009). As the lake is the only source of drinking water and well protected by the state government, in addition to this, a part of the lake which comes in Machia Safari park is also protected under forest act. The depth of water in this lake supports several species of birds like pochards, darters, cormorants, and pelicans. Our continuous study from 1999 to 2013 on avian diversity showed that diversity of the main lake has decreased due to continuous inflow of water through IG canal which maintains water level constant throughout the year. However, there is increase in diversity of adjoining water bodies that are dependent on water through Kaylana Lake.

The increased level of water have destructed breeding colony of large cormorants which were found breeding for the first time in western Rajasthan (Dookia 2001). An average of 5,583 individuals of 170 species of 57 families was recorded from observations from 2008 to 2012. Alpha (α) diversity was found to be about 3.31. Out of 170 species, 84 belonged to wetland and the rest of the species were found up to 100 m from the bank of the pond (Table 17.3 and Fig. 17.2). The diversity of Kaylana Lake ranked 7th out of nine sites; similarly the evenness also attributed with 6th rank. However, the large-sized water body has

Table 17.2 Diversity of different wetlands in and around Jodhpur

	Akheraj pond	Kaylana lake	Umed Sagar	Balsamand lake	Gudha pond	Barli pond	Khejarli pond	Soor Sagar pond	Umed Bhawan pond	Total
No. of species	106	170	100	117	127	132	89	127	64	205
No of individuals	1,457[a]	5,583	1,313	2,076	1,846	1,885	1,567	1,008	2,484	19,537
Families	40	53	41	45	44	48	41	38	28	58
Alpha diversity	3.79	3.31	3.22	4.08	3.74	3.54	3.66	3.76	1.16	3.82
H_{max}	4.66	5.10	4.600	4.76	4.84	4.88	4.49	4.84	4.15	5.32
Evenness	0.81	0.60	0.70	0.866	0.77	0.72	0.81	0.77	0.28	0.72
No. of wetland species	44	57	49	52	69	64	69	37	32	111

[a]No of individuals is an average pooled for number of observations

Table 17.3 General profiles of study ponds

	Akheraj Ji Pond	Kaylana Lake	Umed Sagar Dam	Balsamand Lake	Gudha Tank	Barli Pond	Khejarli Pond	Soor Sagar Pond	Umed Bhawan Pond
Location	26°17′51 N and 72°58′54E	26°17′N 72°58′E	26.15′58 N and7 2.56,32E	26.331°N 73.020°E	26.08′12 N and 73.06′30E	26.62 N and 71.95 E	26°8′59″ N and 73°8′41″ E	26°18′55″ N 73°0′20″ E	26° 16′51″ N, 73° 2′49″ E
Area	0.15 km^2	84 km^2	24 km^2	0.5 km^2	0.2 km^2	0.2 km^2	0.15 km^2	0.34 km^2	0.08 km^2
Depth	5–8 ft	30–40 ft	20–25 ft	30–40 ft	5–8 ft	5–7 ft	10–15 ft	10–15 ft	10–15 ft
Bank type	Rocky	Rocky	Muddy and rocky	Rocky	Muddy	Gravelly	Muddy	Rocky	Rocky
Vegetation type	Floating, amphibious submerged	Scanty floating vegetation and trees of *Acacia nilotica* and *Prosopis juliflora*	Crop land around pond	No vegetation in the lake and on the banks But a lush green garden is associated with the lake	No vegetation except algal blooms, *Spirogyra* sp.	No vegetation except algal blooms, *Spirogyra* sp.	Nil except vegetation on banks	Crop fields around floating and submerged vegetation	*P. juliflora* and floating algae
Water Quality	Turbid water with neutral PH	Clean with neutral PH	Clean with neutral PH	Clean with neutral PH	Turbid with slightly basic PH	Clean with neutral PH	Clean with neutral PH	Turbid water with basic PH	Clean with neutral PH
Threats	Encroach-ments on the banks and cutting of vegetation around pond	Mining activities around the lake	There may be leaching of pesticides from the crops on the banks	Mining activities around the lake	Well protected but scarcity of water during late winters	Construction activity may disturb the diversity of wetland	Nil	Mining activities around the lake & leaching of pesticides form nearby crops	A large number of dogs disturb whole wetland and the birds resting in

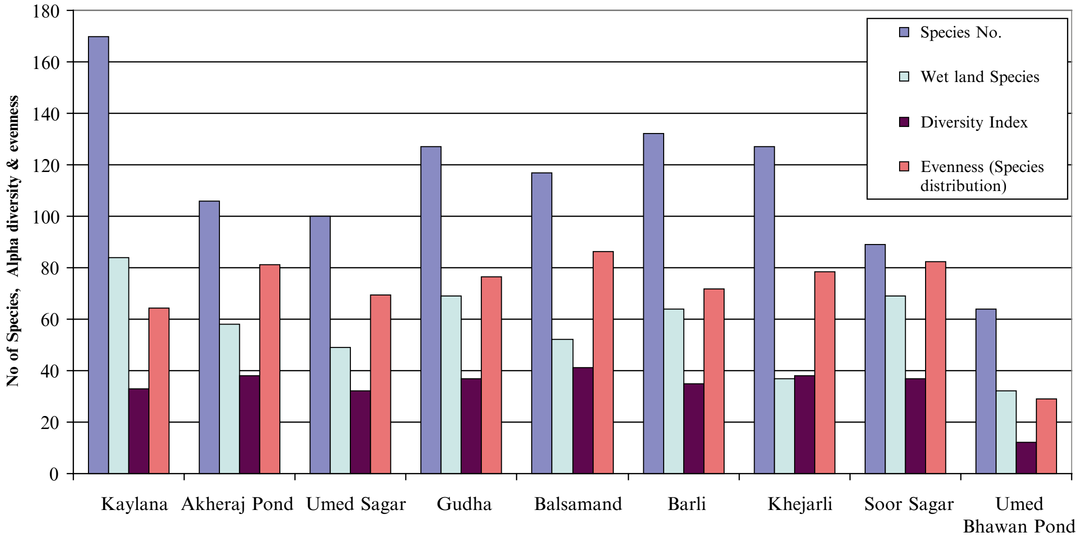

Fig. 17.2 Showing avian diversity study sites

maximum potential to hold diversity (H_{max} = 5.10). The habitat is restricted only to rocky type and some of the disturbance due to tourism and boating might be attributing to the low diversity of the lake.

Akheraj Pond

The pond is situated (26° 17′ 51 N and 72° 58′ 54 E) about 7 km west of Jodhpur besides Kaylana Lake and is filled with the excess water of Kaylana Lake which is a small water body sized 0.15 km^2 surrounded by croplands and commercial buildings (Table 17.3). This small water body is a very good bird watching site as due to its small size with shallow banks with vegetation of *Typha latifolia* (Typha) and *Prosopis juliflora* which support several resident birds like purple moorhen (*Porphyrio porphyrio*), white-breasted waterhen (*Amaurornis phoenicurus*), Indian moorhen (*Gallinula chloropus*), and many other reed loving birds. The floating vegetation is mainly water hyacinth (*Eichhornia* sp.) and submerged vegetation is mainly *Vallisneria spiralis*.

About an average of 1,457 individuals of 106 species of 57 families were recorded from observations from 2008 to 2012. Alpha diversity was found second highest (α = 3.79). Out of 106, only 44 species were wetland species (Table 17.3 and Fig. 17.2).

The water body is small and shallow, its maximum potential of diversity (H_{max}) was found to be 4.66, and the evenness of this water body was ranked 2nd (E = 0.81) which suggest that even after disturbance, the wetland holds good distribution of all occurring species. The pond is disturbed in the recent past, and the crop fields surrounding the pond are increasing the organic contents and increasing eutrophication. Waste disposal near the pond is another threat. Akheraj pond is one of the most diversified ponds in the Jodhpur.

Umed Sagar

The pond is located at the latitude and longitude coordinates of 26.15′58 N and 72.56,32 E near Jodhpur (Table 17.3). Umed Sagar is an artificially constructed dam by Maharaja Umed Singh in 1933 for the supply of drinking water. This pond spreads over an area of 27 km^2. It is located near Kaylana Lake.

It is an open wetland surrounded by crop fields from three sides with a dam on the other side. The banks are muddy and bounded by thatched bio-fencing of dead branches of *P. juliflora*. About an average of 1,613 individuals of 100 species were recorded during the winter study period. Alpha (α) diversity was found to be about 3.22. Out of 100 species, 49 species were wetland dependent. The shallow water body's maximum potential of diversity (H_{max}) was found to be 4.60; the evenness of this water body was ranked 5th ($E=0.81$) among other sites. The pond is disturbed in the recent past since the crop fields surrounding the pond are increasing the organic contents and increasing eutrophication due to cornfields adjoining the lake (Table 17.3 and Fig. 17.2).

The lake harbors good species number; presence of pelican and cormorants indicates good fish fauna in the lake. However, recently, people have started procession of idol submerging processes in this lake which might impact on the water quality and the diversity of the birds.

Gudha Pond

Gudha Tank is located between 26.08′ 12 N and 73.06′ 30 E, 24 km south from Jodhpur. The pond is a village pond of Gudha Bishnoi village which is famous for the inhabiting eco-friendly Bishnoi community. The pond is located in open scrub and comes under forest land. It is protected with wire fencing. The pond has two mud islands inside which provide resting sites to ducks and waders. In the surrounding area, check dam of mud is constructed. *Prosopis juliflora* is among the major vegetation composition with few trees like *Prosopis cineraria* and *Salvadora oleoides*.

Gudha pond is visited by several migratory birds like domicile cranes and other ducks and waders. It is a good spot for ecotourism; some efforts by the state's forest department have been made to develop the watch point and huts for resting at the bank of the pond. Although the tank is small in size, approximately 0.5 km^2 (Table 17.3), only yet it is found rich in its species composition. An average of 2,076 individuals of 132 species was recorded during the study period. The alpha (α) diversity was found to be 3.74. Out of 132 species, 64 were wetland dependent (Table 17.3 and Fig. 17.2). The potential maximum diversity (H_{max}) in the present scenario was found to be 4.84. The evenness of this pond showed that this is less disturbed and well protected. The forest department is planning to build shelter belts on the western bank to reduce the high speed wind.

Balsamand Lake

Balsamand Lake is situated (26.331° N 73.020° E) 5 km from Jodhpur on Jodhpur-Mandore Road. This lake is about 1.5 km long with 50 m width which reduces in the far end opposite to the dam side. The depth of the lake is about 15 m and surrounded with rocky habitat, mostly steep banks except in the far end of the lake. The lake was built in 1159 AD by Balak Rao Parihar. It was designed as a water reservoir to provide water to a nearby Mandore garden.

The lake is surrounded by lush green gardens with large trees of mango, papaya, pomegranate, and guava. Several garden species are resident in this lush green place. However, the main lake is rocky with surrounding vegetations of *Prosopis juliflora, Calotropis procera, Ziziphus nummularia, Euphorbia caducifolia Salvadora oleoides, S. persica,* and *Dactyloctenium aegyptium*. The lake diversity is rich due to admixture of dry and humid habit of the garden.

Alpha (α) diversity was found to be 4.08 which is the highest of all study wetlands; even the number of species were found lower (117) than Kaylana Lake, Barli pond, and Soor Sagar pond; this might be due to the high evenness in the distribution of these species ($E=0.866$). Although the potential species richness ($H_{max}=4.76$) was found to be lower than many study sites. Out of 117, only 52 species were wetland species (Table 17.3 and Fig. 17.2). Balsamand Lake is well protected from the time the state developed a garden in the command area of the dam which is one of the best gardens (privately owned) in Jodhpur, yet there are certain issues like mining on the north side which is now under control after proper intervention by the state government.

Barli Pond

The pond is located at the latitude and longitude coordinates of 26.62 N and 71.95 E. It is an open shallow water pond of village Bali with gravelly banks and open scrub. The pond is surrounded with scrubby *Prosopis juliflora* with trees of *Prosopis cineraria* and few large trees of *Ficus benghalensis* on the check dam side near the temple. Avian diversity was observed to be increasing in the past decade. Barli pond is a unique habitat as a large number of vulture species use to come for water from the nearby Caracas dumping site of Keru village. During the 2008 winter, about 1,400 Egyptian vulture (*Neophron percnopterous*) congregation was observed (Singh 2009). The pond is also site for few important birds like steppe eagle (*Aquila nipalensis*) and tawny eagle (*Aquila rapax*), blue-tailed bee-eater (*Merops philippinus*), desert wheatear (*Oenanthe deserti*), and Isabelline chat (*Oenanthe isabellina*). Due to fewer disturbances, the diversity of this pond has not changed much in the recent past.

