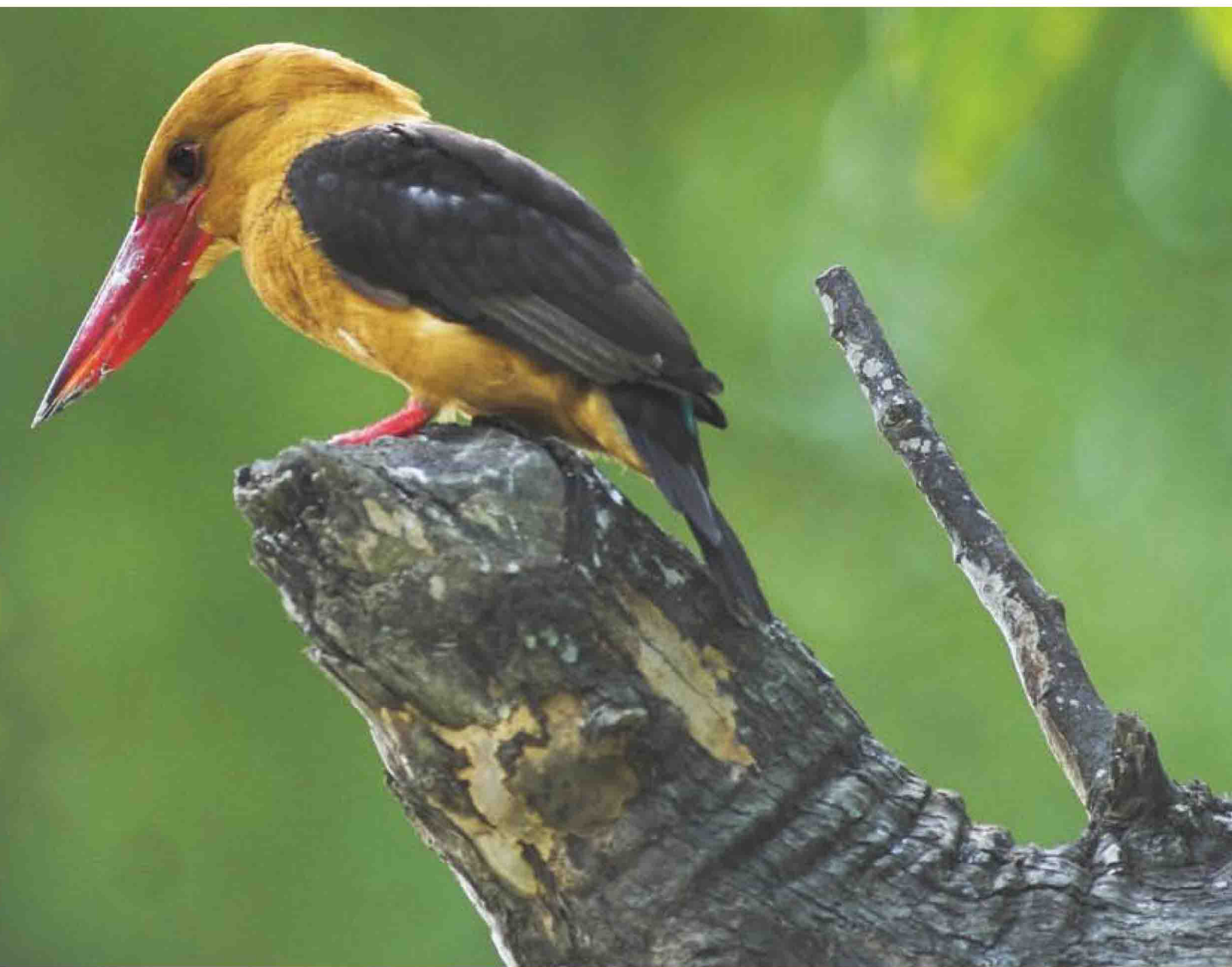




Rivers for Life

Proceedings of the International Symposium on River Biodiversity: Ganges-Brahmaputra-Meghna River System



DIALOGUE FOR SUSTAINABLE MANAGEMENT OF TRANS-BOUNDARY WATER REGIMES IN SOUTH ASIA



Editors

Ravindra Kumar Sinha
Benazir Ahmed

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Ecosystems for Life: A Bangladesh-India Initiative

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This initiative is supported by the Embassy of the Kingdom of the Netherlands (EKN), Bangladesh.

Produced by: IUCN International Union for Conservation of Nature

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Citation: Sinha, R. K. and Ahmed, B. (eds.) (2014). Rivers for Life - Proceedings of the International Symposium on River Biodiversity: Ganges-Brahmaputra-Meghna River System, Ecosystems for Life, A Bangladesh-India Initiative, IUCN, International Union for Conservation of Nature, 340 pp.

ISBN: ISBN 978-93-5196-807-8

Process Coordinator: Dilip Kumar Kedia, Research Associate, Environmental Biology Laboratory, Department of Zoology, Patna University, Patna, India

Copy Editing: Alka Tomar

Designed & Printed by: Ennovate Global, New Delhi

Cover Photo by: Rubaiyat Mowgli Mansur, WCS

Project Team: Brian J. Furze, Bushra Nishat, Archana Chatterjee, Dipankar Aich, Sushmita Mandal, AJM Zobaidur Rahman, Aditi Jha

Available from: IUCN Bangladesh Country Office
House 16, Road 2/3, Banani, Dhaka 1213, Bangladesh
www.iucn.org/Bangladesh

IUCN India Country Office
B 88, Neeti Bagh, New Delhi 110049, India
www.iucn.org/India

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Acknowledgement

The International Symposium on River Biodiversity in Ganges-Brahmaputra-Meghna River System organised under the *Ecosystems for Life: A Bangladesh-India Initiative*, would not have been possible but for the efforts of the several academic experts, institutions, and government departments of the two countries – Bangladesh and India.

Special acknowledgement is due to Prof. R. K. Sinha, Patna University, India and Prof. Benazir Ahmed, University of Chittagong, Bangladesh for collaborating to organise this successful symposium and providing editorial inputs for this publication.

We are specially thankful to the then Secretary, Mr. Dipak Kumar Singh and Principal Chief Conservator of Forests, Bihar and Mr. B. A. Khan, for their support and guidance towards organising the symposium.

The cooperation extended by the Department of Environment and Forests, Government of Bihar, is deeply appreciated.

We are especially grateful to all authors from Bangladesh and India who enriched this Symposium by sharing their insights and experiences from their studies. IUCN would also like to thank faculty members, researchers, students and staff from Patna University who worked tirelessly to make this symposium a success. We are also thankful to all participants at the symposium, including media.

A special thanks to all the reviewers who took out valuable time and made this publication possible.

Foreword

Addressing human and biodiversity concerns in the Ganges-Brahmaputra-Meghna river system

Bangladesh and India have some of the most intricate and complex river systems in the world. Ganges, Brahmaputra and Meghna (GBM), the three major rivers along with their tributaries drain an area of about 1.75 million square kilometres and have around 620 million people dependent on these rivers directly or indirectly. The river system is very rich in terms of fish species and is home to several rare and endangered species such as dolphins, turtles, otter and gharials. But this rich riverine biodiversity is under threat from unplanned development, pollution, habitat fragmentation, degradation and increasing population.

Facilitated and supported by IUCN, an international symposium on “River Biodiversity: Ganges-Brahmaputra-Meghna River System”, organised jointly by Patna University, India and University of Chittagong, Bangladesh was held from April 04-06, 2014 in Patna, Bihar, India. The symposium brought together experts, policy makers and the civil society from Bangladesh and India to draw attention to river biodiversity of the GBM region, its status, threats and conservation imperatives.

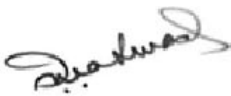
The Symposium was held as part of ‘*Ecosystems for Life: A Bangladesh-India Initiative*’, a civil society led multi-stakeholder dialogue process facilitated by IUCN to promote better understanding of the conservation and management of shared ecosystems in Bangladesh and India.

Through this symposium, *Ecosystems for Life* attempted to facilitate dialogue and deepening engagement in both countries towards conserving riverine biodiversity. The symposium was aimed at fostering knowledge and learning on these issues and throw light on the need for collaboration in sustaining our shared ecosystems.

This publication includes papers that were part of thirty five oral and nine poster presentations on various themes presented by thirty six eminent researchers/ practitioners. The themes included: River Biodiversity Conservation: Issues and Opportunities, Higher Vertebrates, Fish and Fisheries and Plankton and Benthic Organisms.

It is hoped that the knowledge base created through this publication will become a seminal reference point, we hope that this will serve as valuable compendium on some of the key issues related to river biodiversity in the GBM region and provide possible pathways to conserve these river systems for people and biodiversity that inhabit and depend on these rivers.

We invite all readers to an exhaustive and informative read on the GBM region’s river biodiversity.



Ishtiaq Uddin Ahmad

Country Representative, IUCN Bangladesh Country Office



Priya Ranjan Sinha

Country Representative, IUCN India Country Office

Preface

Traversed by three great rivers and their tributaries, the Ganges, Brahmaputra and Meghna (GBM) region is shared by India (64 per cent), China (18 per cent), Nepal (nine per cent), Bangladesh (seven per cent) and Bhutan (three per cent). These rivers are inextricably linked with the history and culture of the region, besides also providing a host of ecosystem services and habitat for riverine species.

The GBM region battles significant challenges related to pollution, biodiversity loss, navigability and flooding, that impacts lives and livelihoods of people who depend upon these rivers. In addition, interventions in the form of dams and barrages, ongoing and proposed water development projects and flood control measures have the potential to affect flows and aquatic biodiversity in the region.

It is crucial to understand these challenges so that steps can be taken to ensure sustainability of the region. The International Symposium on “River Biodiversity: Ganges-Brahmaputra-Meghna System” organised from April 04-06, 2014, was focused on further developing this understanding. Held under the auspices of *Ecosystems for Life: A Bangladesh-India Initiative*, the symposium was jointly organised by Patna University, India and University of Chittagong, Bangladesh, in Patna, Bihar, India. The symposium deliberated on several issues related to river biodiversity of the region, various conservation measures adopted, and also looked at existing gaps that need to be addressed.

The three-day symposium included two days of deliberations and one day field trip to the dolphin habitat in the Ganges, near Patna. The papers and posters presented were selected through an open call for submissions, facilitated by a joint team from Bangladesh and India. The four main themes of the symposium were 1) River Biodiversity Conservation: Issues and Opportunities 2) Higher Vertebrates 3) Fish and Fisheries, and 4) Plankton and Benthic Organisms.

The publication of the Symposium Proceedings is an important step in bringing together the knowledge and experiences from Bangladesh and India. Expectedly this will help to draw up long-term trans-boundary conservation and management plans for riverine species and their habitats.

The publication seeks to encourage representatives of civil society, academia, private sector, and policy makers in both countries to engage in extensive dialogue and information sharing. We hope that it would foster joint research, produce timely and relevant recommendations for policy making and collaborative management.

The ultimate goal remains to develop a mutually beneficial synergy between national interests, people’s well-being and regional prosperity based on sustainable use of the region’s water resources and the conservation of its rich riverine biodiversity.



Benazir Ahmed

Professor, Department of Zoology,
University of Chittagong, (Bangladesh)



Ravindra Kumar Sinha

Professor and Head, Department of Zoology,
Patna University (India)

Symposium Proceedings

The three-day Symposium comprised of six technical sessions spread over two days, followed by a day-long field visit to the dolphin habitat in the Ganges. The inaugural session was graced by the Vice Chancellor Prof. Y. C. Simhadri and Pro-Vice Chancellor Prof. R. K. Verma of Patna University, besides officials from the Department of Environment and Forests, Government of Bihar, India, and eminent experts from Bangladesh. The Vice Chancellor, in his inaugural address, called for greater sharing of knowledge on river biodiversity. He called for action on the ground and training future generations on issues linked to safeguarding rivers for livelihoods and biodiversity.

The Sessions

The six technical sessions were broadly categorised under four themes: River Biodiversity Conservation: Issues and Opportunities, Higher Vertebrates, Fish and Fisheries and Plankton and Benthic Organisms.

Day one of the Symposium saw a total of three sessions chaired by Mr. P. R. Sinha, Country Representative, IUCN India Country Office, New Delhi (India), Prof. Benazir Ahmed, Department of Zoology, University of Chittagong, Chittagong (Bangladesh), and Dr. W. Vishwanath, Department of Life Sciences, Manipur University, Imphal (India), respectively. Nineteen eminent speakers presented papers on the themes of 'Higher Vertebrates' and 'Fish and Fisheries'.

The second day of the Symposium saw three sessions of discussions and a Valedictory Session. The proceedings of the three sessions were chaired by Prof. Ashwani Wanganeo, Department of Environmental Science and Limnology, Barkatullah University, Bhopal (India); Mr. Mihir Kanti Majumder, Dialogue Advisor, IUCN Bangladesh Country Office, Dhaka (Bangladesh), and Prof. Brij Gopal, Centre for Inland Waters in South Asia, Jaipur (India), respectively. The Day two sessions saw seventeen speakers presenting on the themes of 'River Biodiversity Conservation: Issues and Opportunities' and 'Plankton and Benthic Organisms'.

A total of fifty three abstracts were received including seventeen posters for the Symposium and presented during the two-day technical sessions.

Objectives of the Symposium

The symposium sought to provide a platform to foster dialogue and exchange of knowledge on issues pertaining to river biodiversity, with the following objectives.

1. To review and compare the current status of biodiversity of the three large rivers and their wetlands.
2. To evaluate the impacts of anthropogenic stress on biodiversity in the GBM region with special focus on the Gangetic River Dolphin, otters, gharials, and turtles.
3. To review the status of conservation and management of riverine ecosystems, food web dynamics and fisheries.
4. To evaluate the methodology for sound assessment and monitoring of riverine biodiversity.
5. To discuss the need for participation of stakeholders, public education and awareness with a focus on children and youth.
6. To identify areas of collaboration and cooperation on river research between Bangladesh and India.

Recommendations

At the end of the two-day deliberations, the symposium came up with the following recommendations.

1. Develop standard methodology for estimation of river dolphin populations and carry out pilots for the same.
2. Carry out detailed characterisation of dolphin habitats to enable effective action for conservation.
3. Formulate guidelines to regulate and reduce negative impacts of mechanised boats and vessels on biodiversity.
4. Regulate use of destructive fishing gear through provision of alternative livelihood options in order to arrest the loss of non-target species.
5. Promote methods to enhance identification of fish diversity and address anthropogenic threats to enhance survival rate of species.
6. Facilitate continuous research on fish migration and breeding in the light of climate change impacts and devise conservation strategies.
7. Study and assess impacts of exotic and invasive fish species on other riverine biota, drawing linkages and learning from the IUCN Invasive Species Specialist Group.
8. Address increased salinity in the Sundarbans and work towards rejuvenating silted channels providing freshwater to the Sundarbans ecosystem, identified as a key habitat harbouring unique and endemic biodiversity.
9. Fisheries management must be integrated with livelihood security of local stakeholders in conjunction with river biodiversity conservation.
10. Steps need to be taken to ensure lateral, longitudinal and vertical hydrological connectivity in rivers to promote economic development in the region.
11. Study the linkages between biodiversity and ecosystem services that need to be maintained to ensure continued ecosystem benefits to species and people.
12. Establish through research and analysis the critical links pertaining to catchment health and river biodiversity; thus throwing light on the interconnectedness of ecosystems and the need to plan and manage them holistically.
13. Support programmes for mass awareness by communicating science to communities so that they can implement sustainable techniques in their daily lives.
14. Joint/ collaborative research on biodiversity needs to be continued, to generate greater knowledge and understanding on issues related to the GBM region.
15. Work towards establishing a comprehensive and universally accessible knowledge base on GBM river systems' habitat and biodiversity.
16. Provide a platform to share research being done in the countries to enhance knowledge base and consolidate learning in the region on shared ecosystems.



THEME

River Biodiversity Conservation: Issues and Opportunities

List of Papers

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Conserving Riverine Biodiversity - A Himalayan Task?

Brij Gopal

Centre for Inland Waters in South Asia,
41 B, Shiv Shakti Nagar,
Jaipur - 302017, India
E-mail: brij44@gmail.com

INTRODUCTION

Rivers have played a critical role in the growth of human civilisations across the globe. Humans have interacted with rivers and their floodplains over millennia. Rivers were well-known as habitats for turtles, crocodiles as well as mammals such as dolphins.

Fishing in the rivers started, in fact, long before humans learned agriculture (Forteath, Gartside, and Kirkegaard 2004). Yet, scientific investigations of the rivers started very late. Systematic studies on the diversity of organisms, particularly the invertebrates and plankton, occurring in the rivers developed only during the last century (Hynes 1970).

The science of fisheries itself emerged during the middle of the 19th century (Gopal 2013). Biologists focused mainly on the distribution of fish and other fauna and their relationship with different riverine habitat characteristics. An ecosystem perspective of the rivers evolved much later in the last century (Gopal and Chauhan 2013).

In India, river fisheries have been investigated for nearly two centuries (Hamilton 1822; Day 1875-78). Since around 1940s, numerous studies have documented the biodiversity of various Indian rivers, with greater emphasis on the River Ganges (Gopal and Zutshi 1998). Yet, an interest in the conservation of aquatic biodiversity in general and that of rivers in particular, arose only in mid-1990s (Gopal 1997). However, the conservation of some iconic species (e.g., gharial and dolphin) had been initiated much earlier.

Various issues related to biodiversity of river and its conservation have been discussed in several recent publications (Singh and Sharma 1998; Dudgeon 2000 a, b; Rao 2001; Molur et al. 2008; Sarkar et al. 2010; Lakra et al. 2010; Gopal and Chauhan 2013) and hence, I propose to only highlight briefly the most important threats to the riverine biodiversity and to emphasise that its conservation requires a proper understanding of the river ecosystems and a fundamental shift in our approaches.

BIODIVERSITY OF RIVERS

The biodiversity of rivers, particularly those of South Asia, has been summarised by Gopal and Chauhan (2013). This is characterised by high species richness disproportionate to their area, by the occurrence of many rare, endangered, threatened species, many endemics and charismatic species of great interest (dolphin, gharial, otter). Whereas studies on riverine biodiversity have focused mostly on fishes and sometimes on benthic macro-invertebrates, phyto and zooplankton, and benthic diatoms, the biota occurring in associated floodplains, oxbow lakes and other habitats as well as those dependent upon the riverine system seasonally are often not considered.

It should be realised that rhinos, swamp deer and elephants, and many other large herbivores dependent upon the rivers are as much a part of the river's biodiversity as the fish and dolphin. It is surprising that the birds entirely dependent upon the rivers have received little attention.

Interestingly, the riverine landscapes of the Himalayan ranges have the greatest richness of river dependent birds with 13 species out of 60 worldwide (Buckton and Ormerod 2002). The hyporheic fauna are practically completely ignored (Rangareddy 2014).

WHY CONSERVE BIODIVERSITY?

It is not only the biodiversity of the rivers that is not adequately understood or investigated, more significantly the role of biodiversity in the functioning of river ecosystems and hence, in providing various ecosystem services is not even appreciated.

The ecosystem services of a river are not confined to providing water and fish but probably the most important service lies in the assimilation of wastes from their catchments including those from anthropogenic sources. Practically all components of biodiversity contribute to this waste processing function, and thereby result in maintaining high water quality and productivity.

Among other biota, the significant contribution of the hyporheic fauna (subterranean invertebrates residing under the sediment surface) to the improvement of groundwater quality has not yet been recognised (Rangareddy 2014).

Similarly, the importance of the riparian vegetation to fish production has neither been investigated nor appreciated. The carbon sequestered by the riverine biota, especially in the riparian and floodplain areas, is as important contribution to climate change regulation and the large amount of carbon transported to the oceans directly supports the production of coastal waters. Very little is, however, understood of the complex relationships between biodiversity and ecosystem services of the aquatic ecosystems including rivers in South Asia.

THREATS TO RIVERINE BIODIVERSITY

Biodiversity of any ecosystem is threatened foremost by the loss or degradation of the habitats. In case of rivers, their flows are the master variable

that determines all characteristics of the physical habitat as well as directly or indirectly affects other ecosystem attributes including the biota.

Ever-increasing storage, diversion and abstraction of water to meet the growing and divergent human needs through a variety of structural interventions (weirs, barrages, dams, canals and tunnels) have altered the flows drastically to the extent that many long stretches of even large rivers remain dry for most of the year.

The sediments, nutrients, organic matter and propagules of organisms are prevented from being transported downstream. Most of the rivers have been fragmented into alternating pools (rivers) and dry stretches.

The migratory species of fish are most affected directly by this loss of longitudinal connectivity as they are unable to reach their seasonal spawning, nursery and feeding grounds. The loss of hilsa fisheries upstream of Farakka Barrage is a glaring example of the serious impacts of habitat fragmentation in rivers (Bhaumik and Sharma 2012). Further habitat loss and destruction is caused by the elimination of floodplains by construction of embankments to channelise the rivers in the name of flood control.

The loss of lateral connectivity and elimination of river channel-floodplain interactions have a direct and severe impact on biodiversity. Habitat loss and degradation continues further with the disposal of solid wastes and using river margins/ floodplains as landfill sites and for reclaiming land for various uses. The unregulated and excessive mining of sand and gravel from river beds disrupts the habitats of benthic and hyporheic biota.