About an average of 1,885 individuals of 132 species was recorded during the winter study period out of which 64 species were wetland dependent. The alpha (α) diversity was found to be 3.54 which was ranked 5th compared to the other study sites. The potential richness of the site ($H_{max}=4.88$) was found highest after Kaylana Lake, and the evenness of the site was quite good ($E=0.72$) (Table 17.3 and Fig. 17.2). Barli pond is culturally protected by social fencing of the people of Barli village, yet mining and new constructions may pose some disturbance to the existing diversity in the near future.

Soor Sagar Pond

The pond is located between 26° 18′55″N 73° 0′20″E about 6 km north of Jodhpur main city. The pond is surrounded by crop lands and human residences. White pelicans, cormorants, pochards, moorhens, and other dwindling ducks are the major species composition of this pond. In spite of being smaller in size (0.34 km^2), 127 species of 38 families of birds were recorded out of which only 37 species were wetland dependent; other congregation of species was due to dense vegetation and cropland around the pond. Alpha (α) diversity of this wetland was found to be 3.76; the evenness was found to be ranked 3rd compared with the other sites ($E=0.77$) (Table 17.3 and Fig. 17.2). The wetland is surrounded by old buildings from one side, and the shallow end is encroached with continuation of cropland which is a major cause of eutrophication and reduction in the quality of water due to increasing organic material and insecticide leaching of crop fields.

Khejarli Pond

The pond is small sized (0.5 km^2) located between 26° 8′59″ N 73° 8′41″ E, 26 km southeast of the city of Jodhpur in Khejarli village (Table 17.3). The village is also known internationally for their dedication in saving trees from cutting; the *Chipko movement* headed by a local woman called "Amrita Devi" protested against the tree-felling and gave her life in protection of tree along with 300 other villagers. The pond though is very small and mostly dry during the winters as it is rain dependent yet is abode for birds like demoiselle cranes, cormorants, and dwindling ducks. Due to fare protection by the villagers to wildlife, the number of Indian peafowl is higher. The pond is small in size with muddy banks with surrounding vegetation of shrubs *Prosopis juliflora, Calotropis procera,* and *Capparis decidua* and trees of *Prosopis cineraria* and *Salvadora oleoides*. Alpha (α) diversity of this wetland was found to be 3.66, with 89 bird species of 41 families recorded during the study duration out of which 69 species were wetland dependent species; the evenness was found to be high and ranked second among the other wetlands due to distribution of species in the wetland ($E=0.81$) (Table 17.3 and Fig. 17.2). There is no threat to the wetland except the continuous supply of water to the wetland.

Umed Bhawan Pond

This small pond is situated (26° 16′51″ N, 73° 2′49″ E) on the foot hills of Umed Bhawan Palace, Jodhpur, and was built for drinking water supply to the fort. The large flock of ruff (1500–2000), greater flamingoes, demoiselle cranes, cormorants, and dwindling ducks is the main feature of this pond. Though the pond is on a rocky bed, yet it has both shallow and deep water for both wades and dwindling ducks, respectively. The vegetation is mainly composed of shrubs *Prosopis juliflora, Euphorbia caducifolia,* and *Capparis decidua*.

The size of this pond is very small (0.8 km^2) (Table 17.3). About 64 species of 28 families were recorded during the study period out of which about 32 were wetland species and the rest were scrubland and garden species. The diversity was found to be the lowest ($\alpha = 1.16$). The evenness of the pond species was found to be the lowest of all sites ($E = 0.28$) (Table 17.3 and Fig. 17.2). The pond is well protected as it is privately owned and a part of Umed Bhawan Palace which is a known tourist center of Jodhpur. Stray dogs are a major threat in the enclosed area of the pond.

Diversity of Migratory Species

The number of migratory species has increased with increase in the overall species profile of Jodhpur avifauna. One hundred and twenty four migratory species were recorded during 2005–2013, out of which 46 species are rare migrant and 32 species are common migrant to this place. Rosy pastor (*Sturnus roseus*) of Sturnidae family was found to be the most abundant migrant species. Anatidae is also a common migrant family; species like pochards, shoveler, coots, geese, and other ducks are common migrants likewise families Scolopacidae (12 migrant species) and Charadriidae (4 species). In family Gruidae, demoiselle crane (*Anthropoides virgo*) is a common and regular migrant. Likewise migration of scrubland bird species to this place has also increased, almost 48 species of 23 families. Out of 17 species of Accipitridae family, 3 species of vultures are now common and migrant, cinereous vulture, griffon vulture, and Himalayan Griffon. Imperial sandgrouse (*Pterocles orientalis*), Sind sparrow (*Passer pyrrhonotus*), Spanish sparrows (*Passer hispaniolensis*), European Chiffchaff (*Phylloscops collybita*), and lesser whitethroat (*Sylvia curruca*) are migrant species.

Diversity Among the Study Sites

Ponds and lakes of study area were compared for the estimation of similarity in the composition of species excluding the species other than wetland dependent. Kaylana Lake and Soor Sagar pond were found most similar beta diversity (β; Sorenson's index) being 0.405; these two wetlands shared about 63 species out of 153 in both wetlands. The cluster analysis also showed both of these wetlands combine at the least distance in the dendrogram (Fig. 17.3). Likewise Barli pond showed similarity with Kaylana Lake, sharing 60 species out of 148 total species. Umed Bhawan pond shared the least number of species with all others. However, it showed some similarity with Balsamand Lake ($\beta = 0.298$) (Table 17.4).

Cluster analysis showed three main clusters, Kaylana Lake and Soor Sagar pond cluster which is joined by Barli pond and Akheraj pond, thereafter the second cluster of Gudha pond and Balsamand Lake joins the first cluster, and the third cluster of Umed Sagar pond and Kherjarli pond showed less similarity with both clusters, whereas the pond Umed Bhawan was found to be the least similar and joined the cluster separately (Fig. 17.4).

Discussion

Jodhpur City is changing its ecological profile at a very fast pace as there has been a tremendous change in land use pattern due to increased human population. This has resulted in the shrinking of available habitats for the native birds. On the other hand, there is increase in the garden-loving species of birds (Singh 2010) due to the introduction of gardens as a result of

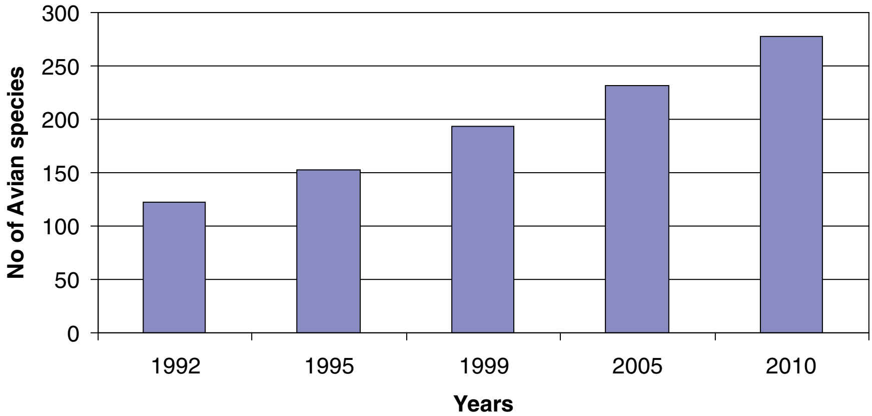

Fig. 17.3 Graph showing increase in avian diversity of Jodhpur in the recent past

Table 17.4 Beta diversity among the study sites (Sorenson 1948)

	Kaylana Lake	Umed Sagar	Gudha tank	Balsamand Lake	Barli pond	Khejarli pond	Soor Sagar	Umed Bhawan pond
Akheraj pond	0.373	0.327	0.37	0.336	0.369	0.305	0.394	0.278
Kaylana		0.338	0.373	0.353	**0.405**	0.298	**0.412**	0.267
Umed Sagar			0.339	0.317	0.363	0.36	0.339	0.272
Gudha tank				0.331	**0.391**	0.34	**0.37**	0.272
Balsamand Lake					0.336	0.337	0.38	0.298
Barli pond						0.337	0.368	0.26
Khejarli pond							0.349	0.261
Soor Sagar pond								0.287

continuous water supply from Indira Gandhi Canal. Kaylana Lake is filled with Indira Gandhi Canal water regularly which has resulted in the rise in groundwater level in the Jodhpur City area (Central Ground water Department Reports 2008). The increase in water table helped in establishing good gardens which attracts thicket-loving bird species.

Though the largest water body is Kaylana Lake in Jodhpur, it has the highest species count of about 170 species, yet its diversity was found lower than that of Balsamand Lake in species composition of both wetland and other surrounding birds because Balsamand Lake is associated with a well-maintained garden also which increases the diversity. It is interesting to note that even the species count of Kaylana Lake is high, yet the diversity was lower than Balsamand; this may also be due to the distribution of individual species numbers.

Out of the total records of 278 species belonging to 63 families in and around Jodhpur, about 205 species of 58 families were recorded form 9 wetlands of Jodhpur, out which 111 were wetland species. When compared with observations of the previous years, the diversity of wetlands was found to be increased in the past decade. The increase in the alpha diversity of the individual pond might also be due to the shrinking of the surrounding habitats. Akheraj and Soor Sagar ponds are examples of such conditions where the surrounding areas have been encroached.

It is also observed that muddy shallow banks are more supportive to the wader community;

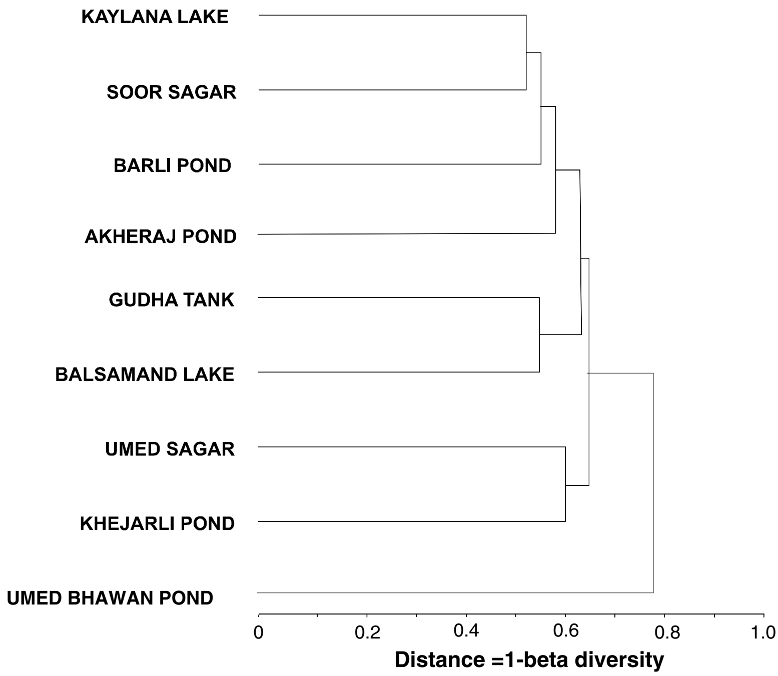

Fig. 17.4 Dendrogram showing similarity in species sharing of different study wetland

therefore, in certain ponds like Gudha Barli and Khejerli, the diversity of wades was higher as compared to other wetlands. The size and depth of water bodies are also important factors for avian diversity. The shallow water supports certain waders and dwindling ducks, whereas the deep water bodies support deep diving birds like darters and cormorants and fish-eating-surface birds like pelicans. The condition of wetland water is also an important factor for the distribution of certain species like stilts, pied avocet, ibis, storks, and flamingoes. The distribution of species like flamingoes and pied avocet is salinity dependent; they were recorded more from slightly saline water.

Similarly black-winged stilt number is directly proportional to the degree of sewerage mixture. Soor Sagar, Akheraj, and Umed Bhawan ponds have increased number of this species and were found polluted as well. Although there is a large difference in the position and size of Kaylana Lake and Soor Sagar pond, yet they were found to share most species in common; the cluster of similar ponds and lake is also nearby each other. Balsamand Lake showed similarity with Gudha tanks which is perplexing as they are not nearby. Balsamand is a water body with rocky banks and with more depth of water, whereas Gudha tank is a muddy bank with shallow water with open scrub. As our observation period was only during the winter, therefore, the similarity results are confided to the winter seasons only. Umed Bhawan pond is unique and not much disturbed therefore showed lesser similarity with others.

Conclusion

A rich diversity exists in and around wetland of Jodhpur. The size, location, depth, and type of banks wetland are the key features for distribution of types of avian species. As there is a considerable rise in the population of Jodhpur in the recent past, the scrub habitats have shrunken, and the wetland habitat which earlier were found in continuation with scrublands is reduced; this might also have increased the density of scrub-loving birds around wetlands. Increase in diversity of birds recently may be alarming to the existence of native bird species. The study has shown that there is considerable change in species composition due to altered land use pattern which might initiate the irreversible loss to native bird species due to habitat sharing and competition.