The impacts of reduced flows are aggravated by the discharge of both domestic and industrial waste waters, without any or only partial treatment, and in amounts that far exceed the assimilative capacity of the normally flowing rivers. Overexploitation of biological resources of the riverine ecosystems

is generally a consequence of the decline in biodiversity caused by habitat destruction and pollution. Introduction of exotic invasive species of plants and animals only adds salt to the injury, adversely affecting the native biodiversity.

Other major threats to riverine biodiversity come from anthropogenic activities throughout the river basins - changes in land use-land cover, intensive agriculture; urban and industrial development, mining, etc. - which contribute to flow alteration, pollution and sediment load.

These aspects have been discussed in detail in many publications, and in particular South Asian context by Dudgeon (2000 a,b) and Gopal and Chauhan (2013).

HOW TO CONSERVE RIVER BIODIVERSITY?

Conservation of riverine biodiversity requires that it is based on adequate understanding of the structure and functioning of particular river system and the factors which govern and regulate the biodiversity as well as a proper assessment of the threats to it.

As a first starting point, it needs to be emphasised that the rivers differ greatly from the terrestrial systems despite being dependent upon them for their water sediments and other inputs. Unlike terrestrial systems, rivers are three-dimensional systems involving longitudinal, lateral and vertical transfers of material, energy and biota.

They are open, highly dynamic systems dependent upon constant inputs of water and nutrients. Concepts borrowed from terrestrial ecology for conserving river biodiversity are not generally applicable.

As mentioned earlier, the flow regimes of a river play the most critical role in determining the characteristics of the entire ecosystem, and hence it will be futile to attempt conservation of rivers' biodiversity without considering the flows requirement for all the concerned species.

In India, there has been considerable emphasis on the treatment of domestic and industrial wastewaters for "restoring" the water quality while the flows continued to be increasingly diverted and their importance totally overlooked until very recently.

Similarly, rivers have been perceived only as channels which could be modified at human will. The floodplains have been eliminated and, in most cases, the riparian vegetation completely lost. Much of the riverine biodiversity cannot be conserved without their floodplain habitats which are also allowed to interact with the river channels. Also, the impacts of catchment degradation cannot be overlooked.

Finally, the conservation of riverine biodiversity cannot rely upon the ex-situ and protected area approaches. Fish nurseries, induced breeding and river ranching may be appropriate for a couple of endangered species but cannot substitute for the loss of populations in their natural habitats. Rivers may also not be able to sustain them in the face of rapidly ongoing alterations in flows.

Pockets of conservation areas cannot be created in a river system without ensuring that the upstream reaches and catchments do not impinge upon it. A "Protected Area Approach" has been used for the conservation of gharials (National Chambal Gharial sanctuary since 1979) and dolphins (Vikramshila Gangetic Dolphin Sanctuary, Bhagalpur since 1990) and Upper Ganges — Brij Ghat to Narora — Ramsar site since 2005.

However, these protected areas cannot guard the species against the risks from pollution, flow alteration and other anthropogenic impacts upstream and in the catchments beyond their boundaries.

CONCLUDING REMARKS

A discussion on the conservation of river biodiversity shall remain incomplete without referring to the projected impacts of climate change. Whereas increased variability in precipitation is projected for all river basins of south Asia, the variability is expected to be much higher in the Himalayan region.

Another more significant impact on the rivers originating in the Himalaya will be, however, through the accelerated rate of melting of glaciers, and both short and long term consequences for river flows.

As the Himalayan rivers are particularly subjected to intensive exploitation for hydropower, the likely human response to the altered flow regimes will certainly, and most probably adversely, impinge upon the riverine biodiversity.

Unfortunately, the flow data are highly classified and their non-accessibility is in itself a major stumbling block in biodiversity conservation. If the much talked about plans of the Indian Government for interbasin transfer of flows between Himalayan and peninsular rivers are implemented, the future of riverine biodiversity can only be speculated in the absence of ecosystem level understanding and especially the studies on flows-biodiversity relationships in Indian rivers. Conserving biodiversity of Indian rivers, indeed, remains a Himalayan task.

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An Educational Outreach Strategy for Freshwater Dolphin Conservation: Measuring the Results

Elisabeth Fahrni Mansur, Farhana Akhtar and Brian D. Smith

Wildlife Conservation Society Bangladesh Program,
Bangladesh Cetacean Diversity Project,
House 89, Road 2, Sonadanga R/A (1st phase),
Khulna - 9000, Bangladesh
E-mail: emansur@wcs.org

ABSTRACT

The *Shushuk Mela*, a month-long boat-based dolphin exhibition aiming to share information about threatened freshwater dolphins and their conservation, and engage local communities in discussions about sustainable livelihoods and environmental changes, reached over 54,000 visitors from villages bordering the Sundarbans between 2011-2014.

Results from yearly interview surveys documenting changes in knowledge and attitude indicated an increase from 65 per cent to 100 per cent in the awareness of the presence of dolphins, an increase from 34 per cent to 77 per cent in knowledge that dolphins are air-breathing mammals, an increase from 17 per cent to 54 per cent in awareness about existing laws protecting freshwater dolphins, a decrease from 23 per cent to 0 per cent in attributing blame for declining fisheries to freshwater dolphins, and an increase from 83 per cent to 98 per cent among fisherfolk indicating their willingness to cut their nets to save entangled dolphins. These interview surveys demonstrate the value of our educational outreach efforts in changing the knowledge and attitudes of local communities.

BACKGROUND

In 2012, the Government of Bangladesh, based on recommendations from the Wildlife Conservation Society (WCS)'s Bangladesh Cetacean Diversity Project (BCDP), declared three new wildlife sanctuaries for freshwater dolphins in the eastern Sundarbans.

The BCDP is currently focusing on developing and implementing a science-based, community-informed management plan. The BCDP recognises that community participation and cooperation are key elements of successful conservation management. The BCDP Educational Outreach Programme (EOP) aims to foster support for cetacean conservation by creating outreach networks, providing training

opportunities and developing innovative, locally appropriate tools to disseminate information on cetaceans and sustainable fisheries management.

The EOP has established a strong foundation that provides a rich base of human resources, materials, and understanding among stakeholders, including local fishers and other community members, forest department (FD) officials, university students and faculty, tourism operators, and NGO workers.

CREATING OUTREACH NETWORKS

A network of trained community facilitators was established to extend the reach and multiply the impact of educational outreach on cetacean conservation. Altogether eight non-governmental

organisations (NGOs) were selected to participate in the network. All these NGOs had been involved in conducting regular (e.g., bimonthly) meetings linked to biodiversity conservation and/ or the promotion of sustainable resource use for a minimum of five years in communities near the Sundarbans.

In January 2012, 14 grass-roots-level facilitators from these organisations completed an intensive two-day training workshop on cetacean conservation and interactive environmental education techniques. They were also given media materials developed by the BCDP (see below) for dissemination during community meetings. Based on information collected during follow-up interviews with community facilitators, between May 2012 and December 2013, cetacean conservation messages were communicated during 418 meetings to about 10,780 people living in close proximity to critical dolphin habitat.

PROVIDING TRAINING OPPORTUNITIES

Seminars and Workshops

The goal of the BCDP training programme is to create a network of skilled and motivated local scientists and resource managers by enhancing their capacity to devise, advocate and implement cetacean conservation research and interventions.

A total of 18 seminars, training workshops and presentations were convened or facilitated by the BCDP during the past three years, reaching about 500 participants. These gatherings, which took place between December 2010 and February 2014, covered subjects such as mortality monitoring, GPS navigation, community facilitator classes, freshwater dolphin survey techniques, protected area management, interpretation and communication training.

Development, Publication and Dissemination of Training Materials

A wide variety of effective media materials for training have been developed and published in both the English and Bengali languages. All participants

in training workshops received training manuals or handbooks along with educational outreach materials.

Training materials include:

- How to operate a global positioning system (GPS) and depth sounder: An illustrated manual in Bengali.
- Identification guide to the cetaceans of Bangladesh: A plastic laminated illustrated guide in Bengali.
- Cetacean carcass examination and sampling: An illustrated protocol produced in both English and Bengali.
- Field handbook for captains' calibration: Practical instruction for collecting data to calibrate the sighting rates of cetaceans by captains of nature tourism vessels.
- Handbook on freshwater cetacean survey techniques: Prepared for comprehensive survey of the western SRF conducted with university interns, FD staff, and international participants from the Zoological Society of London.
- Protocol for hotspot investigations: Connecting ecology with the human element in cetacean habitats in the eastern Sundarbans Reserved Forest, Bangladesh.

Support for Graduate Students and Research Fellowships

Financial and technical support was provided to four university students to complete their Master of Science (M.Sc.) and Doctorate of Philosophy (Ph.D.) dissertations on topics related to freshwater dolphin conservation in the Sundarbans of Bangladesh. Their findings were integrated into conservation planning, and the students are encouraged to collaborate with the WCS team in producing published papers based on their dissertations.

With mentoring support from WCS's educational outreach programme, 10 students received fellowships, internships, and leadership awards from international conservation programmes to

conduct studies related to cetacean conservation in the Sundarbans. All of these students had previously assisted the BCDP as research and educational outreach interns.

DEVELOPING INNOVATIVE EDUCATIONAL OUTREACH TOOLS

Development, Publication and Dissemination of Educational Outreach Materials

A wide variety of effective media materials has been developed and published in both English and Bengali languages to support educational outreach in the three wildlife sanctuaries for freshwater cetaceans in the Sundarbans. One example is *Shuba and the Cyclone*, a children's book featuring Ganges River dolphins in Bangladesh. The book was developed collaboratively with Dot-to-Dot Books (<http://www.dot-to-dot-books.org/>) and high school students from villages surrounding the three new wildlife sanctuaries. Altogether a total of 60 students, ranging in age from 10 to 18, participated in a five-day interactive workshop on creative writing techniques and dolphin conservation, with the final day consisting of a boat trip to the wildlife sanctuaries.

The book is richly illustrated and features a young river dolphin that loses her way during a cyclone, gets caught in a fishing net, but then is rescued and reunited with her mother. The English language version of the book was published in 2011, and both hardback and paperback versions were published in Bengali language in 2014.

Other educational outreach materials include:

- ***Share our Smiles - Whales and Dolphins of Bangladesh***, a richly illustrated guide to the cetaceans of Bangladesh, including freshwater dolphins, published in Bengali and English.
- ***Dolphins and Whales of Bangladesh***, a children's colouring booklet in Bengali.
- ***Shushuk the River Dolphin***, a children's colouring booklet in Bengali.
- Posters and stickers in Bengali language that provide information on safely releasing

entangled or stranded dolphins, their legal status, and promote the dolphin Hotline.

In addition, the BCDP maintains a dedicated website (www.shushuk.org) which serves as an online resource for educators and community facilitators and provides updates on project activities, announcements of internship, and volunteer opportunities. Additionally, a documentary film about freshwater dolphins was produced in both English and Bengali languages. *Shushuk, Our Rivers and Mankind* (<http://www.wildeye.bd.net/Gallery.htm>) focuses on the plight of the Ganges River dolphins in Bangladesh and highlights the need to conserve the biodiversity of Bangladesh's rivers and ensure the long-term survival of communities that depend on these waterways for their lives and livelihoods. *Shushuk, our Rivers and Mankind* was nominated for a ROSCAR Award at the Wild talk Africa Film Festival, Durban, South Africa (2009).

To raise awareness among local communities that depend on the natural resources in waterways of the Sundarbans mangrove forest supporting two threatened freshwater dolphins: Ganges River dolphins (*Platanista gangetica*), locally known as *Shushuk*, and Irrawaddy dolphins (*Orcaella brevirostris*), with funding from The Foundation for the Third Millennium, the BCDP convened four boat-based dolphin exhibitions or *Shushuk Melas* (one each year in 2011-2014; Figure 1, Table 1). The exhibitions incorporated informative panels and



Figure 1: During the past 4 years the boat-based *Shushuk Mela* visited an average of 13 villages bordering the Sundarbans mangrove forest to share information about threatened freshwater dolphins and their conservation, and engage local communities in discussions about sustainable livelihoods, and coping with declining freshwater flows and climate change.

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Table 1: Details on boat-based *Shushuk Melas* convened between 2011-2014 in villages and towns near the three newly declared wildlife sanctuaries for freshwater dolphins in the Sundarbans

Year	Dates	Number of villages visited	Number of visitors	Number of viewers at film shows	Number of Interpreters
2011	January 15 - 31	7	~5,000	~ 3,000	5
2012	February 18 - March 16	15	19,128	6,345	9
2013	February 8 - March 6	15	13,112	4,463	12
2014	February 6 - March 2	15	16,846	5,145	15

interactive elements, including life-size models of dolphins, games, a bioscope showing the live birth of a dolphin, and a showcase with dolphin bones, skulls and teeth, providing visitors with visual and tactile experiences facilitating an emotional connection with cetaceans (Figure 2).

These outreach campaigns also included evening shows of our two internationally acclaimed documentary films in Bengali language *Shushuk, Rivers and Mankind* and *Exploring our Waters*.

Altogether the exhibitions reached over 54,000 people in villages adjacent and near the three wildlife sanctuaries.

During all four floating exhibitions, a team of interpreters guided groups of visitors through the exhibits. The interpreters, now totaling 41 individuals over a four-year period, were recruited from the zoology, geography, environmental science, fisheries and forestry departments of Chittagong, Dhaka, Khulna, Rajshahi, Jahangirnagar, Jagannath, North



Figure 2: The life-size models of eight dolphin species (top left) and interactive games (bottom left) were favorites among visitors of all ages. The games were developed around key messages to encourage a playful testing of acquired knowledge. Teachers and students of schools, colleges and madrassas were invited to attend the exhibition (top right). Trained interpreters enhanced the visitors understanding and encouraged solution-oriented discussions about the recommended regulations in the three wildlife sanctuaries for freshwater dolphins (bottom right). ©WCS Bangladesh

South, and Independent universities, and from among Forest Department field staff.

All interpreters participated in an intensive one or two days training course, and received mentoring during daily feedback sessions with WCS staff. Several of the interpreters had participated in our field research activities and were therefore, well versed on cetaceans, their habitat, and threats to their survival. Others, who had not been previously engaged with our project, became experienced members of our growing network of environmental educators.

The first boat-based *Shushuk Mela* in 2011 focused on three key messages:

- *Shushuk* is a dolphin
- Dolphins are mammals, and
- Bangladesh supports a large diversity of dolphins, whales, and porpoises.

Interwoven into these messages was the overall theme of the importance of protecting areas where dolphins occur in high numbers to benefit people too. The exhibition was convened over two weeks at seven villages welcoming about 5,000 visitors. Interpreters explained the displays and engaged visitors in interactive games and discussions.

This proved crucial for achieving effective outreach due to low literacy. Visitors were drawn most strongly to the interactive elements, specifically the games. During informal discussions with visitors we learned that fisherfolk face challenges related to unofficial payments required for fishing permits, and that most lack confidence in their ability to generate sufficient income from sustainable fishing practices.

Based on feedback from the first *Shushuk Mela*, the use of images, illustrations and opportunities for direct interaction were increased in 2012. Key messages were also expanded to include the following:

- Freshwater dolphins are threatened.
- The three newly declared wildlife sanctuaries aim to protect dolphins and aquatic resources essential for human communities, and

- News about entangled or dead dolphins should be shared through the Dolphin Hotline.

In the weeks before the second *Shushuk Mela*, based on conservation research (Smith et al. 2006, 2009, 2010; Mansur et al. 2008) and educational outreach conducted by WCS and its partners, the Government of Bangladesh declared three new wildlife sanctuaries for the protection of freshwater dolphins in the Eastern Sundarbans Reserved Forest.

Visitors to the exhibition were, therefore, particularly interested about implications of the new sanctuaries to their livelihoods. The number of interpreters was therefore also increased, as well as the intensity of their training, to better engage visitors in solution-oriented discussions.

Games were developed to communicate information about sensitive but vital issues related to the need for changing fishing practices to ensure sustainability and protect dolphins. The exhibition was also extended to a full month to cover 15 villages that we had previously identified as the homes of fisher folk active in the wildlife sanctuaries.

Knowledge gained from the second boat-based *Shushuk Mela* included reports of more frequent entanglements in fishing gear than previously thought, and an increasing use of dolphin products (oil for medicinal purposes and, in some cases, meat for human consumption) as carcasses were becoming more widely available from incidental catches. If a market develops for these products, it could provide an incentive for the emergence of directed hunts.

The third boat-based *Shushuk Mela* focused on empowering communities to participate in the conservation planning process for the new wildlife sanctuaries. This exhibition was designed around communicating three key messages:

- Dolphins are our pride and need protection.
- Fishermen should attend their nets and safely

- release dolphins that become entangled, and
- Measures taken to protect dolphins can improve fisheries.

The exhibition layout was partitioned into different sections. In the first section, visitors were introduced to the fascinating world inhabited by freshwater dolphins, and the threats they share with local human communities (e.g., depleted fisheries and an altered environment from declining freshwater flows and sea-level rise).

In the next section, visitors were requested to decide whether or not they would release a live dolphin that became entangled in the fishing net, or whether they would keep it to sell in the market. Those who chose to release the dolphins were given a small prize.

Prizes for children included a dolphin hat or colouring book, and adults were given a copy of *Share our Smiles* (an introduction to the whales and dolphins of Bangladesh) or a poster with an illustration of how to release a dolphin from fishing net, which included the Dolphin Hotline number. Those choosing to keep the dolphin were directed to a “jail” with information posted about the legal protections for these animals. In reality, the choice was presented as a fun game and all participants received an educational prize.

The exhibition’s third section focused on other actions that visitors could take to protect freshwater dolphins, such as preventing pollution of waterways or refraining from using mosquito nets to catch shrimp larvae — a widespread practice that has depleted fisheries due to the enormous bycatch of fish fingerlings and non-target crustacean post larvae.

In this section, we also included a display of handicrafts made from locally available materials.

The fourth boat-based *Shushuk Mela* was designed to synthesise and reinforce lessons learned from earlier years. Key messages were:

- Our waters support a great abundance and diversity of cetaceans.
- The three new wildlife sanctuaries aim to secure local livelihoods and protect threatened freshwater dolphins, and
- Following fishery regulations can ensure healthy fish stocks.

The sections of the exhibition on fishery regulations and sustainable practices were enriched with new interactive displays that encouraged visitors to discuss the potential benefits of sustainable fishing practices for their livelihoods as well as for freshwater dolphins.

Formal consultations were incorporated into the 2014 *Shushuk Mela*. Altogether 220 people in 80 groups participated in consultations. Questions used to initiate discussions included:

- What regulations do you suggest for effective sanctuary management?
- How can the forest department involve local communities in the sanctuary management?
- What challenges do you face due to living near the sanctuaries?
- What would convince you to follow sanctuary regulations?, and
- What alternative income generating activities do you suggest for fisher folk engaged in illegal fishing practices?

Participants generally agreed that illegal fishing must be stopped in the sanctuaries, and many thought that all fishing should be prohibited in the sanctuaries. Participants generally thought that awareness-raising programmes, such as the *Shushuk Mela*, were very useful for disseminating information about conservation management in the wildlife sanctuaries.

They recommended that the FD organise similar events, possibly in collaboration with local conservation committees. Challenges mentioned included declining freshwater supplies, increasing

salinity, land being taken over by shrimp farms, storms, pirates and poverty.

Suggestions for ensuring compliance with regulations in the sanctuaries included regular patrolling and monitoring by the forest department, strengthening law enforcement and pursuing violations, and stopping the production/ import and sale of illegal nets.

Income generating activities proposed included day labour, homestead vegetable cultivation, tailoring, embroidery work, and tourism-related enterprises. In general, participants were anxious to share their ideas, but many found it challenging to discuss aspects not directly related to their livelihoods or beyond their own personal experiences.

MEASURING THE RESULTS

Based on yearly interview surveys conducted during 2011 to 2013 in four villages that were not visited by the exhibition (202 interviewees) and 12 villages that were visited by the exhibition on 1-3 occasions (603 interviewees), changes were documented in the knowledge and attitude of local people (Table 2).

Interview results from villages never visited by the *Shushuk Mela* and villages visited on 1-3 occasions indicated an increase from 65 per cent to 100 per cent in the awareness of the presence of dolphins, an increase from 34 per cent to 77 per cent in knowledge that dolphins are air-breathing mammals, an increase from 23 per cent to 71 per cent in the perception that freshwater dolphin populations are declining, an increase from 17 per cent to 54 per

cent in awareness about existing laws protecting freshwater dolphins, a decrease from 23 per cent to 0 per cent in attributing blame for declining fisheries to freshwater dolphins, and an increase from 83 per cent to 98 per cent among fisher folk indicating that they were willing to cut their nets to save an entangled dolphin.

These interview surveys demonstrate the value of our educational outreach efforts in changing the knowledge and attitudes of local communities.

CONCLUSION

In-depth knowledge of local communities is required for developing appropriate tools to convey key messages for educational outreach activities. The interactive, travelling exhibition and the NGO partner network are (cost-) effective educational outreach tools for building local constituencies for conservation.

By collaborating with selected social service organisations already actively engaged in the focal area, impact and outreach radius can be amplified substantially. Emerging issues related to biodiversity conservation and natural resource management can be identified through these information-sharing platforms and subsequently addressed through dedicated studies.