References

Adams A (1899) Western Rajputana state. Taylor & Francis, London

Agoramoorthy G, Mohnot SM (1986) Migratory water birds around Jodhpur (India). Tigerpaper 13(1):4–7

Agoramoorthy G, Mohnot SM (1989) Checklist of birds around Jodhpur. Tigerpaper 16(1):11–13

Ali S (1975) On some birds of Indian desert. In: Gupta RK, Prakash I (eds) Environmental analysis of the Thar Desert. English Book Depot, Dehradun, pp 423–431

Ali S, Ripley SD (1983) Compact handbook of the birds of India and Pakistan. Oxford University Press, Oxford, 737 p

Barnes HE (1886) Birds nesting in Rajputana. J Bombay Nat Hist Soc 1:38–62

Barnes HE (1891) Nesting in western India. J Bombay Nat Hist Soc 6:1–25

Bohra HC, Goyal SP (1992) Checklist of birds of Machia Safari Desert Park Jodhpur (Rajasthan). Pavo 30(1&2):87–97

Census of India (2011) Available at http://www.census2011.co.in/census/district/438-jodhpur.html

Chhangani AK (2002) Birds of different sub-habitats in and around Jodhpur, Rajasthan, India. Cheetal 41(3&4):37–42

Chhangani AK (2004) Geophagy by three species of crows near carcass dumping ground at Jodhpur, Rajasthan. Newsl Ornithol 1(5):71–72

Chhangani AK (2005a) First record of Indian Grey Hornbill (*Ocyceros birostris*) in the Thar Desert, Jodhpur, India. Newsl Birdwatch 44(6):94

Chhangani AK (2005b) House Crow (Corvus splendens) feeding on gum of Acacia nilotica at Jodhpur, Rajasthan. Newsl Birdwatch 45(1):14

Chhangani AK (2008) Sightings and nesting sites of Red-headed Vulture Sarcogyps calvus in Rajasthan, India. Indian Birds 3(6):218–221

Dookia S (2001) Breeding colonies of Cormorants (Phalacrocorax carbo). Newsl Birdwatch 41(4):54

Dookia S, Pandey VK (2004) Additions to the birds of Jodhpur city, Rajasthan. Zoos' Print J 19(5):1474

Grimmett R, Inskipp C, Inskipp T (1998) Birds of the Indian subcontinent. Oxford University Press, Delhi

Hume AO (1873) Contribution to the ornithology of India: Sindh II. Stray Feathers 1:44–290

Hume AO (1878) The birds of a drought. Stray Feathers 7:52–68

Ground water scenario Jodhpur District Rajasthan, Central Ground Water Board, Ministry of Water Resources Government of India 2008, pp 1–19

Idris M, Singh P, Johari S (2009) Impact assessment of the Indira Gandhi canal on the avifauna of the Thar desert. In: Faunal ecology and conservation of the great Indian desert. Springer, Berlin/Heidelberg, pp 119–135

Katju D, Mohnot SM (1995) A check-list of the winter birds of the Kailana-Bijolai area, Jodhpur. Newsl Birdwatch 35(1):13–15

Manakadan R, Pittie A (2001) Standardized common and scientific names of the birds of Indian Subcontinent. Buceros 6(1):1–37

National Wetland Atlas: Rajasthan Ministry of Environment and Forests Government of India Space Applications centre Indian Space Research Organisation Ahmedabad 2010, pp 1–214

Pielou ECJ (1966) The measurement of diversity in different types of biological collections. J Theor Biol 13:131–144

Prakash I, Ghosh PK (1964) The Great Indian Bustard breeding in Rajasthan. Ibid 3:2

Rahmani AR (1997) Wildlife in the Thar. WWF, New Delhi, pp 1–100

Rahmani AR, Soni RG (1997) Avifaunal changes in the Indian Thar desert. J Arid Environ 36:687–703

Rana BD, Rana RN (1985) Common birds of Dhawa, Jodhpur. Newsl Birdwatch 25(9–10):8

Roberts TJ (1991) The birds of Pakistan: Regional studies and non-passeriformes, vol 1. 2 vols. Oxford University Press, Karachi

Shannon CE (1948) A mathematical theory of communication. Bell Syst Tech J 27:379–423, 623–656

Singh H (2002) Indian Pitta Pitta brachyuran in the Thar Desert. J Bombay Nat Hist Soc 101(2). 2004:319–320

Singh H (2005) Sighting of Sirkeer Malkoha (Phaenicophaeus rachyurania) in the Thar Desert. Zoo Print 20(6):1903

Singh H (2009) Changing avian diversity in Jodhpur, Western Rajasthan. In: Faunal ecology and conservation of the Great Indian Desert. Springer, Berlin/Heidelberg, pp 99–112

Singh H (2010) Invasion of garden species in the Thar Desert. In: Impact of climate change on biodiversity and challenges in the Thar Desert. Golden Jubilee of DRS, ZSI pp 277–288

Sivaperuman C, Kumar S, Rathore NS (2004) Avifauna of Desert Regional station, Zoological Survey India. Campus, Jodhpur, Rajasthan. Zoo's Print J 19(12):1718–1719

Sorenson T (1948) A method of establishing groups of equal amplitude in plant society based on similarity of species content. K Danske Vidensk Selsk 5:1–34

Whistler H (1938) The ornithological survey of Jodhpur State. J Bombay Nat Hist Soc 40:213–235

18 Galloanserae and Aquatic Neoaves of Pong Dam Wetland, Himachal Pradesh: Status and Conservation Issues

Anil Kumar and Rahul Paliwal

Abstract

The Pong Dam wetland located in Beas River in Kangra district of the Himachal Pradesh is known for its rich and diverse aquatic birdlife and one of the important Ramsar sites in India. This article aimed to review the present status of Galloanserae and aquatic Neoaves in context with their conservation issues. It is based on information generated through field surveys of this wetland and adjacent areas and published literature. A total of 165 species of aquatic birds belonging to 2 clades (namely, Galloanserae and Neoaves), 9 orders and 26 families were recorded. Of these, 30.3 % were very rare and 35.15 % rare, followed by 19.4 % common and 4.24 % very common species. Only 7.88 % species including thousands of goose and ducks and some Neoaves were abundant. The status of 3.03 % species was uncertain and their occurrence seems doubtful. Pong Dam wetland is also facing anthropogenic pressure in the form of urbanization/settlements, unplanned agriculture and resource extraction.

Keywords

Pong Dam • Himachal Pradesh • Aquatic birds • Galloanserae • Conservation

Introduction

Wetlands are aquatic habitats, which comprise a wide variety of forms and are found throughout the country. The significance of these habitats has been increasingly recognized in recent years. The Pong Dam wetland (32°01′N 76°05′E) is created as a water storage reservoir impounded across Beas River primarily for irrigation and hydroelectric power generation in Kangra district of the state of Himachal Pradesh (Fig. 18.1). Created in 1975, the dam is also known as Maharana Pratap Sagar Dam (Islam and Rahmani 2004). It is a 133 m tall and 1,951 m long earth-fill embankment dam with a gravel shell with 13.72 m wide crest and 610 m wide base at an elevation

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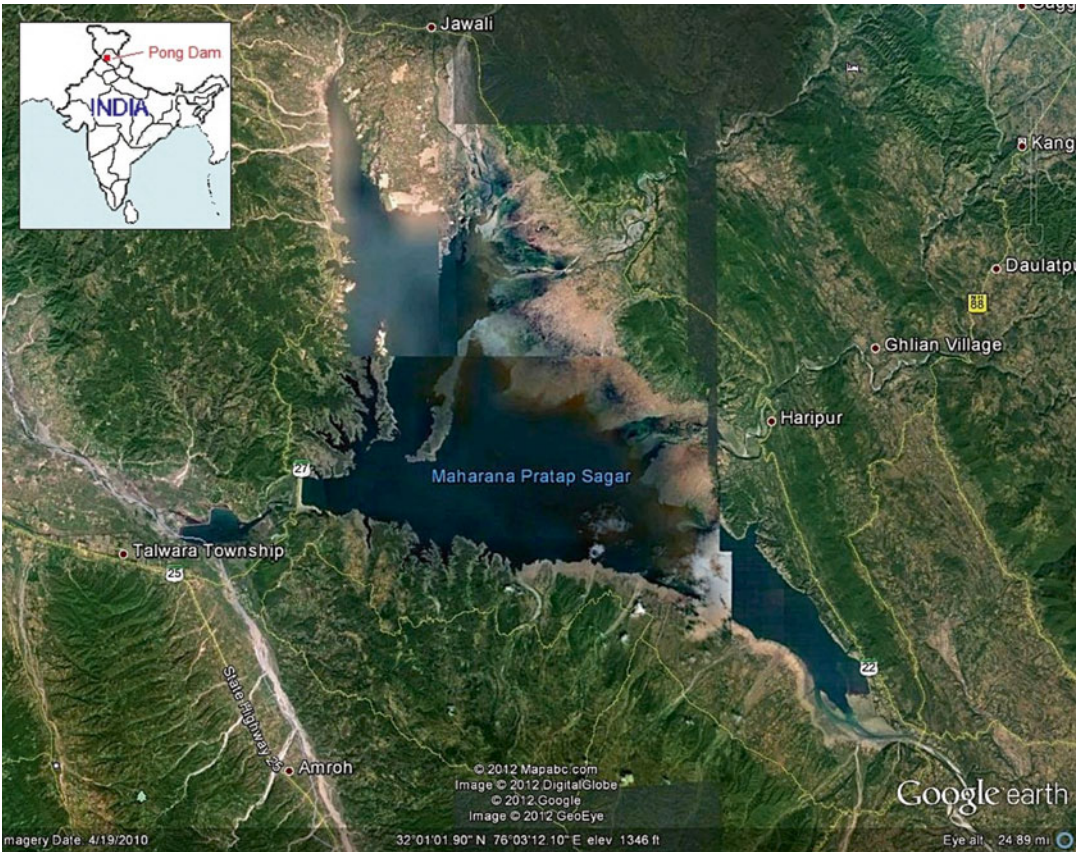

Fig. 18.1 Imagery of the Pong Dam wetlands, Himachal Pradesh

of 426.72 m. The catchment area of reservoir is 12,560 km^2 with a 35,500,000 m^3 maximum water holding capacity. The reservoir span is about 42 km in length and covers a surface of 260 km^2. Monsoon rains between July and September are a major source of water supply into the reservoir, apart from snow and glacier melt from Dhauladhar ranges (Editor-Director 2009). The reservoir or the lake is a well-known wildlife sanctuary and is one of the 25 international wetland sites recognized in India by the Ramsar Convention. The reservoir was declared as a bird sanctuary in 1983. The national and global significance of the sanctuary is enhanced due to its aquatic bird diversity (Kumar 2011). In terms of wildlife and faunal distribution, the outlet of the dam and water-logged area adjacent to the dam are also included in Pong Dam wetland as it significantly supports to the fauna of the area. The peripheral land area of the reservoir has mixed evergreen and deciduous pine forests on surrounding hills. Eucalyptus trees have also been grown in the area. The forest growth provides enough sustenance to the migratory birds. The tree species of the forest area are *Acacia* sp., *Syzygium cumini*, *Dalbergia sissoo*, *Mangifera indica*, *Morus* sp., *Ficus*, *Bauhinia variegata*, *Phyllanthus emblica* and *Prunus*. A variety of shrubs, grasses and climbers are also abundant in the forested tracts. Seasonal water-level fluctuation of the reservoir between the maximum and the minimum levels does not permit significant growth of hydrophytes; however some amount of vegetation has been noticed in marshy puddles and pools downstream.

Table 18.1 Summary of the faunal groups reported so far in the Pong Dam wetland area (Editor-Director 2009)

Faunal group	Taxa covered	No. of Genera/families	Number of species
Oligochaeta	Earthworms	09	12
Odonata	Dragonflies and damselflies	10	15
Orthoptera	Grasshoppers, crickets and grouse locusts	35	38
Lepidoptera	Butterflies	37	52
Pisces	Fishes	32	57
Amphibia	Frogs and toads	07	08
Reptilia	Lizards, snakes and tortoises	14	15
Aves	Birds	65[a]	412
Total species			**609**

[a]Families

The reservoir attracts a sizeable number of migratory birds from the plains of India and Central Asian countries owing to its strategic location in the extreme north-west of the northern plains and carrying capacity. The interception of the birds on their trans-Himalayan flyways, during each migratory season, has enriched the biodiversity values of the reservoir. More than 412 avian species of 65 families have been recorded (Pandey 1989, 1993; Editor-Director 2009). A wide variety of commercial fish, such as *Tor putitora*, *Catla catla*, *Cyprinus* sp. and others, are recorded in the Pong Dam reservoir and its tributaries (Negi 2008). The Pong sanctuary supports wildlife, including *Muntiacus muntjak*, *Rusa unicolor*, *Vulpes bengalensis*, *Sus scrofa*, *Prionailurus viverrinus*, *Boselaphus tragocamelus*, *Hystrix indica* and *Panthera pardus* and a variety of reptiles. The Pong Reservoir is one of the two most important fishing reservoirs in the Himalayan foothills of Himachal Pradesh. These reservoirs are the leading sources of fish in Western Himalaya (Negi 2008). Apart from the major faunal elements as mentioned above, the wetland and its catchment area also support the diversity and distribution of a large number of other faunal groups (Table 18.1). As in most other wetlands of the country, Pong Dam wetland is also facing almost similar conservation problems. It prompted us to review the present status of aquatic Neoaves and Galloanserae in context with their conservation issues, so that preventive measures could be framed, to conserve and sustain the aquatic biodiversity of this globally important wetland.

Methods

This article is based on the published literature and information generated through field surveys of Pong Dam wetland and adjacent areas undertaken by RP (second author) during the last decade and some recent opportunistic surveys undertaken by AK (first author) during the last 2 years. During the field surveys, observations on birds were made every day during 6:00 a.m. to 4:00 p.m. (with few exceptions), with the help of prismatic field binoculars (10 × 50), and the identification of species was carried out with the help of *A Field Guide to the Birds of India* written by Kazmierczak (2000) and a *Pocket Guide to the Birds of the Indian Subcontinent* by Grimmett et al. (2003).

In the present article, avian species of two clades (i.e. Galloanserae and Neoaves) were studied and analysed. Recently, the higher taxonomy of birds has changed significantly (Hackett et al. 2008; Mayr 2011). Now orders Anseriformes and Galliformes fall in a distinct clade named as Galloanserae (Montgomerie and Briskie 2007; Brennan et al. 2008; Mayr 2008) and the remaining orders under superorder Neognathae covered in Neoaves (sister clade of Galloanserae). We included Galloanserae in the present study, as it comprised of a most significant group of birds, i.e. ducks (family Anatidae), and family Phasianidae as the birds of this group often exhibit their presence near wetlands. The rest of the aquatic birds of Pong Dam belong to Neoaves. We included raptors (family Accipitridae) and kingfishers (order Coraciiformes) as many of them belong to aquatic/ marsh habitats. Recent taxonomic changes (Mayr 2011) and conservation status (IUCN 2012) of the species have been incorporated in the study. The abundance of the species is based on the number of individuals of each species recorded/reported at Pong Dam wetland during last few years. The number of individuals of a species <10 was treated as very rare, followed by 11–100 as rare, 101–1,000 as common, 1,001–5,000 as very common and >5,000 as abundant.

Results and Discussion

Avian Diversity

A total of 165 species of aquatic birds belonging to two clades (i.e. Galloanserae and Neoaves), 9 orders and 26 families were recorded (Tables 18.2 and 18.3). Of these, 30.3 % were very rare and 35.15 % rare, followed by 19.4 % common and 4.24 % very common species

Table 18.2 List of the Galloanseraes of Pong Dam wetlands

Sl. no.	Name of the species	Scientific name	Status (IUCN)	Abundance at Pong Dam
Order: Galliformes				
Family: Phasianidae				
1	Black francolin	*Francolinus francolinus*	LC	2
2	Grey francolin	*Francolinus pondicerianus*	LC	3
3	Common quail	*Coturnix coturnix*	LC	2
4	Rain quail	*Coturnix coromandelica*	LC	1
5	Jungle bush quail	*Perdicula asiatica*	LC	2
6	Red junglefowl	*Gallus gallus*	LC	2
7	Kalij pheasant	*Lophura leucomelanos*	LC	1
8	Indian peafowl	*Pavo cristatus*	LC	2
Order: Anseriformes				
Family: Anatidae				
9	Lesser whistling duck	*Dendrocygna javanica*	LC	2
10	Greylag goose	*Anser anser*	LC	3
11	Greater white-fronted goose	*Anser albifrons*	LC	2
12	Bar-headed goose	*Anser indicus*	LC	5
13	Common shelduck	*Tadorna tadorna*	LC	2
14	Ruddy shelduck	*Tadorna ferruginea*	LC	4
15	Falcated duck	*Anas falcata*	NT	1
16	Gadwall	*Anas strepera*	LC	4
17	Eurasian widgeon	*Anas penelope*	LC	5
18	Mallard	*Anas platyrhynchos*	LC	4
19	Spot-billed duck	*Anas poecilorhyncha*	LC	3
20	Northern shoveler	*Anas clypeata*	LC	5
21	Northern pintail	*Anas acuta*	LC	5
22	Garganey	*Anas querquedula*	LC	4
23	Common teal	*Anas crecca*	LC	5
24	Red-crested pochard	*Netta rufina*	LC	3
25	Common pochard	*Aythya ferina*	LC	5
26	Ferruginous duck	*Aythya nyroca*	NT	2
27	Tufted duck	*Aythya fuligula*	LC	5
28	Greater scaup	*Aythya marila*	LC	1
29	Goosander	*Mergus merganser*	LC	2

LC least concern, *NT* near threatened

Table 18.3 List of the aquatic Neoaves (including raptors and kingfishers) of Pong Dam wetlands

Sl. no.	Name of the species	Scientific name	Status	Abundance at Pong Dam
Order: Podicipediformes				
Family: Podicipedidae				
1	Little grebe	*Tachybaptus ruficollis*	LC	3
2	Red-necked grebe	*Podiceps grisegena*	LC	?
3	Great crested grebe	*Podiceps cristatus*	LC	3
4	Horned grebe	*Podiceps auritus*	LC	1
5	Black-necked grebe	*Podiceps nigricollis*	LC	2
Order: Ciconiiformes				
Family: Ciconiidae				
6	Painted stork	*Mycteria leucocephala*	NT	2
7	Asian openbill	*Anastomus oscitans*	LC	1
8	Black stork	*Ciconia nigra*	LC	2
9	Woolly necked stork	*Ciconia episcopus*	LC	2
Family: Threskiornithidae				
10	Eurasian spoonbill	*Platalea leucorodia*	LC	2
Family: Ardeidae				
11	Yellow bittern	*Ixobrychus sinensis*	LC	1
12	Cinnamon bittern	*Ixobrychus cinnamomeus*	LC	1
13	Black bittern	*Dupetor flavicollis*	LC	1
14	Black-crowned night heron	*Nycticorax nycticorax*	LC	2
15	Indian pond heron	*Ardeola grayii*	LC	2
16	Cattle egret	*Bubulcus ibis*	LC	4
17	Grey heron	*Ardea cinerea*	LC	3
18	Purple heron	*Ardea purpurea*	LC	2
19	Great egret	*Ardea alba*	LC	3
20	Intermediate egret	*Egretta intermedia*	LC	2
21	Little egret	*Egretta garzetta*	LC	3
Order: Pelecaniformes				
Family: Pelecanidae				
22	Dalmatian pelican	*Pelecanus crispus*	VU	?
Family: Phalacrocoracidae				
23	Little cormorant	*Phalacrocorax niger*	LC	5
24	Indian cormorant	*Phalacrocorax fuscicollis*	LC	1
25	Great cormorant	*Phalacrocorax carbo*	LC	5
Family: Anhingidae				
26	Oriental darter	*Anhinga melanogaster*	NT	1
Order: Falconiformes				
Family: Falconidae				
27	Common kestrel	*Falco tinnunculus*	LC	2
28	Red-necked falcon	*Falco chicquera*	LC	1
29	Eurasian hobby	*Falco subbuteo*	LC	2
30	Saker falcon	*Falco cherrug*	EN	1
31	Peregrine falcon	*Falco peregrinus*	LC	2
Family: Accipitridae				
32	Crested honey buzzard	*Pernis ptilorhynchus*	LC	2
33	Black-winged kite	*Elanus caeruleus*	LC	2
34	Black kite	*Milvus migrans*	LC	3

(continued)

Table 18.3 (continued)

Sl. no.	Name of the species	Scientific name	Status	Abundance at Pong Dam
35	Brahminy kite	*Haliastur indus*	LC	?
36	Pallas's fish eagle	*Haliaeetus leucoryphus*	VU	1
37	White-tailed eagle	*Haliaeetus albicilla*	LC	1
38	Egyptian vulture	*Neophron percnopterus*	EN	3
39	Indian white-backed vulture	*Gyps bengalensis*	CR	2
40	Slender-billed vulture	*Gyps tenuirostris*	CR	2
41	Himalayan vulture	*Gyps himalayensis*	LC	2
42	Griffon vulture	*Gyps fulvus*	LC	2
43	Red-headed vulture	*Sarcogyps calvus*	CR	2
44	Cinereous vulture	*Aegypius monachus*	NT	1
45	Short-toed snake eagle	*Circaetus gallicus*	LC	1
46	Crested serpent eagle	*Spilornis cheela*	LC	1
47	Western marsh harrier	*Circus aeruginosus*	LC	2
48	Hen harrier	*Circus cyaneus*	LC	1
49	Pallid harrier	*Circus macrourus*	NT	1
50	Pied harrier	*Circus melanoleucos*	LC	1
51	Shikra	*Accipiter badius*	LC	2
52	Besra	*Accipiter virgatus*	LC	1
53	Eurasian sparrowhawk	*Accipiter nisus*	LC	2
54	Northern goshawk	*Accipiter gentilis*	LC	1
55	White-eyed buzzard	*Butastur teesa*	LC	2
56	Common buzzard	*Buteo buteo*	LC	1
57	Long-legged buzzard	*Buteo rufinus*	LC	2
58	Black eagle	*Ictinaetus malayensis*	LC	1
59	Greater spotted eagle	*Aquila clanga*	VU	1
60	Tawny eagle	*Aquila rapax*	LC	1
61	Steppe eagle	*Aquila nipalensis*	LC	2
62	Eastern imperial eagle	*Aquila heliaca*	VU	1
63	Bonelli's eagle	*Hieraaetus fasciatus*	LC	1
64	Booted eagle	*Hieraaetus pennatus*	LC	1
Family: Pandionidae				
65	Osprey	*Pandion haliaetus*	LC	2
Family: Rallidae				
66	Water rail	*Rallus aquaticus*	LC	1
67	Brown crake	*Amaurornis akool*	LC	2
68	White-breasted waterhen	*Amaurornis phoenicurus*	LC	2
69	Baillon's crake	*Porzana pusilla*	LC	1
70	Ruddy-breasted crake	*Porzana fusca*	LC	1
71	Purple swamphen	*Porphyrio porphyrio*	LC	3
72	Common moorhen	*Gallinula chloropus*	LC	3
73	Common coot	*Fulica atra*	LC	5
Order: Gruiformes				
Family: Gruidae				
74	Demoiselle crane	*Anthropoides virgo*	LC	2
75	Sarus crane	*Grus antigone*	VU	3
Family: Turnicidae				
76	Barred buttonquail	*Turnix suscitator*	LC	2

(continued)

Table 18.3 (continued)

Sl. no.	Name of the species	Scientific name	Status	Abundance at Pong Dam
Order: Charadriiformes				
Family: Burhinidae				
77	Eurasian stone curlew	*Burhinus oedicnemus*	LC	2
78	Great stone curlew	*Esacus recurvirostris*	LC	3
Family: Haematopodidae				
79	Eurasian Oystercatcher	*Haematopus ostralegus*	LC	1
Family: Recurvirostridae				
80	Black-winged stilt	*Himantopus himantopus*	LC	3
81	Pied avocet	*Recurvirostra avosetta*	LC	2
Family: Charadriidae				
82	Northern lapwing	*Vanellus vanellus*	LC	3
83	River lapwing	*Vanellus duvaucelii*	NT	3
84	Yellow-wattled lapwing	*Vanellus malabaricus*	LC	2
85	Red-wattled lapwing	*Vanellus indicus*	LC	3
86	White-tailed plover	*Vanellus leucurus*	LC	1
87	Pacific golden plover	*Pluvialis fulva*	LC	2
88	Grey plover	*Pluvialis squatarola*	LC	1
89	Common ringed plover	*Charadrius hiaticula*	LC	1
90	Little ringed plover	*Charadrius dubius*	LC	4
91	Kentish plover	*Charadrius alexandrinus*	LC	3
92	Lesser sand plover	*Charadrius mongolus*	LC	1
93	Greater sand plover	*Charadrius leschenaultii*	LC	?
Family: Rostratulidae				
94	Greater painted snipe	*Rostratula benghalensis*	LC	1
Family: Jacanidae				
95	Pheasant-tailed jacana	*Hydrophasianus chirurgus*	LC	1
Family: Scolopacidae				
96	Jack snipe	*Lymnocryptes minimus*	LC	1
97	Pintail snipe	*Gallinago stenura*	LC	1
98	Common snipe	*Gallinago gallinago*	LC	3
99	Black-tailed godwit	*Limosa limosa*	NT	1
100	Whimbrel	*Numenius phaeopus*	LC	1
101	Eurasian curlew	*Numenius arquata*	NT	2
102	Spotted redshank	*Tringa erythropus*	LC	2
103	Common redshank	*Tringa totanus*	LC	3
104	Marsh sandpiper	*Tringa stagnatilis*	LC	1
105	Common greenshank	*Tringa nebularia*	LC	3
106	Green sandpiper	*Tringa ochropus*	LC	3
107	Wood sandpiper	*Tringa glareola*	LC	3
108	Terek sandpiper	*Xenus cinereus*	LC	2
109	Common sandpiper	*Actitis hypoleucos*	LC	3
110	Ruddy turnstone	*Arenaria interpres*	LC	2
111	Little stint	*Calidris minuta*	LC	2
112	Temminck's stint	*Calidris temminckii*	LC	5
113	Curlew sandpiper	*Calidris ferruginea*	LC	2
114	Dunlin	*Calidris alpina*	LC	2
115	Ruff	*Philomachus pugnax*	LC	2
116	Red-necked phalarope	*Phalaropus lobatus*	LC	1