Actively engaging students, community facilitators, resource managers and resource users in research and educational outreach activities helps build the local capacity necessary for developing and implementing these studies and science-based,

Table 2: Details of Knowledge-Attitude-Practice surveys conducted after the 2011-2013 *Shushuk Melas*, in which people were interviewed from villages and towns visited by the exhibition and not visited by the exhibition

Year	Date	Number of villages where exhibition was held	Number of villages where the exhibition was not held	Number of interviewees	Number of university interns conducting interviews
2011	Nov 13 - 16	2	2	202	4
2012	June 24 - 27	4	2	303	5
2013	June 25 - 27	6	0	300	4

community-informed conservation approaches in general.

Regular impact evaluation surveys can effectively measure changes in knowledge, attitude and practices. Results from these assessments generate additional evidence to inform locally appropriate and effective educational outreach strategies and tools.

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Biodiversity of Upper Ganges: Status, Stresses and Management

Ramesh C. Sharma

Department of Environmental Sciences,
H. N. B. Garhwal University, Post Box 67,
Srinagar-Garhwal - 246174, Uttarakhand, India
E-mail: drrameshcsharma@gmail.com

ABSTRACT

The upper Ganges (Gomukh to Haridwar) supports a distinct biodiversity with rich habitat diversity in terms of rapids, runs, riffles and pools. Biodiversity of upper Ganges is represented by plant diversity (periphyton and phytoplankton) animal diversity (zooplankton, zoobenthos, fish and other vertebrates) and microbes (bacteria, fungi, actinomycetes).

Diatoms (Bacillariophyceae) are predominantly present. Zoobenthos represented by nymphs and larvae of freshwater insects are very common under the boulders, pebbles and cobbles. Sixty fish species belonging to 27 genera and 12 families in addition to fish, otters (*Lutra perspicillata*) and water snakes (*Xenochrophis piscicator*) were present in the upper Ganges.

The upper Ganges is under several natural and anthropogenic pressures. These stresses alter the flow regimes, stability of substrates, river channel morphology, riparian vegetation, functional habitat, migration of fish and composition of biodiversity. Few specific remedial measures for maintaining downstream ecology and management of biodiversity of upper Ganges have been suggested.

Keywords: Upper Ganges, Gomukh, biodiversity, Garhwal-Himalayas, Bhagirathi

INTRODUCTION

Biodiversity has been recognised as one of the most potential and essential characteristics of life for proper functioning of ecosystem including the riverine ecosystem and a means for coping with natural and anthropogenic environmental changes. The river Ganges, life line for millions of people is aptly called the “River of India”.

This river is the most widely written about and worshipped. The Ganges is the most sacred, the symbol of our tradition and values providing physical and spiritual nourishment to millions of devotees

(Kumar 2001). The entire ecosystem of Ganges provides innumerable number of goods and services to the people of India. The upper Ganges is an important stretch of the *national river Ganges* flowing in the mountainous region of Garhwal Himalayas.

The lotic ecosystem of Upper Ganges is characterised by cold water, high water velocity, low productivity and distinct biodiversity with abundant rapids, runs, riffles and few deep pools. The bottom substrates are mostly bed rocks, boulders, cobbles, pebbles and coarse sand, quite different from counterpart of lower region of the Ganges.

Due to extreme environmental conditions, the upper Ganges is very vulnerable to any natural and anthropogenic pressure. Therefore, to provide information on the status of biodiversity, stresses and management of the Upper Ganges is of paramount importance.

Few scattered attempts have been made on the different aspects of the Upper Ganges. Sharma (1984a, 1986); Singh et al. (1994); Sharma et al. (2004); and Ayyoade et al. (2009) have provided information on water quality of upper stretch of River Bhagirathi.

Sharma (1985, 1991); Kala and Sharma (1999); Sharma et al. (2008a) have provided information on phytoplankton and periphyton of upper Ganges. Sharma (1986, 1991) and Sharma et.al. (2008b) have contributed on the macrozoobenthos of upper Ganges. Sharma (1983, 1988, 2003a); Singh et al. (1983); and Singh and Sharma (1998) have made contributions on the diversity of fish of the upper Ganges.

However, no sincere attempt has been made so far to provide a detailed picture of river biodiversity

of the Upper Ganges. Therefore, the present contribution will fill up this gap on the knowledge of the biodiversity of the upper Ganges from Gomukh to Haridwar.

PHYSIOGRAPHY OF THE UPPER GANGES

The River Ganges, originates from the Gangotri glacier at Gaumukh at an altitude of 4,100 metres above m.s.l. and flows down to Gangasagar traversing a distance of above 2,700 kilometres. During its course through eleven states, the Ganges receives numerous tributaries. The entire stretch of the River can be divided into three major segments: Upper Ganges (Gaumukh to Haridwar), Middle Ganges (Haridwar to Varanasi) and Lower Ganges (Varanasi to Ganga Sagar) based on the geomorphology, stream order, substrate, physico-chemical environmental variables and the biodiversity.

The Upper Ganges begins as the River Bhagirathi from Gangotri glacier (Gaumukh) and meets the River Alaknanda at Devprayag, after which the river is known as the Ganges (Figure 1). The Upper Ganges has first stream order to seventh stream order up to



Figure 1: Confluence of Bhagirathi and Alaknanda at Deoprayag

Hardwar. Epirhithron has first to third stream order, while, metarhithron has fourth to sixth stream order, and the hyporhithron has seventh stream order (Sharma 1992; Chauhan 2007).

About 294 kilometres from Gaumukh to Haridwar, the river leaves the mountains to enter the alluvial plain at Haridwar at an elevation of about 290 metres above m.s.l. The Upper Ganges passes through Bhairi Ghati, Maneri, Uttarkashi, Tehri, Devprayag and ends at Haridwar (Figure 2). The Upper Ganges is a highly incised valley in bedrock, meandering, broadening at the end with braided channel, and gorges and alluvium-filled segments with paired and unpaired terraces. The valley consists of channel and active floodplain, and gravel and sand bars in the channel with some mud. Tributary mouth fans are prominent (Khan et al. 1982; Rawat and Gairola 1997; Bali et al. 2003).



Figure 2: Location map of the upper Ganges

The Upper Ganges course of the River is the rhithron zone based on the ecological classification of Illies and Botosaneanu (1963). The rhithron zone of the river is characterised as extending from the source to the point where mean monthly temperatures rise to 20°C, where dissolved oxygen concentrations are always high, flow is fast and turbulent and the bed is composed of rocks, stones and gravel with occasional sandy or silty patches. The rhithron is again subdivided into three zones — the epi, meta

and hyporhithron — based on geomorphology, bottom substrate composition, physico-chemical environmental variables, patterns of rapids and pools and other ecological attributes (Sharma 1992).

The reach from Gaumukh (4,100 metres) to Gangnani (1,855 metres) can be designated as epirhithron (No Fish Zone) with dominant rapids, runs, riffles, waterfalls and cascades. The reach between Gangnani to Devprayag (460 metres) is inhabited by hill stream fishes characterised by “Snow Trout Zone” (metarhithron) with few pools. From Devprayag to Haridwar (290 metres) is characterised by “Mahseer Zone” (hyporhithron) dominated by pools and few runs and rapids (Sharma 1992; Singh 2008).

METHODOLOGY

Analysis of the physico-chemical environmental variables and the components of biodiversity of all the three zones (epirhithron, metarhithron, hyporhithron) of the upper Ganges were made following the methods outlined in Wetzel and Likens (1991) and Standard methods (APHA 1998).

Sampling of periphyton was made using a timed scraping technique of Wetzel (1979). Collection and estimation of phytoplankton present in depositional zones of the lotic environment were made after sieving 10 litres of water through bolting silk plankton net of mesh size 20 µm and immediately preserved in four per cent formalin.

Zooplanktons were also collected by the same method. Sampling of benthic macro invertebrates colonising the substrate was made with the help of the Surber sampler (0.50 mm mesh net) to a depth of about 10 centimetres in a quadrat.

The qualitative and quantitative analyses were made by using the standard methods outlined in Ward and Whipple (1992) and several standard taxonomic keys of Freshwater Biological Association, UK. Isolation of microbes was made through suitable culture media. Analysis of microbial population was made through Most Probable Number (MPN) following standard

methods (APHA 1998). Microbial identifications were done using morphological, biochemical and molecular methods (Sharma 2009).

Fish sampling was carried out during different times and seasons at all the three stretches of the Upper Ganges. Fishing was also undertaken at night to ensure representation of all the species. Fish were caught with the help of cast net bearing heavy sinkers weighing more than five kilograms or seine nets and by angling. Standard taxonomic manuals in addition to the fish taxonomists were used for the identification of fish Talwar and Jhingran (1991); Jayaram (1999).

HABITAT DIVERSITY

Stream ecosystem are also highly variable over space and time, and exhibit high degrees of longitudinal, lateral and vertical connectivity between systems (Allan and Castillo 2009). The ecosystem of Upper Ganges has a rich habitat diversity in terms of dominance of high gradient rapids with swift flow, cascades with steep reaches with alternating small waterfalls and riffles of steep shallow zones having coarse bottom of boulders, rocks and pebbles in

the epirhithronic stretch and dominance of flatter, deeper zones of pools bottom of fine materials in hyporhithronic stretch. Secondary channel pools, backwater pools, tench pools, plunge pools, dammed pools and later scour pools are also common in the lower stretch of the Upper Ganges (Sharma 1992).

PHYSICO-CHEMICAL PROFILE OF UPPER GANGES

Air temperature, water temperature, hydrogen-ion concentration, biological oxygen demand (BOD), free carbon dioxide, phosphates and nitrates and the concentration of Sodium and Potassium increased from upper (epirhithron) to lower reaches (hyporhithron) of the Upper Ganges. Other environmental variables — water velocity and dissolved oxygen decreased from epirhithron stretch to hyporhithronic stretch of the Upper Ganges (Table 1).