(continued)

Table 18.3 (continued)

Sl. no.	Name of the species	Scientific name	Status	Abundance at Pong Dam
Family: Glareolidae				
117	Oriental pratincole	*Glareola maldivarum*	LC	1
118	Little pratincole	*Glareola lactea*	LC	5
Family: Laridae				
119	Common gull	*Larus canus*	LC	1
120	Caspian gull	*Larus cachinnans*	LC	2
121	Lesser black-backed gull	*Larus fuscus*	LC	?
122	Pallas's gull	*Ichthyaetus ichthyaetus*	LC	3
123	Brown-headed gull	*Chroicocephalus brunnicephalus*	LC	3
124	Black-headed gull	*Chroicocephalus ridibundus*	LC	4
125	Slender-billed gull	*Chroicocephalus genei*	LC	1
126	Little gull	*Hydrocoloeus minutus*	LC	1
127	Gull-billed tern	*Gelochelidon nilotica*	LC	3
128	River tern	*Sterna aurantia*	NT	5
129	Little tern	*Sterna albifrons*	LC	2
130	Black-bellied tern	*Sterna acuticauda*	EN	2
131	Whiskered tern	*Chlidonias hybridus*	LC	3
Family: Rynchopidae				
132	Indian skimmer	*Rynchops albicollis*	VU	2
Order: Coraciiformes				
Family: Halcyonidae				
133	White-throated kingfisher	*Halcyon smyrnensis*	LC	3
Family: Alcedinidae				
134	Common kingfisher	*Alcedo atthis*	LC	2
Family: Cerylidae				
135	Crested kingfisher	*Megaceryle lugubris*	LC	2
136	Pied kingfisher	*Ceryle rudis*	LC	3

LC least concern, *NT* near threatened, *VU* vulnerable, *EN*, endangered, *CR* critically endangered, and *?* occurrence of the species is doubtful

(Fig. 18.2). Only 7.88 % species including thousands of geese and ducks (namely, bar-headed goose *Anser indicus*, northern shoveler *Anas clypeata*, northern pintail *Anas acuta*, common teal *Anas crecca*, common pochard *Aythya ferina* and tufted duck *Aythya fuligula*) and some Neoaves (namely, little cormorant *Phalacrocorax niger*, great cormorant *Phalacrocorax carbo*, common coot *Fulica atra*, little pratincole *Glareola lactea* and river tern *Sterna aurantia*) were abundant. Large flocks of wintering bar-headed goose are the major attraction for most ornithologists/birdwatchers (Fig. 18.3a, b) since this is one of the most abundant and graceful species of Pong wetland. However, in recent years, the population of this species has declined as compared to the previous years. A rare species of goose, namely, greater white-fronted goose *Anser albifrons*, was also observed (Fig. 18.4). Some species such as common pochard *Aythya ferina* (Fig. 18.5) and great cormorant *Phalacrocorax carbo* (Fig. 18.6) were seen in large flocks. Slender-billed gull *Chroicocephalus genei* is an occasional winter visitor at this wetland. Only a few individuals were seen in different morphs (Fig. 18.7a, b). This wetland is also preferred by a number of waders most probably due to availability of large mud flats. About 12 species of both migratory and resident lapwings and plovers have been reported from the area. Red-wattled lapwing *Vanellus indicus* is a common resident, while northern lapwing *Vanellus*

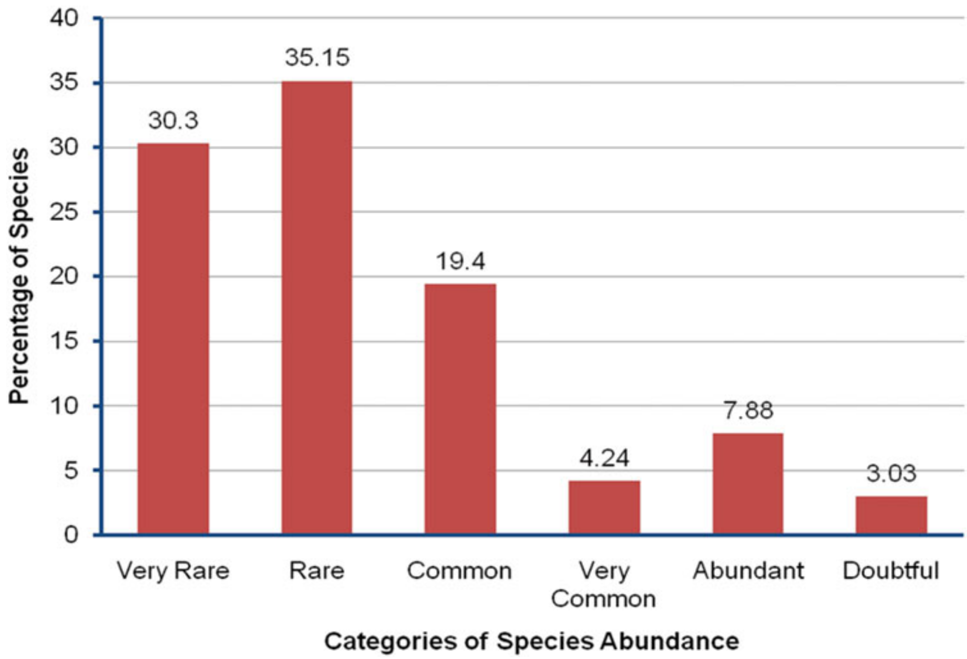

Fig. 18.2 Percentage of the species based on categories of abundance

vanellus (Fig. 18.8) visits during winter. The status of 3.03 % species such as red-necked grebe *Podiceps grisegena*, dalmatian pelican *Pelecanus crispus*, brahminy kite *Haliastur indus*, greater sand plover *Charadrius leschenaultii* and lesser black-backed gull *Larus fuscus* was uncertain, and their occurrence seems doubtful.

On the basis of the IUCN conservation status, out of 165 avian species, 1.82 % species belong to Critically Endangered category, followed by 1.82 % Endangered, 3.63 % Vulnerable and 6.06 % Near Threatened (Fig. 18.9). About 86 % species were falling under Least Concern category. Most endangered and critically endangered species of birds recorded in the present study belong to vultures and falcons (Table 18.3) except black-bellied tern *Sterna acuticauda*. However, abundance of these species was very low. Ransar Island of the reservoir was used by thousands of river tern *Sterna aurantia* for breeding. It is being treated as a safe nesting site by this 'near-threatened' species of tern. It enhances the significance of this wetland for conservation point of view. Sightings of some rare species of birds such as Falcated duck *Anas falcata*, Ferruginous duck *Aythya nyroca*, Saker falcon *Falco cherrug*, black-tailed godwit *Limosa limosa* and Eurasian curlew *Numenius arquata* make the wetland one of the most significant wetlands in India.

Recently, during the waterfowl census 2013 (conducted on 31 January to 1 February 2013), a very rare winter visitor whooper swan has been sighted after a gap of 113 years in this wetland. Another species ruddy-breasted crake was also recorded for the first time from Pong wetland. Recent waterfowl census data revealed the prominence of about 34,000 individuals of bar-headed goose, followed by 21,000 northern pintail, 14,000 common coot, 12,000 common pochard, 8,000 tufted pochard, 7,700 little cormorant and 6,800 common teal. Now the total number of avian species listed so far from the wetland and surroundings is 418 (source: http://www.millenniumpost.in, 1 February 2013, Dharamsala, Agencies).

Fig. 18.3 (**a**) Flock of bar-headed goose *Anser indicus* foraging on grass leaves. (**b**) Flock of bar-headed goose during the flight in wheat crop fields

Fig. 18.4 Flock of greater white-fronted goose *Anser albifrons* in Pong Dam area

Fig. 18.5 Large flock of common pochard *Aythya ferina*

Fig. 18.6 Individuals of great cormorant *Phalacrocorax carbo* and river tern *Sterna aurantia* are basking on the shores of reservoir

Conservation Issues

As in the case of other wetland habitats in the country, Pong Dam wetland is also facing anthropogenic pressure in the form of various activities such as urbanization/settlements, unplanned agricultural development, resource extraction (fish culture), indirect pollution (through insecticides used in agriculture) and disposal of waste. However, situation is not so grim as in other parts of the country. But climate change may emerge as serious concern threatening biodiversity in near future owing to increasing trends in air temperature, irregular precipitation and decreased carbon sequestration.

Pong Dam wetland is known to host a sizeable population of bar-headed goose during winter in India. This species migrates over the Himalaya to spend the winter in many parts of South Asia. The foraging habitat of the bar-headed goose is cultivated fields adjoining to wetlands, where it feeds on barley, paddy and wheat, and may damage crops. At Pong wetland, they usually feed on grasses on the peripheral area of reservoir. Every year, after the end of rainy season (July to September), water level of the reservoir recedes; consequently the submersed shallow peripheral areas are exposed. These areas are being used by local people for the cultivation of wheat. The tender leaves of the wheat allure the bar-headed goose in large number. It has been observed that locals usually dislike the foraging of bar-headed goose on their crop. For prevention often they use loose thread nets/reflecting objects in fields or produce noise by different means. This practice makes the birds very scared and restless. It is not only harmful for geese, but many other birds also feel very unsafe and scared. If it is not prevented, the Pong Dam might not be a preferable wintering ground for these birds. It may lead to decrease in species diversity and richness. Occasional

Fig. 18.7 Slender-billed Gull *Chricocephalus genei*. (**a**) Adult individual, (**b**) 1st Year winter individual

Fig. 18.8 Northern lapwing *Vanellus vanellus* is a winter migrant of Pong Dam

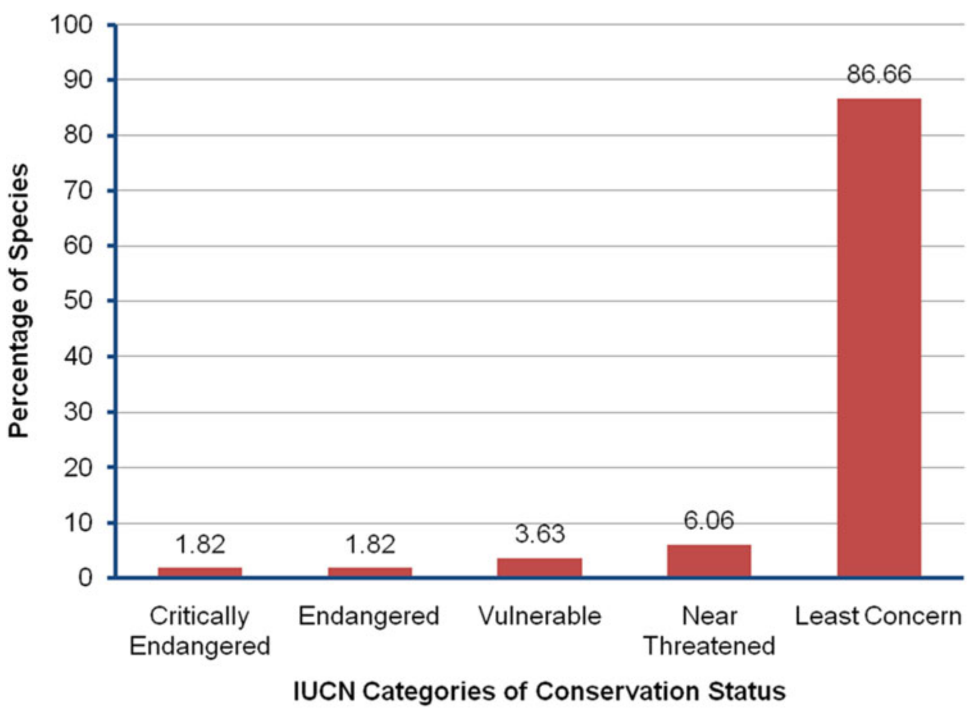

Fig. 18.9 Bar diagram showing the percentage of species under IUCN conservation categories

poaching is also perceived in the area. Resource extraction in the form of fishing is another threat for aquatic birds since reservoir is being used for fish culture. It directly/indirectly imposes an adverse impact on birds.

The conservation efforts of Himachal Pradesh Forest Department (HPFD) are worth appreciating. In 1986, the entire reservoir was declared as a wildlife sanctuary by the HPFD. A management plan has been developed for the sustainability, conservation and management of birds of Pong Dam Bird Sanctuary. The HPFD has undertaken plantation work in the peripheral area of the reservoir. The island of Ransar has been developed for nature conservation education. However, the use of this island may be avoided for any human activities as it is the safe breeding site for thousands of river terns, which is a near-threatened avian species. Every year, during the last week of January, with the support of various govt./non-govt. organizations, birdwatchers and ornithologists, HPFD organizes the aquatic bird census programme. It is not only useful to collect the yearly data on bird diversity but also helpful to monitor wetland-related threats in addition to creating awareness among local people. In the last it can be concluded that Pong Dam is one of the most important wetland habitats in the country. To understand the impact of climate change on bird migration, the Pong Dam may act as suitable field site for such studies. All necessary measures should be adopted to conserve and sustain the avian diversity of this wetland.

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References

Brennan PLR, Birkhead TR, Zyskowski K, van der Waag J, Prum RO (2008) Independent evolutionary reductions of the phallus in basal birds. J Avian Biol 39:487–492

Editor-Director (2009) Faunal diversity of Pong Dam and its catchment area, Wetland ecosystem series 12, pp 1–138. Published by the Director, Zoological Survey of India, Kolkata

Grimmett R, Inskipp C, Inskipp T (2003) Pocket guide to the birds of the Indian subcontinent. Oxford University Press, New Delhi

Hackett SJ, Kimball RT, Reddy S, Bowie RCK, Braun EL, Braun MJ, Chojnowski JL, Cox WA, Han KL, Harshman J, Huddleston CJ, Marks BD, Miglia KJ, Moore WS, Sheldon FH, Steadman DW, Witt CC, Yuri T (2008) A phylogenomic study of birds reveals their evolutionary history. Science 320:1763–1768

Islam MZ, Rahmani AR (2004) Important bird areas in India: priority sites for conservation. Indian Bird Conservation Network: Bombay Natural History Society and BirdLife International, Oxford, pp xviii + 1133

IUCN (2012) IUCN red list of threatened species. Version 2012.2. www.iucnredlist.org. Downloaded on 23 Jan 2013

Kazmierczak K (2000) A field guide to the birds of India. Om Book Service, Darya Ganj, New Delhi

Kumar A (2011) Pong Dam Wetlands and Zoological Survey of India. Curr Sci 85(10):1398

Mayr G (2008) Avian higher-level phylogeny: well-supported clades and what we can learn from a phylogenetic analysis of 2954 morphological characters. J Zool Syst Evol Res 46:63–72

Mayr G (2011) Metaves, Mirandornithes, Strisores and other novelties – a critical review of the higher-level phylogeny of neornithine birds. J Zool Syst Evol Res 49(1):58–76

Montgomerie R, Briskie JV (2007) Anatomy and evolution of copulatory structures. In: Jamieson BGM (ed) Reproductive biology and phylogeny of birds. Science Publishers Inc., Enfield, pp 115–148

Negi RK (2008) Impact of hydrological projects on the fishing of Pongdam reservoir wetland and Gobindsagar reservoir in Himachal Pradesh (India). In: Sengupta M, Dalwani R (eds) Proceedings of Taal 2007: the 12th world lake conference, pp 2001–2008, Jaipur, India

Pandey S (1989) The birds of Pong Dam Lake bird sanctuary. Tiger Paper 16(2):20–26

Pandey S (1993) Changes in waterbird diversity due to the conservation of Pong Dam Reservoir, Himachal Pradesh, India. Biol Conserv 66(2):125–130

Living with Wetlands: A Case Study from the Wetlands (*Beels*) of Barpeta District, Assam

19

Prakash Sarma and Kiranmay Sarma

Abstract

This study was conducted in the wetlands of Barpeta District, Assam, to assess the chemical, biological parameters and biodiversity. Detailed chemical parameters, biological parameters of this wetlands and availability of biodiversity resources have been presented and conservation measures are discussed in this chapter.

Keywords

Wetland • Floodplain • Livelihood • Fishery • Assam

Introduction

Wetlands of floodplain provide valuable ecosystem services to society all over the world. From the time immemorial, there has been symbiotic association of man and aquatic ecosystem. The first sign of civilization is traced to wetland areas (Selvamani and Mahadevan 2008). The floodplains of the Indus, the Nile delta and the fertile crescent of the Tigris and Euphrates rivers are the footprint of modern civilizations. In India most of the natural wetlands are connected with the river system, and the management of this natural resource to meet people's requirements has been practiced since the pre-Vedic era (Dholakia 2004). Until recently, the special role played by fish and other aquatic resources as essential component of poor people's livelihoods has been almost ignored (Ramakrishna 2008). Fishery is one of the high-priority sectors of Indian economy. In the rural economy of Assam, the importance of fishery is next to agriculture (Baruah 1999). The sector contributes about 2.4 % of the state's net domestic product and provides employment to about 4.75 lakh persons. Although over 95 % of the population consumes fish, the state produces less than 50 % of her total requirement and as such the per capita consumption rate is less than 1.9 kg as to the national average of 5.0 kg. Assam produces about 53,000 tons of fish annually and 14 % of it comes from culture fishery; 40 % from wetlands (locally known as *beels*) and 46 % from the riverine resources (Statistical Hand Book of Assam 2001).

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Barpeta district of Assam has high potential for fishery development (Patowari 1983), with about 130 ha of cultured ponds and 1,560 ha of *beels*. Production from the riverine sources, over the years, remained stagnant due to various reasons and so also from the *beel*. Like other parts of the Brahmaputra floodplain zones of Assam, the southern part of Barpeta district was also once a place with very thin population because of its lowland character. These lowlands are full of aquatic resources (Sarma 2007; Patra 1990). The *beels* are in the verge of extinction due to high rate of encroachment of marginal population, high growth rate of weeds, siltation, blocking of mouth of the beels and other developmental activities in and around the wetlands carried out during the last few decades (Bhuyan et al. 2009). However, it can be recognized as a potential source of high quantum of fish production for the state. The present study attempts to assess how the local livelihood issues are related to the natural resources base of the region and what ways people are adapting to the changing situation. The study also aims at exploring new avenues of livelihood in the background of shrinking resource base though the role of aquatic resources have appeared quite promising as the income source. Apart from this, the study will examine to what extent the people of the district can be able to depend on existing aquatic resources as their perennial income source in the socioeconomic regional framework. Also attempt has been made to understand whether the aquatic sector has the potentiality to stand as an alternative to livelihood in the phase of diminutive agriculture.

The studies related to the culture and livelihoods generated from the wetlands have become a global concern (William and Comish 2008). Small-scale fisheries provide employment for millions of fisheries directly engaged in fishing activities, including rural aquaculture, and for millions more working fishery-related activities such as processing and marketing, boat building and net making (FAO 2008). The aquaculture has significant role in eradicating the hunger and poverty among the villagers which are solely dependent on wetland resources. However, a policy framework is essential for the long-term sustainability of the world's fisheries and the long-term employment of those who rely on the aquaculture industry for their livelihoods (Haylor 2004). Tengo and Belfrage (2004) summarized complex relationship between the different levels of interventions in connection among wetlands' functions, uses and values. In India the poorest sector of the society are mostly engaged in the fishery sector (DFID 2003). It is encouraging that besides other resources even the wetland weeds also could be commercially utilized for their rare, endangered, threatened and vulnerable status. These all have been done in the wetlands of Gujarat (Dholakia 2004). For India it is highly necessary for the government to develop imaginative and practical way to enable fishing communities to be more self-sufficient (Ramakrishna 2008), whether through increase local control, health and education programmes or assistance with the development of sustainable livelihoods (IDRC 2008).

Methods

Study Area

The study area comprises of two developmental blocks of Barpeta district of Assam, viz., Barpeta and Paka-Betbari with 136 villages and few small growing service centres. The area is situated between 26°18′N to 26°28′N latitudes and 90°59′E to 91°13′E longitudes. The area is drained by Manas and Beki rivers which join in the south with the mighty river Brahmaputra. The Manas and Beki river systems have made the area fertile, and 95 % of the total population solely depends on agriculture. Due to the abundance of wetlands, about 3.5 % of the population are engaged in aquaculture and the remaining 1.5 % on livestock. River-induced lowlands are mostly common in the area. Being the braided nature of the channels, they always tend to shift their courses in accordance with the geological texture (Bora and Barman 1998). When a river shifts its courses, the abandoned channel appears as a lowland or *beel* (Bhagabati et al. 2007). At present 68.45 km^2 of the study area (22.58 %) are occupied

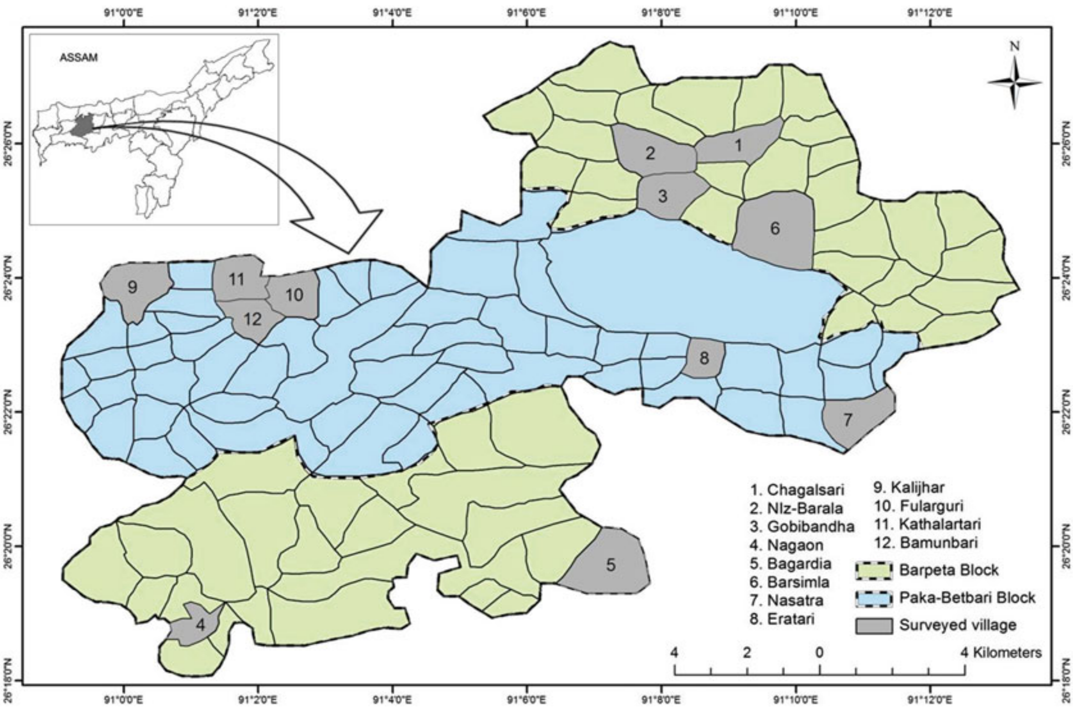

Fig. 19.1 Location of studied villages in Barpeta and Paka-Betbari blocks of Barpeta district of Assam

by *beels* (ARSAC 1990) and some important of them are Ghandhi, Baramara, Hahsara, Sigmara, Morachaulkhowa, Chichajan, Baira, Boha, Paghda, Korila, Raumari, Uri, Chagalsari, Halaldai, Golibandha, Finga and Bara.

Twelve villages have been selected for the present study, viz., Chagalsari, Niz Barala, Galibandha, Nagaon, Baragdia, Barsimla, Nasatra, Aratari, Kaljhar, Fularguri, Kathalartari and Bamunbari (Fig. 19.1). Household is the main unit of observation and stratified random sampling is used to extract the representative nature of the population. Structured questionnaires are framed to collect the field data. Besides, secondary data were collected from all the line departments. Physical, chemical and biological aspects of the wetlands were assessed to know their impacts on fish population. For the purpose, Ghandhi, Sigmara, Bara, Korila, Halaldai, Raumari, Baira, Boha, Paghda and Finga wetlands are considered.