Seasonally, the atmospheric temperature was found maximum during peak summer and monsoon seasons and minimum during winter season. However, the water temperature was recorded maximum during summer season and minimum

Table 1: Physico-chemical environmental variables (Mean $\pm$ SD) in epirhithron, metarhithron and hyporhithron stretches of the Upper Ganges (Sharma 1984,1986; Singh et al. 1994; Ayyoade et al. 2009)

Environmental Variable	Epirhithron	Metarhithron	Hyporhithron
Air temp (0C)	10.65 $\pm$ 3.4	17.7 $\pm$ 4.25	21.78 $\pm$ 2.75
Water temp. (0C)	7.30 $\pm$ 2.85	12.9 $\pm$ 3.15	18.12 $\pm$ 2.12
Water velocity (m sec-1)	2.75 $\pm$ 0.75	1.74 $\pm$ 0.38	1.32 $\pm$ 0.167
HMD (m)	1.21 $\pm$ 0.71	2.21 $\pm$ 1.72	2.64 $\pm$ 1.74
Turbidity (NTU)	65.25 $\pm$ 109.6	138.13 $\pm$ 244.75	156.32 $\pm$ 160.02
Transparency (m)	0.98 $\pm$ 0.81	0.35 $\pm$ 0.01	0.25 $\pm$ 0.12
Conductivity (μ Scm-1)	0.13 $\pm$ 0.34	0.15 $\pm$ 0.52	0.17 $\pm$ 0.54
TDS (mg l-1)	14.1 $\pm$ 12.24	34.0 $\pm$ 33.39	96.17 $\pm$ 39.12
Dissolved oxygen (mg l-1)	11.44 $\pm$ 2.60	10.55 $\pm$ 0.84	8.65 $\pm$ 0.42
Free CO2 (mg l-1)	0.62 $\pm$ 0.12	1.02 $\pm$ 0.32	1.32 $\pm$ 0.42
pH	7.32 $\pm$ 0.17	7.56 $\pm$ 0.19	8.083 $\pm$ 0.37
BOD (mg l-1)	0.24 $\pm$ 0.5	1.29 $\pm$ 0.28	2.45 $\pm$ 0.32
Phosphates (mg l-1)	0.102 $\pm$ 0.10	0.150 $\pm$ 0.12	0.175 $\pm$ 0.15
Nitrates (mg l-1)	0.101 $\pm$ 0.01	0.140 $\pm$ 0.10	0.162 $\pm$ 0.13
Sodium (mg l-1)	5.19 $\pm$ 1.72	7.85 $\pm$ 1.85	8.95 $\pm$ 1.95
Potassium (mg l-1)	3.62 $\pm$ 0.50	6.23 $\pm$ 0.65	7.25 $\pm$ 0.72

during winter season. Water temperature of upper Ganges gradually increases from February to April and therefore, showed a declining trend up to the month of August, because of the melting of snow and at the higher elevation from where the river originates. The water velocity and hydromedian depth were found maximum during monsoon months (July-August) and minimum in winter months (November-January) (Sharma 1984a).

Dissolved oxygen was recorded highest during winter season and minimum during monsoon season. The physico-chemical environmental variables of any aquatic ecosystem are of great importance in predicting type, composition and diversity of the biological communities in the aquatic habitat (Hutchinson 1957; Rutner 1963).

High elevation streams have less acid neutralising capacity, hardness, total ions and nutrients than low land water. Increase in these characteristics in low elevation streams are attributed to changes in soil and bed rocks as well as urban development, agriculture and other human activities (Welch 1952).

Potassium occurs in various minerals from which it may be dissolved through weathering. Weathering of rocks is very common in lower stretches of upper Ganges. Chemical fertilisers and land filling of domestic water in lower stretches contributes for high level of potassium through run-off in the catchment area of lower stretches of upper Ganges.

Sodium ion is ubiquitous in water, owing to high solubility of its salts and the abundance of sodium containing mineral deposits. A number of anthropogenic activities — water treatment chemicals and sewage effluents in lower stretches of upper Ganges can contribute to high level of sodium in surface water.

Correlation between different hydrological parameters revealed that air temperature, water temperature, water current, hydromedian depth and

turbidity were found to be highly correlated at both the sites. Dissolved oxygen was found to have a negative correlation with air temperature ($r = -0.830$, $p < 0.001$), water temperature ($r = -0.692$, $p < 0.01$), water current ($r = -0.805$, $p < 0.001$), hydromedian depth ($r = 0.851$, $p < 0.001$) and free CO_2 ($r = -0.911$, $p < 0.001$) in the natural environment of Bhagirathi (Sharma 2008 a, b).

PLANT DIVERSITY

Aquatic plant diversity of the Ganges was represented by periphyton and phytoplankton. The periphyton were generally found attached to rocks, submerged wood, and floating or submerged vegetation and were abundant in the fast currents of shallow rapids and riffles. The periphyton were common (45 species) in the epirhithronic stretch of the upper Ganges. Periphyton along with phytoplankton and macrophytes contributed as primary producers. Phytoplanktons were common in the depositional zones of metarhithron (43 species) and hyporhithron (32 species). Periphyton and phytoplankton were represented by Bacillariophyceae (26 species), Chlorophyceae (20 species), Cynophyceae (four species), Eugleniaceae (one species) and Xanthophyceae (one species), (Table 2).

Diatoms (Bacillariophyceae) were predominantly present throughout the river in the upper stretch. However, the blue green algae (Cyanophyceae) appeared scanty in the epirhithronic stretch and common in metarhithron and hyporhithron upper Ganges. The members of Eugleniaceae and Xanthophyceae were present only in the lower stretch (hyporhithron) of the upper Ganges (Figure 3).

Riparian vegetation along the river banks was common in the metarhithronic and hyporhithronic stretches of the Upper Ganges. These were not present in the epirhithronic stretch. The common riparian plants in the lower stretches were *Equisetum*, *Polygonum*, *Ajuga*, *Artemisia*, *Poa*, *Ageratum*, *Fagopyrum* and *Chenopodium*.

Table 2: Presence of periphyton/ phytoplankton in epirhithron, metarhithron and hyporhithron of the Upper Ganges (Sharma 1985, 1991; Kala and Sharma 1999; Sharma et al. 2008a)

Periphyton	Epirhithron	Metarhithron	Hyporhithron
Bacillariophyceae			
<i>Achnanthes</i> sp.	+	+	+
<i>Amphora ovalis</i> (Kützing) Kützing 1844	+	+	+
<i>Cyclotella</i> sp.	+	+	+
<i>Cymbella lata</i> Grunow ex Cleve 1894	+	+	+
<i>Coconeis placentula</i> (Ehrenberg 1838)	+	-	-
<i>Ceratoneis arcus</i> (Ehrenberg) Kützing 1844	+	+	-
<i>Caloneis amphisbaena</i> (Bory de Saint Vincent) Cleve 1894	+	+	-
<i>Denticula</i> sp.	+	+	+
<i>Diatoma vulgare</i> (Bory de Saint-Vincent 1824)	+	-	-
<i>D. balfouriana</i> (Greville 1855)	+	+	-
<i>Fragilaria inflata</i> (Pantocsek 1902)	+	+	+
<i>Gomphonema</i> sp.	+	+	+
<i>Gomphonema herculeanum</i> (Ehrenberg 1845)	+	+	-
<i>Gryosigma kutzingee</i>	+	+	-
<i>Hantzchia</i> sp.	+	+	+
<i>Meridion circulare</i> (Greville) C. Agardh 1831	+	+	-
<i>Navicula radiosa</i> (Kützing 1844)	+	+	+
<i>Nitzschia</i> sp.	+	+	+
<i>Opephora</i> sp.	+	+	-
<i>Pinnularia</i> sp.	+	+	-
<i>Rhoicosphenia</i> sp.	+	+	+
<i>Syndra ulna</i> (Nitzsch) Ehr.	+	+	+
<i>S. utermohli</i>	+	-	-
<i>Stauroneis phoenicentron</i> (Nitzsch) Ehrenberg (1843)	+	+	+
<i>Tabellaria fenestrata</i> (Lyngbye) Kützing 1844	+	+	+
<i>Tetracyclus rupestris</i> (Braun) Grunow 1881	+	+	+
Chlorophyceae			
<i>Chlamydomonas</i> sp.	-	+	+
<i>Chlorella vulgaris</i> Beyerinck (Beijerinck) 1890	-	-	+
<i>Cledophora</i> sp.	+	+	+
<i>Closterium Leibleinii</i> (Schmidle 1894)	+	+	-
<i>Cosmarium granatum</i> (Croasdale 1973)	+	+	-
<i>Chlorococcium humicola</i> (Naegeli)	+	+	-
<i>Desmidium</i> sp.	+	+	-
<i>Gonatozygon</i> sp.	+	-	+
<i>Hydrodictyon reticulatum</i> (Linnaeus) Bory de Saint-Vincent 1824	+	+	-
<i>Microspora</i> sp.	+	+	-
<i>Navicula</i> sp.	+	-	+
<i>Nitzschia</i> sp.	+	+	+
<i>Oedogonium</i> sp.	+	+	+
<i>Rhoicosphenia</i> sp.	-	+	+
<i>Spirogyra</i> sp.	-	-	+
<i>Synedra</i> sp.	-	+	-

Periphyton	Epirhithron	Metarhithron	Hyporhithron
<i>Stigeoclonium sp.</i>	+	+	-
<i>Tabellaria sp.</i>	+	+	+
<i>Ulothrix zonata</i> (Weber & Mohr) Kützing 1843	+	+	+
<i>Zygnema sp.</i>	+	+	+
Cyanophyceae			
<i>Anabena sp.</i>	+	+	+
<i>Coccochloris stagnina</i> (Sprengel 1807)	+	+	-
<i>Phorimidium sp.</i>	+	+	+
<i>Oscillatoria tenuis</i> (C.Agardh ex Gomont 1892)	+	+	+
Eugleniaceae			
<i>Euglena sp.</i>	-	-	+
Xanthophyceae			
<i>Vaucheria sp.</i>	-	-	+
Grand Total	45	43	32

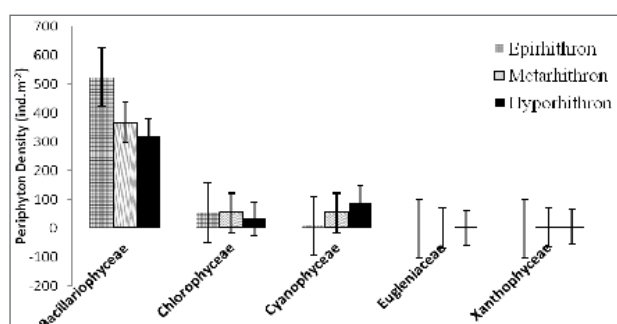


Figure 3: Periphytonic abundance in different zones of the upper Ganges (Sharma 1985, 1999, 2008a)

Physico-chemical environmental variables (temperature, water current, substrate, scouring effect of floods, nutrients and light penetration) play an important role in the growth of primary producers (Hynes 1971; Whitton 1975; Biggs 1996). Sediment and silt, which are present in the lower stretch of upper Ganges, scour the substrates and thus reduce the density of primary producers (Negi 1993). The density of primary producers was found maximum in winters and minimum in monsoon season in the Upper Ganges.

Periphytonic density had a negative correlation with air temperature ($r = -0.748$, $p < 0.001$), water temperature ($r = -0.776$, $p < 0.01$), water velocity ($r = -0.844$, $p < 0.001$), hydromedian depth ($r = -0.894$, $p > 0.001$), turbidity ($r = -0.835$, $p > 0.001$), total

dissolved solids ($r = -0.750$, $p < 0.001$) and free CO_2 ($r = -0.880$, $p > 0.001$). While, a positive correlation was found between periphytonic density and dissolved oxygen ($r = 0.785$, $p < 0.001$). (Sharma et al. 2008a). Mountain streams have very little plankton and true plankton are almost absent in the upper parts of the stream system (Welch 1952). Water velocity showed negative correlation with phytoplankton density ($r = -0.794$, $p < 0.001$). Turbidity had inverse relationship with phytoplankton density ($r = -0.707$, $p < 0.01$). Total dissolved solids showed a negative relationship with phytoplankton density ($r = -0.77$) (Bahuguna 2008).