Results and Discussions

Impact of Flood

The water is the vital ingredients for the survival of human being, but sometimes it may cause woe to the human life not due to insufficient water but due to abundant water which in turn causes the natural disaster like floods (Bhowmick 1999). The district of Barpeta is situated at the foothills of the Himalaya. Every year the district experiences a huge amount of losses due to devastating flood caused by the river Beki and Manas and its tributaries along with the river Brahmaputra. The problem of flood is perennial in the area, and the solution is difficult due to complex and devastating nature of the rivers during monsoon period. In this part of the study, socioeconomic impact of flood is taken into consideration in the two studied blocks and tried to find out the adaptability of the local people.

Table 19.1 Major flood-affected villages along with the tributaries of Manas and Beki rivers

Names of the rivers	Affected villages
Tihu	Eratari, Era gaon, Nawlarvitha, Era kasari para, Bamundi
Kaldia	Golibandha, Chagalsari, Debra, Kaimari, Bagana
Pahumara	Niz Barala, Chagalsari, Amda gaon, Amda Pathar, Chapar Bari, Bhera gaon
Palla	Kaljhar, Barbala, Kathalortari, Kujarpith
Chaulkhola	Sundardia, Major gaon, Bamuna, Patbausi
Buradia	Eratari, Rampur, Maripur

Table 19.2 Details of population affected (during 1980 and 2008)

Item	Number
Number of families affected	287
Total population affected	1,705
Male population	88
Female population	820
Children population (0–14)	721
Elderly person population (Above 60 years)	50

Table 19.3 Damages caused by flood in the study area (during 2003 and 2009)

Sl. No.	Damages	2003	2004	2005	2006	2007	2008	2009
1.	Area affected (ha)	24.3	34	26	31	27	30	20
2.	Cropped area affected (ha)	12.2	21	14	20	15	20	10
3.	No. of Village affected	35	40	37	39	38	38	30
4.	Population affected	45,000	55,000	49,000	51,000	49,500	50,000	32,000
5.	No. of cattle lost	18	26	20	26	26	6	–
6.	No. of house damaged	510	640	550	620	550	580	440
7.	Value of crops (Lakh)	3.5	5	3.3	4	2.3	4	2.5

The low-lying villages have become frequently victimized due to the danger of floods caused by the inundation of tributaries of Manas and Beki rivers (Table 19.1). Damaging houses, roads and silting in agriculture fields and *beels* are the common impact of flood which causes the degradation to the entire environment.

The main impacts of flood in the study area could be attributed to physical damage, cropped area affects, heavy siltation and reduction of water reservoir capacity, public and private property loss, effects of residential, commercial and industrial areas, human and livestock population loss, health damage, degradation to environment and socio-economic distresses (Tables 19.2, 19.3, and 19.4).

It is observed that the economic consequence is very large in terms of damage to property and loss of agricultural crops. Children and women are the worst sufferer of the flood, and displacements of the children from their locations will have worse impact on their education, health and livelihood. Due to siltation, several hectares of crop land have been converted into barren sandy land. Siltation in the low-lying water reservoirs affects the aquatic ecosystem in enormous ways. Even some wetlands have been converted into shallow crop fields due to heavy siltation. During the devastating flood in 2004, there were huge losses of properties. There were completely destroyed thatch houses which were the prominent house type in the area. Public properties like library, school buildings, hospital building, *Anganbadi* centre, temple and mosque were found lying damaged in Chagalsari and Barsimla villages. The flood water is the cause of the environment damage as it pollutes air, water and soil. The area is predominantly agro based, and rice, pulses, mustard and potato are extensively practiced. Advent of flood completely breaks the backbone of the economy of the area. Some of

Table 19.4 The percentage of the occupational structure

Sl. No.	Occupation	Percentage
1.	Agricultural labour	53.31
2.	Agriculturist	5.02
3.	Petty business	2.33
4.	Govt. job	0.74
5.	Factory workers	1.23
6.	Animal husbandry	36.76
7.	Caste based	0.61
Total		**100.00**

Table 19.5 Average income per month

Average income per month in Rupee	No. of villages
<500	72
500–1,000	35
1,000–1,500	10
1,500–2,000	8
2,000–2,500	4
2,500–3,000	3
>3,000	4
Total villages	136

Sources: Census of India 2001

the post flood problems turn the society into social disorder. Economic distresses due to flood compel male members of the family to migrate to distant places in search of employment. It is one of the important flood-related social problems in the rural areas. As per the present study, in the village, Golibandha alone, most of the school-goer children were dropped out and engaged as daily workers to quench their families. Flood damaged almost all agro-based survival potentialities and people who have no other substitute for survival except agriculture have to force to indulge antisocial malpractices like theft, robbery and so on.

Table 19.6 Educational status including illiterate

Literacy	Percentage
Primary level (up to class iv)	20.27
Middle school (up to class vii)	5.65
Secondary (up to class x)	13.26
Higher secondary	10.80
Graduation level	4.57
Professional (ITI)	0.32
Professional (diploma)	0.14
Professional (degree)	0.46
Postgraduation level	0.79
Illiterate	24.74
Total	**100**

Socioeconomic Impacts

Poverty is prevalent in the study area where more than 78 % of the populations earn less than Rs. 1,000 per month (Table 19.5). Some important characteristics of the economy of the study area could be slow growth of the income pattern, low per capita income, poor rate of capital formation, excessive dependence on primitive agriculture, population pressure and unemployment, shortage of technology and skills, lack of infrastructure, underutilization of natural resources and poverty (Tables 19.6, 19.7, and 19.8).

As per the Census Report of India, 2001, the annual income of 72 villages of Barpeta and Paka-Betbari development block is below Rupees 500/- per month which is remarkably low in present-day context. The main source of income is agriculture and this sector has been suffering from frequent floods. This is the main cause of the limited income of the inhabitants of the area.

Table 19.7 Human Poverty Index

Human Poverty Index	Percentage
Average life expectancy	55 years
Adult illiteracy	26.34
Access to health services	34.75
Access to safe water	65.82
Malnourished children under five	33.45

Table 19.8 Occupational status

Occupational status	Percentage
Nonworkers (age below 14 and above 65)	31.4
Farmers	14.15
Agricultural labourer	28.1
Casual labourer (works for wage)	5.87
Government service holders	7.3
Private services	4.7
Self-employed	6.1
Contractor	.3
Fishing/ hunting	2.08
Total	**100**

The decadal growth rate of population is 20 % during 1991–2001, which is still high. A rising population imposes greater economic burden, and consequently, society has to make a much greater effort to initiate the process of growth. The economically stressed populations are mostly concentrated in the low-lying areas and are never spared from flood hazards. As a result of that they are largely dependent on casual labour. These workers get low wages and are unable to find employment throughout the year. The position of agricultural marketing is still deplorable. Most of the farmers do not have facilities for storing his produce. The average farmer is so poor and indebted that he does not have the capacity to wait for better prices. He is forced to sell his output to the money lender or to the traders. Difficult terrain and lack of government attention are some of the basic factors which are responsible for poor transport and communication facilities. Maintenance of a clean administration is very essential for achieving sound level of development. But administrative machinery especially low-level hierarchy in rural area is neither efficient nor clean. The proportion of child population in the 0–14 age group was 45 % in 2001. The principal reason for a higher child population in the area is the high birth rate. The density of population in the study area rose to 190 persons per km^2 in 1931 and significantly jumped to 304.2 persons per km^2 in 2001. The situation in primary education as it is obtained today is that the study area has reached a gross enrolment level of 20.27 % at the primary level, but despite this, the rate of literacy achieved is only 56.26 %. In the case of rural females, the literacy rate is as low as 23 %. It is really socking that in some villages, female literacy is even below 12 %. Owing to the low-lying nature of the zone, people are victimized by the water-borne diseases like *jaundice, cholera*, *malaria* and pox. Health centres are not yet well developed in the respective area. It is noted that people of the flood-affected areas have learnt to live with the floods from their age-old practices and techniques, which need further studies and appreciation so that the people can have better output for a better living. A multilayered agricultural system could be recommended for the economic betterment of the society. In this system, wet paddy cultivation should be given priority in the flood-affected areas along with the implementation of aquaculture especially pisciculture in bigger ways than the existing practices.

Impacts of Physical, Chemical and Biological Aspects on Fish Productivity

The physical, chemical and biological information have relevance in fish production, and they play a major role in the overall improvement of fish productivity. The obtained data on these aspects are summarized hereunder.

Physical Aspects of Wetlands (*Beels*)

Depth (m): 0.9–3.4
Width (m): 85–200
Transparency (cm): 25.4–110.0
Water temperature (°C): 21–25

Chemical Aspects of Wetlands (*Beels*)

The details of the chemical characteristic of the wetlands are presented in Tables 19.9, 19.10, 19.11, 19.12, 19.13, 19.14, 19.15, 19.16, 19.17, and 19.18.

Biological Aspects of Wetlands (*Beels*)

Phytoplankton: 0.7–7.4 ml/100 l
Types:
Myxophyceae
Microcystis sp.
Chlorophyceae
Pediastrum duplex, Volvox sp.*, Sirogonium stictatum, Zygnema* sp.*, Eudorina* sp.*, Staurastrum* sp.*, Spirogyra* sp.*, Closterium* sp.
Chrysophyceae
Dinobryon sp.
Dinophyceae
Ceratium sp.
Zooplankton:0.85–3.5 ml/100 l
Types
Rotifera
Polyarthra vulgaris, Keratella cochlearis, Asplanchna priodonta, Asplanchna brightwelli, Brachionus sp.*, Trichocerca capucina, Horaela brehmii*
Copepoda

Table 19.9 Chemical aspects of Ghandhi wetland

	Amount present (mg.l^{-1} except p^{H})			
Parameters	Minimum	Maximum	Mean	Amplitude
p^{H}	6.4	7.9	7.1	1.5
Dissolved oxygen (DO)	6.5	7.5	7.0	1.0
Free carbon dioxide (FCO_2)	9.0	10.5	9.7	1.5
Total alkalinity	22.0	24.0	23.0	2.0
Total hardness	14.0	16.0	15.0	2.0

Table 19.10 Chemical aspects of Finga wetland

	Amount present (mg.l^{-1} except p^{H})			
Parameters	Minimum	Maximum	Mean	Amplitude
p^{H}	6.5	7.1	6.8	0.6
Dissolved oxygen (DO)	6.0	6.4	6.2	0.4
Free carbon dioxide (FCO_2)	12.0	14.0	13.0	2.0
Total alkalinity (TA)	26.0	30.0	28.0	4.0
Total hardness (TH)	27.0	32.0	29.5	5.0

Table 19.11 Chemical aspects of Paghda wetland

	Amount present (mg.l^{-1} except p^{H})			
Parameters	Minimum	Maximum	Mean	Amplitude
p^{H}	6.4	6.9	6.6	0.5
Dissolved oxygen (DO)	6.5	6.7	6.6	0.2
Free carbon dioxide (FCO_2)	4.0	7.5	5.7	3.5
Total alkalinity (TA)	34.0	38.0	36.0	4.0
Total hardness (TH)	14.0	20.0	17.0	6.0

Table 19.12 Chemical aspects of Boha wetland

	Amount present (mg.l^{-1} except p^{H})			
Parameters	Minimum	Maximum	Mean	Amplitude
p^{H}	6.0	7.0	6.5	1.0
Dissolved oxygen (DO)	6.4	7.5	6.9	1.1
Free carbon dioxide (FCO_2)	8.2	11.5	9.8	3.3
Total alkalinity (TA)	18.0	24.0	21.0	6.0
Total hardness (TH)	12.0	18.0	15.0	6.0

Table 19.13 Chemical aspects of Baira wetland

	Amount present (mg.l^{-1} except p^{H})			
Parameters	Minimum	Maximum	Mean	Amplitude
p^{H}	7.4	7.9	7.6	0.5
Dissolved oxygen (DO)	7.5	8.2	7.8	0.7
Free carbon dioxide (FCO_2)	0.0	1.5	0.7	1.5
Total alkalinity (TA)	25.0	30.0	27.5	5.0
Total hardness (TH)	14.0	18.0	16.0	4.0

Table 19.14 Chemical aspects of Raumari wetland

	Amount present ($mg.l^{-1}$ except p^H)			
Parameters	Minimum	Maximum	Mean	Amplitude
p^H	7.4	7.8	7.6	0.4
Dissolved oxygen (DO)	6.5	7.8	7.1	1.3
Free carbon dioxide (FCO_2)	8.0	11.0	9.5	3.0
Total alkalinity (TA)	22.0	24.0	23.0	2.0
Total hardness (TH)	12.0	16.0	14.0	4.0

Table 19.15 Chemical aspects of Halaldai wetland

	Amount present ($mg.l^{-1}$ except p^H)			
Parameters	Minimum	Maximum	Mean	Amplitude
p^H	5.2	5.9	5.5	0.7
Dissolved oxygen (DO)	6.8	7.5	7.1	0.7
Free carbon dioxide (FCO_2)	8.2	12.5	10.3	4.3
Total alkalinity (TA)	24.0	28.0	26.0	4.0
Total hardness (TH)	14.0	18.0	16.0	4.0

Table 19.16 Chemical aspects of Korila wetland

	Amount present ($mg.l^{-1}$ except p^H)			
Parameters	Minimum	Maximum	Mean	Amplitude
p^H	6.8	7.2	7.0	0.4
Dissolved oxygen (DO)	6.5	7.5	7.0	1.0
Free carbon dioxide (FCO_2)	10.0	11.5	10.7	1.5
Total alkalinity (TA)	22.0	28.0	25.0	6.0
Total hardness (TH)	13.0	16.0	14.5	3.0

Table 19.17 Chemical aspects of Bara wetland

	Amount present ($mg.l^{-1}$ except p^H)			
Parameters	Minimum	Maximum	Mean	Amplitude
p^H	6.4	7.8	7.1	1.4
Dissolved oxygen (DO)	6.2	6.8	6.5	0.4
Free carbon dioxide (FCO_2)	8.0	11.0	9.5	3.0
Total alkalinity (TA)	28.0	32.0	30.0	4.0
Total hardness (TH)	18.0	21.0	19.5	3.0

Table 19.18 Chemical aspects of Sigmara wetland

	Amount present ($mg.l^{-1}$ except p^H)			
Parameters	Minimum	Maximum	Mean	Amplitude
p^H	6.2	7.2	6.7	1.0
Dissolved oxygen (DO)	5.4	6.5	5.9	1.1
Free carbon dioxide (FCO_2)	8.0	12.0	10.0	4.0
Total alkalinity (TA)	23.0	28.0	25.5	5.0
Total hardness (TH)	21.0	27.0	24.0	6.0

Mesocyclops leuckarty, Mesocyclops hyalinus, Neodiaptomus sp., *Nauplius* (*calanoid*), *Nauplius* (*cyclopoid*)

Cladocera

Moina brachiata, Diaphanosoma sp., *Alona affinis, Bosmina longirostris*

Macrophytes: 2.1–7.2 ($\bar{x}$.4.65) kg/m^2

Category and Types

Submerged:

Vallisneria spiralis, Niasindica, Hydrilla verticillata, Trapa bispinosa

Floating Leaved:

Euryale ferox, Hygrorhiza sp.

Emergent:

Alpinia sp., *Alocasia* sp.

Floating:

Pistia sp., *E. crassipes, Salvinia* sp.

Fishes

Fish species composition recorded during the study period is presented in the Table 19.19. The major fish group constitutes about 55 % followed by intermediate group (25 %) and minor group (18 %) in the catch record. The non-piscean crustaceans, *Macrobrachium* sp., are also recorded. According to the fishermen of the locality, some fishes were abundant in the past, namely, *Nandus nandus, Gudusia chapra, Salmostoma bacaila, Rasbora elenga, Aspidoparia morar, Aspidoparia jaya* and *Amblypharyngodon mola*, but have disappeared from the wetlands at present. The species composition recorded during the period of investigations is summarized hereunder.

Labeo rohita, Labeo calbasu, Cirrhinus mrigala, Catla catla, Notopterus chitala, Notopterus notopterus, Wallago attu, Channa striata, Channa punctata, Channa marulius, Anabas testudineus, Mystus vittatus, Amblypharyngodon mola, Clarias batrachus, Heteropneus tesfossilis, Puntius sophore, Rasbora daniconius, Chanda ranga, Chanda nama, Xenentodon cancila, Colisa fasciatus, Mystus puncalus, Mystus oculatus, Lepidocephalichthys guntea, Tetraodon cutcutia, Bedis bedis, Glossogobius giuris, Macrobrachium sp. (non-piscean).

Table 19.19 Catches of different species fishes and their wetland distributions

Group and species	Catch (%)	Wetland distribution
Major		
Labeo rohita	17	Mid column
Cirrhinus mrigala	8	Bottom
Catla catla	7	Surface
Hypophthalmichthys molitrix	5	Surface
Cyprinus carpio	5	Bottom
Ctenopharyngodon idella	8	Spatial
Channa marulius	3	Spatial
Notopterus chitala	2	Spatial
Intermediate		
Notopterus notopterus	6	Spatial
Ompok pabo	1	Spatial
Xenentodon cancila	2	Surface and peripheral
Clarias batrachus	9	Bottom
Channa punctatus	7	Surface and peripheral
Minor		
Puntius sophore	7	Surface and littoral
Puntius conchonius	4	Surface and littoral
Chanda nama	1	Littoral and bottom
Chanda ranga	1	Surface and littoral
Mystus vittatus	5	Spatial
Non-piscean		
Macrobrachium spp.	2	Bottom and mixed

The wetlands exhibit a productive range of p^H, DO, FCO$_2$, TA and temperature, while total hardness remains far below the productive range. The p^H profile of the studied wetlands exhibits circum neutral to alkaline range. Since the 5.2–7.9 is the most productive range of p^H, the upper limit of p^H in the wetlands was found to be slightly high which are equivalent to the pH of normal sea water. However, the obtained range of p^H is highly favourable for Indian major carp population. The dissolved oxygen and free carbon dioxide showing ranges of 5.4–8.2 mg/l and 0.0–14.0 mg/l, respectively, fairly indicate highly productive condition for culture of indigenous and exotic carps in the wetlands. Total alkalinity level of the wetlands is absolutely perfect for high yield of fishes since total alkalinity below 20.0 mg/l is indicative of poor production and above 20.0 mg/l does not appear to influence productivity. Total hardness in the studied wetlands shows very productive range of 12–32.0 mg/l, since TH below 15.0 mg/l is indicative of unproductive water. The fluctuations of water temperature between 21.0 and 25.0 °C during summer facilitate high growth rate of fishes by inducing tropical eutrophic condition. Suitable bottom soil condition and high water quality are essential ingredients for successful freshwater pisciculture.

Four ecological groups of phytoplankton encounter with the wetlands to form the productive area. Three species, viz., *Volvox* sp., *Dinobryon* sp. and *Microcystis* sp., produce high abundance. These three species contribute to the appreciable density. High abundance of *Microcystis* sp. and *Dinobryon* sp. indicates a productive water condition favourable for fish growth. Outburst of *Volvox* species is a surplus chlorophycean biomass which is not properly utilized by the grazers. Significant absence of Euglenineae and Bacillariophyceae of some wetlands affects the overall fish productivity of the wetlands. Considering the observed plankton volume (0.7–7.5 ml/100 l) against 10 ml/m^3 prescribed plankton volume for excellent culture of Indian major carp species, the studied wetlands proved to be highly productive water for fish culture.

Zooplankton productivity in the wetlands was contributed by three important groups, namely, Rotifera, Copepoda and Cladocera. These three groups exhibit significant growth and show richness in productivity. Due to the presence of healthy growth of planktonic crustacean and rotifer, the individual growth rate of *Catla catla* and *Hypophthalmichthys molitrix* is significantly high. Emergence of floating macrophytes, namely, *Eichhornia crassipes* is not encouraged in the wetlands due to its active participation in the removal of water by transpiration in eutrophication and for preventing entry of sunlight to the lower column of water. However, the submerged vegetation recorded in the wetlands is helpful for balancing the ecosystem. Some major fishes like grass carp and even rohu are directly dependent upon Hydrilla, Vallisneria and Nias, while Catla feed on the decomposed biomass of these vegetations. Most of the fish species recorded in the wetlands are found to be dependent upon the submerged macrophytes. However, the occurrence of *Euryale ferox* may create a lot of problems for fish culture. All macrophytes take part in recycling of nutrients in the wetlands.

The annual fish yield record collected from the abounding fishermen community of the wetlands shows that the fish productivity remains at 3,500–4,200 kg/year. Considering the total wetland water area, the fish production with natural stocking is high. The total production of the major fish group includes Indian major carps and exotic carps that constitute 55 %, intermediate fish group 25 % and the minor fish group 18 %. The record shows that the remaining 2 % is constituted by *Macrobrachium* sp. The record of fish growth obtained from the old fisherman community indicates that some fish species were predominant during past which are not found in the present wetlands. These fishes are *N. nandus, G. chapra, A. mola* and *S. bacaila*. On the other hand, according to the fishermen, some other fishes, namely, *L. rohita, C. catla, N. chitala, H. molitrix* and *C. idella*, show very good growth in the wetlands. From their perspective, even common carp (*Cyprinus carpio*) and *Cirrhinus mrigala* could show better growth in culture.

Conclusions

In the background of overall scenario, pisciculture at global level clearly depicts the economic potentials in Barpeta and Paka-Betbari developmental blocks of Barpeta district of Assam. The importance of pisciculture is increasing day by day with the increasing population. However, land to man ratio is decreasing. It is, therefore, inevitable to utilize the water resources for food production. The land with low-lying character found in the form of natural reservoir which is not used for agriculture can be used for pisciculture. There is certainty of catching fish from the cultured waters. Because of the presence of favourable geo-environmental condition for aquaculture, it is more important to culture fish in the concerned area of the district of Barpeta, Assam, where large natural water bodies are available. Environmental factors, however, have come to pose problematical issues in pisciculture development of the concerned area. In order to propagate pisciculture activities, more and more species are needed to cultivate in culture condition. Hence, the knowledge of the wetlands ecology is most essential, and there is tremendous scope for future prospect to culture fishes of different commercially important species in different wetlands of Assam. In Barpeta district, wetlands have been facing crisis for their existence during recent decades due to high rate of encroachment of marginal population, frequent floods, siltation, blocking of mouth of the *beels* and other developmental activities carried out in and around the wetlands. However, it can be recognized as a potential source of high quantum of fish production for the state with proper planning. For the state like Assam which is endowed with numerous wetlands of varied sizes, pisciculture could be the main alternative for the areas which are frequently plagued with flood hazard.

References

ARSAC (1990) District report on land use/land cover, Barpeta district, Assam, Assam Science Technology & Environment Council

Baruah AR (1999) Alternative livelihood in flood affected area of Brahmaputra valley. Plavan 4:5–9

Bhagabati AK, Bora AK, Kar BK (2007) Geography of Assam. Rajesh Publication, New Delhi

Bhowmick BC (1999) Socio-economic impact on flood affected area of Assam. Plavan 4:19–24

Bhuyan RN, Gosh D, Sarma D (2009) Fish and fisheries in North-East India, recent advances and rebuilding. Geophil Publishing House, Shillong

Bora AK, Barman B (1998) A Geo- ecological study of the wetlands of Barpetadistrict, Assam. North East Geogr 29(1 & 2):44–51

Census of India (2001) Assam administrative atlas. Director Census Operation

Census of India (2001) Assam administrative atlas. Office of the Registrar General & Census Commissioner, India, Ministry of Home Affairs, Government of India, New Delhi

DFID (2003) Final technical report (R8294) on Natural Resources Systems Programme

Dholakia AD (2004) Fisheries and aquatic resources of India. Mar Ecosyst 3(3):581–695

FAO (2008) EC – FAO Food Security Programme

Haylor G (2004) Poverty reduction and aquatic resources. In: NACA (eds) Emerging trends in aquaculture in Asia Pacific aquaculture: 2003, pp 51–57

IDRC (2008) International Development Research Centre Annual Report 2007–2008. Canada

Patowari R (1983) Barpeta district: a study in settlement Geography. Unpublished M. Phil dissertation, Gauhati University

Patra JK (1990) Barpeta district – a study in wetland and natural drainage. Silver Jubilee Souvenir, Barpeta District

Ramakrishna K (2008) Fisheries development in India: the political economy of unsustainable development. Kalpaz Publications, Delhi

Sarma P (2007) Ecological basis of the economy of periodic markets in Barpeta district, Assam. PhD thesis. North-Eastern Hill University, Shillong

Selvamani BR, Mahadevan RK (2008) Fish and fishery culture: assessment and evaluation. Campus Books International, New Delhi

Statistical Handbook of Assam (2001) Directorate of Economics and Statistics, Government of Assam, India

Tengo M, Belfrage K (2004) Local management practices for dealing with change and uncertainty: a cross scale comparison of cases in Sweden and Tanzania. Ecol Soc 9(3)

William LC, Comish WL (2008) A survey of alternative livelihoods options for Hong Kong fishers. Int J Soc Econ 35(5):380–395