The disturbance on aquatic life influenced by high flow of water had been reported by Cushman (1985). Biggs (1996) reported low primary production during monsoon due to frequent floods and unstable bed sediments. Cline et al. (1982) reported the distinct deleterious effect of highway construction on the epilithic algae and macroinvertebrates of a high mountain streams in Northern Colorado, USA.

ANIMAL DIVERSITY

Animal diversity of the Upper Ganges was represented by zooplankton, macrozoobenthos, fish and other higher vertebrates.

Zooplankton

The zooplanktons are an important component of the animal diversity of Upper Ganges and act as primary consumers. Zooplanktons are relatively few in number (10 genera) in the erosional zone of epirhithron. However, considerable number (18 genera) of zooplankton was present in the metarhithron and hyporhithron stretches of the upper Ganges (Sharma 1991).

These are common in the depositional zone of pools and backwaters. The mean density of zooplankton based on the monthly sampling from epirhithron, metarhithron and hyporhithron stretches of the upper Ganges revealed that it increases from epirhithron to hyporhithron (Figure 4). The richness of zooplankton of Upper Ganges was contributed by Cladocera (five genera), Copepoda (two genera), Protozoa (four genera) and Rotifera (seven genera) in the Upper Ganges (Table 3).

Abundance of zooplankton (Cladocera, Copepoda and Rotifera) was higher in hyporhithron than in the epirhithron (Figure 4). This may be due to high food supply in the form of higher phytoplankton in lower stretches of Upper Ganges. Abundance of zooplankton is directly affected by food supply, phytoplankton production, water temperature and water current (Wetzel 2001).

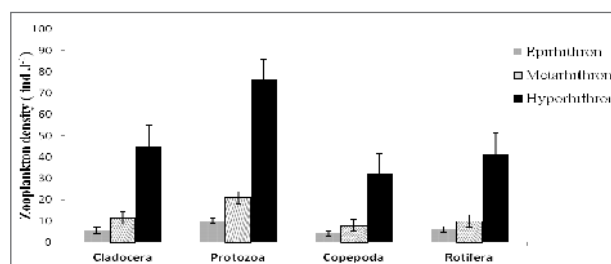


Figure 4: Abundance of zooplankton in different stretches of upper Ganges (Sharma 1991, 2006)

Table 3: Presence of zooplankton in epirhithron, metarhithron and hyporhithron stretches of the Upper Ganges (Sharma 1991, 2006)

Zooplankton	Epirhithron	Metarhithron	Hyporhithron
Cladocera			
<i>Bosmina longirostris</i> Muller, 1776	+	+	+
<i>Chydorus angustirostris</i> Frey, 1987	-	+	+
<i>Daphnia lumholzi</i> Sars, 1885	+	+	+
<i>Moina micrura</i> Kurz, 1874	-	+	+
<i>Pleuroxus laevis</i> Sars, 1862	-	+	+
Copepoda			
<i>Cyclops</i> Muller, 1785	+	+	+
<i>Diaptomus</i> sp.	+	+	+
Protozoa			
<i>Arcella vulgaris</i> Ehernberg, 1830	-	+	+
<i>Centropyxis aculeata</i> Ehernberg, 1838	-	+	+
<i>Vorticella campanula</i> Linnaeus 1767	+	+	+
<i>Zoothamnium</i> Ehernberg, 1838	+	+	+
Rotifera			
<i>Asplanchna priodonta</i> Gosse, 1850	+	+	+
<i>Brachionus angularis</i> Gosse, 1851	-	+	+
<i>Keratella cochlearis</i> Gosse, 1851	+	+	+
<i>Filinia brachiata</i> Rousselet, 1901	-	+	+
<i>Beauchampiella eudactylota</i> Gosse, 1886	+	+	+
<i>Colurella adriatica</i> Ehernberg, 1831	-	+	+
<i>Trichocerca abilioi</i> Segers & Sharma, 1993	+	+	+
Grand Total	10	18	18

Macrozoobenthos

Aquatic macrozoobenthos are extremely diverse group of animals dwelling in the Upper Ganges (Table 4). Macrozoobenthos of the Upper Ganges were contributed by nymphs and larvae of Ephemeroptera (15 species), Plecoptera (five species), Trichoptera

(four species), Hemiptera (three species), Diptera (seven species), Coleoptera (eight species), Odonata (five species), Mollusca (four genera) and Annelida (two genera) also contributed towards the macrozoobenthos of the Upper Ganges (Sharma 1986, 1991; Sharma et al. 2008b).

Table 4: Presence of macrozoobenthos in epirhithron, metarhithron and hyporhithron of the Upper Ganges (Sharma 1986, 1991; Sharma et al. 2008b)

Macrozoobenthos	Epirhithron	Metarhithron	Hyporhithron
Ephemeroptera			
<i>Bateis niger</i> (Linnaeus, 1761)	+	+	+
<i>Bateis muticus</i> (Linnaeus, 1758)	+	+	+
<i>Bateis rhodoni</i> (Pictet, 1843)	+	-	-
<i>Caenis robusta</i> (Eaton 1894)	+	-	-
<i>Centroptilum luteolum</i> (Müller 1776)	+	+	+
<i>Cloeon</i> sp.	+	-	-
<i>Ephemera vulgata</i> (Linnaeus, 1758)	+	+	+
<i>Ephemerella notata</i> (Eaton 1887)	+	+	+
<i>Ephemerella ignita</i> (Poda, 1761)	+	+	-
<i>Ecdyonurus</i> sp.	+	+	-
<i>Habrophlebin</i> sp.	+	+	-
<i>Heptagenia lateralis</i> (Curtis, 1834)	+	+	-
<i>Leptophlebia marginata</i> (Linnaeus 1767)	+	-	-
<i>Rhithrogena</i> sp.	+	+	-
<i>Siphonurus</i> sp.	+	-	+
Placoptera			
<i>Acroneuria</i> sp.	+	+	-
<i>Brachyptera</i> sp.	+	-	-
<i>Isoperla</i> sp.	+	+	+
<i>Perla</i> sp.	+	+	+
<i>Taeniopteryx</i> sp.	+	+	+
Trichoptera			
<i>Glossosoma</i> sp.	+	+	-
<i>Hydroptela</i> sp.	+	+	-
<i>Hydropsyche</i> sp.	+	+	-
<i>Rhyacophila</i> sp.	+	+	-
Hemiptera			
<i>Corexia</i> sp.	+	+	+
<i>Gerris</i> sp.	-	+	+
<i>Hesperocorixa obliqua</i> (Hungerford, 1925)	-	+	+
Diptera			
<i>Antocha</i> sp.	+	+	+
<i>Chironomus</i> sp.	-	+	+
<i>Culex</i> sp.	-	-	+
<i>Simulium</i> sp.	-	-	+
<i>Psychoda</i> sp.	+	+	+

Macrozoobenthos	Epirhithron	Metarhithron	Hyporhithron
<i>Tabanus sp.</i>	+	+	+
<i>Tendipes sp.</i>	+	-	+
Coleoptera			
<i>Agabus glabellus</i> (Motschulsky, 1859)	+	+	+
<i>Amphizoa lecontei</i> (Matthews, 1872)	+	+	+
<i>Hydaticus sp.</i>	-	+	+
<i>Dineutus sp.</i>	+	+	+
<i>Ochthebius sp.</i>	+	+	+
<i>Limnius latiusculus</i> (LeConte 1866)	+	+	+
<i>Psephenus sp.</i>	-	+	+
<i>Peltodytes sp.</i>	+	+	+
Odonata			
<i>Agrion sp.</i>	-	+	+
<i>Ceragrion cerinorubellum</i> (Brauer, 1865)	-	-	+
<i>Hagenius sp.</i>	+	+	+
<i>Ischnura sp.</i>	-	+	+
<i>Ophiogomphus sp.</i>	-	+	+
Mollusca			
<i>Bithynia sp.</i>	-	+	+
<i>Campeloma sp.</i>	-	+	+
<i>Lymnaea sp.</i>	+	+	-
<i>Pleurocera sp.</i>	-	+	+
Annelida			
<i>Hirudinaria sp.</i>	-	+	+
<i>Tubifex sp.</i>	-	+	+
Grand Total	37	43	37

May-flies (Ephemeroptera), Caddies Flies (Trichoptera) and Stone Flies (Plecoptera) contributed maximum in the epirhithronic stretch of the Upper Ganges. However, Diptera, Coleoptera, Odonata, Mollusca and Annelida were very common in the lower zones (metarhithron and hyporhithron) of the Upper Ganges (Figure 5).

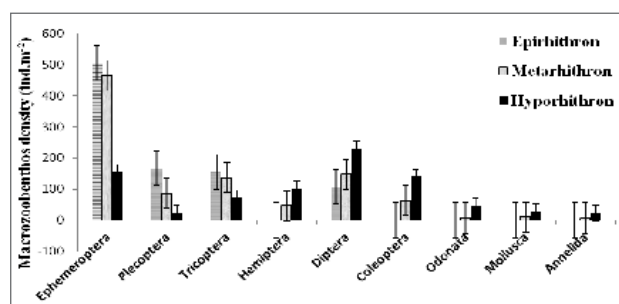


Figure 5: Abundance of macrozoobenthos in different stretches of the upper Ganges (Sharma 1986, 1991, 2008b)

Macrozoobenthic density was maximum during winter and early summer and minimum during monsoon season in the Upper Ganges (Sharma 1986). Macroinvertebrates density had inverse relationship with air temperature ($r = -0.788$, $p < 0.001$), water temperature ($r = -0.386$, $p > 0.001$), water current ($r = -0.834$, $p < 0.001$), hydromedian depth ($r = -0.870$, $p < 0.001$), turbidity ($r = -0.611$, $p < 0.05$), total dissolved solids ($r = -0.557$, $p < 0.05$) and free CO_2 ($r = -0.881$, $p < 0.001$). Dissolved oxygen ($r = 0.834$, $p < 0.001$) and transparency ($r = 0.450$) had positive correlation with macroinvertebrate density (Sharma et al. 2008b).

Ward and Stanford (1979) opined that water flow, temperature and substrate are the major factors determining the composition and abundance of

benthic macroinvertebrates. Benthic invertebrates are particularly sensitive to water velocity and river bed substrate (Stevenson 1996). The decrease in the quantity of oxygen and organic matter with increasing depth results in lowering of biodiversity (Bretschko and Leichtfried 1988). Thus, the higher diversity of macrozoobenthos during winter of low water and high dissolved oxygen and lower density during monsoon of high depth and low dissolved oxygen in the Upper Ganges is understandable.

The biological community composition, inclusive of macrozoobenthos changes from headwater to downstream of river due to change in physical and chemical characteristics of the river (Vannote et al. 1980). The same was reflected in the composition of the biotic communities dwellings — epirhithron, metarhithron and hyporhithron stretches of the upper Ganges.

The macrozoobenthos are commonly used to evaluate the ecological integrity of streams and as indicators of water quality assessment (Norris and Norris 1995; Fore et al. 1996). Many species of May-Fly Nymphs, Caddis-Fly Larvae, Water Pennies and Stone-Fly Larvae can survive only in swift, cool

and well-oxygenated water. Bellinger et al. (2006) observed greater species richness in the undisturbed systems and stated that minor disturbance in the environmental factor reduces the species richness or diversity in any aquatic ecosystem. The same observation was recorded in case of the fluvial ecosystem of the Upper Ganges.

Fish

Fish is an important component of biodiversity of the Upper Ganges. The uppermost stretch is the “No Fish Zone” as the fish cannot survive under the extreme environmental conditions of very low temperature and turbulent water current. The metarhithronic zone is known as “Snow Trout Zone” which provides conducive habitat for the species of *Schizothorax* and *Schizothoraichthys* from Devprayag to Haridwar.

Hyporhithron is characterised by “Mahseer Zone” dominated by pools and few runs and rapids (Sharma 1992; Singh 2008). This zone has a high volume of water and sufficient food to cater the needs of the big fish, Mahseer. Sixty fish species belonging to 27 genera and 12 families are represented in the upper stretch of the river Ganges. Cyprinidae was the biggest family with 35 fish species (Table 5).

Table 5: Fish dwelling in metarhithron and hyporhithron stretches of the Upper Ganges (Sharma 1983, 1988, 2003a; Singh et al. 1983; Singh and Sharma 1998)

Fish species*	Metarhithron	Hyporhithron
Family: Cyprinidae		
<i>Schizothorax richardsonii</i> (Gray)	+	+
<i>Schizothorax plagiostomus</i> (Heckel)	+	+
<i>Schizothorax curvifrons</i> (Heckel)	+	+
<i>Schizothorax intermedius</i> (McClelland)	+	+
<i>Schizothorax micropogon</i> (Heckel)	+	+
<i>Schizothorax sinuatus</i> (Heckel)	+	+
<i>Schizothorax niger</i> (Heckel)	+	+

Fish species*	Metarhithron	Hyporhithron
<i>Schizothoraichthys progastus</i> (McClelland)	+	+
<i>Schizothoraichthys esocinus</i> (Heckel)	+	+
<i>Tor putitora</i> (Hamilton)	+	+
<i>Tor tor</i> (Hamilton)	+	+
<i>Tor chilinoides</i> (McClelland)	+	+
<i>Labeo dero</i> (Hamilton)	+	+
<i>Labeo dyocheilus</i> (McClelland)	-	+
<i>Labeo calbasu</i> (Hamilton)	-	+
<i>Labeo gonius</i> (Hamilton)	-	+
<i>Labeo angra</i> (Hamilton)	-	+
<i>Gara gotyla gotyla</i> (Gray)	+	-

Fish species*	Metarhithron	Hyporhithron
<i>Gara lamta</i> (Hamilton)	+	-
<i>Gara prashadi</i> (Hora)	+	+
<i>Barilius barila</i> (Hamilton)	+	-
<i>Barilius barna</i> (Hamilton)	+	-
<i>Barilius bendelisis</i> (Hamilton)	+	+
<i>Barilius bola</i> (Hamilton)	+	+
<i>Barilius vagra</i> (Hamilton)	+	-
<i>Crossocheilus latius latius</i> (Hamilton)	+	-
<i>Puntius sarana sarana</i> (Hamilton)	-	+
<i>Puntius sophore</i> (Hamilton)	-	+
<i>Puntius ticto</i> (Hamilton)	-	+
<i>Raiamas bola</i> (Hamilton)	-	+
<i>Rasbora daniconius</i> (Hamilton)	-	+
<i>Danio devario</i> (Hamilton)	+	+
<i>Danio rerio</i> (Hamilton)	+	+
<i>Esomus danricus</i> (Hamilton)	-	+
<i>Salmostoma bacaila</i> (Hamilton)	+	-
<i>Nemacheilus beavani</i> (Gunther)	+	-
<i>Nemacheilus botia</i> (Hamilton)	+	-
<i>Nemacheilus montanus</i> (McClelland)	+	-
<i>Nemacheilus multifasciatus</i> (Day)	+	+
<i>Nemacheilus rupicola</i> (McClelland)	+	+
<i>Nemacheilus savona</i> (Hamilton)	+	-
<i>Nemacheilus zonatus</i> (McClelland)	+	-
<i>Bagarius bagarius</i> (Hamilton)	-	+
<i>Glyptothorax cavia</i> (Hamilton)	+	+
<i>Glyptothorax lineatus</i> (Day)	+	+
<i>Glyptothorax conirostris</i> (Steindachner)	+	+

Fish species*	Metarhithron	Hyporhithron
<i>Glyptothorax madraspatanum</i> (Day)	+	+
<i>Glyptothorax pectinopterus</i> (McClelland)	+	+
<i>Glyptothorax trilineatus</i> (Blyth)	+	+
<i>Pseudecheneis sulcatus</i> (McClelland)	+	+
<i>Xenentodon cancila</i> (Hamilton)	-	+
<i>Botia dario</i> (Hamilton)	-	+
Family: Channidae		
<i>Channa gachua</i> (Hamilton)	-	+
Family: Clariidae		
<i>Clarias batrachus</i> (Linnaeus)	-	+
Family: Schilbeidae		
<i>Clupisoma garua</i> (Hamilton)	+	-
Family: Osphronemidae		
<i>Colisa fasciata</i> (Bloch & Schneider)	-	+
Family: Mastacembelidae		
<i>Mastacembelus armatus</i> (Lacepede)	-	+
Family: Bagridae		
<i>Mystus tengara</i> (Hamilton)	-	+
<i>Rita rita</i> (Hamilton)	-	+
Family: Mugilidae		
<i>Rhinomugil corsula</i> (Hamilton)	-	+
Grand Total	40	47

* Epirhithron: No Fish zone

The epirhithronic stretch of the Upper Ganges does not support fish life due to extreme environmental conditions. Metarhithronic stretch had 40 species, while the hyporhithronic stretch had higher number of fish species (47 species).

Preferred habitats, feeding habits, breeding and spawning grounds of important fishes dwelling the Upper Ganges have been presented in Table 6.

Table 6: Preferred habitat, feeding habits, breeding and spawning grounds of important fishes dwelling the Upper Ganges (Sharma 1983, 1988, 2003)

Zoological Name	Local Name	Preferred Habitat	Feeding Habits	Breeding and Spawning grounds
Family : Cyprinidae				
<i>Schizothorax richardsonii</i> (Gray)	Maseen	Prefers cold water, torrential water of streams, rivers, riffle, runs and rapids	Herbivorous: feeds on green matter, periphyton, bottom dweller	Breeding period from September January, breeds on graveled surface
<i>S. plagiosomus</i> (Heckel)	Maseen	Prefers fast running water(rapids), bottom dwellers	Herbivorous: feeds on green matter and periphyton,	Breeds during September to January in shallow running and semi stagnant water of 25-30cm depth
<i>S. sinuatus</i> (Heckel)	Maseen	Prefers torrential water current (rapids),dwells at the bottom under stones and rocks	Herbivorous: feeds on green matter and periphyton	Breeds during September to January and spawns on the gravelled surface of sediments
<i>Schizothoraichthys progastus</i> (McClelland)	Chengu	Prefers headwater zone of the coldwater streams	Omnivorus: feeds on insects larvae and green matter ,green algae	Breeds during September to January and spawns in the semi-stagnant water on gravelled surface
<i>Tor tor</i> (Hamilton)	Dansulu	Adult prefers deep water pools with rocky bottom, Juveniles: side and semi-stagnant water	Adults are omnivorous: feeds on green matter, insects and their larvae, zoobenthos, column dweller. Juveniles are planktivorous	Spawns from April to June, turbid water due to melting of snow, migratory fish
<i>Tor putitora</i> (Hamilton)	Dansulu	Adult: prefers deep water pools with rocky bottom, Juveniles prefer side, semi stagnant water	Omnivorous: Green matter, Insects & their larvae column feeder, Juveniles: Planktivorous, surface feeders.	Spawns from April to June in turbid water due to melting of snow, migratory fish
<i>Labeo dero</i> (Hamilton)	Dansulu	Prefers deep pools, rapids, torrential water current	Herbivorous, Mid bottom feeder	Spawns from March to June, prefers shallow water migratory fish
<i>Crossocheilus latius</i> (Hamilton)	Sunhara	Prefers runs, riffles with abundant green matter	Herbivorous, bottom feeder	Breeds from April to September, migratory fish
<i>Garra gotyla gotyla</i> (Gray)	Gondal	Prefers deep water pools with runs, riffles with abundant green matter	Herbivorous bottom feeder	Breeds from April to September, migratory fish
<i>Garra lamta</i> (Hamilton)	Gondal	Prefers side water with abundant green matter	Herbivorous bottom feeder	Breeds from April to September, migratory fish
<i>Barilius bendelisis</i> (Hamilton)	Fulra	Prefers small spring fed streams, common in side water	Omnivorous : feeds on nymphs, larvae and algae Surface feeders	Breeds from April to June side stagnant water
<i>B. barna</i> (Hamilton)	Fulra	Prefers small spring fed streams, common in side waters	Omnivorous: feeds on nymphs, larvae and algae, surface feeders	Shallow pockets of water under stones and macrophytes

Zoological Name	Local Name	Preferred Habitat	Feeding Habits	Breeding and Spawning grounds
<i>B. vagra</i> (Hamilton)	Fulra	Prefers small spring fed streams, common in side waters	Omnivorous: feeds on nymphs, larvae and algae, Surface feeders	Shallow pockets of water under stones and macrophytes
<i>B. barila</i> (Hamilton)	Fulra	Prefers small spring fed streams, common in side water	Omnivorous: feeds on nymphs, larvae and algae, Surface feeders	Shallow pockets of water under stones and macrophytes
<i>Cyprinus carpio communis</i> (Linnaeus)	Common carp	Deep water pools and stagnant water	-	Cultured
Family: Balitoridae				
<i>Noemacheilus rupecola</i> (Hamilton)	Gadiyal	Prefers to stay in rivulets and streams (bottom gravels under stones)	Omnivorous mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August, spawns in small streams
<i>N. beavani</i> (Gunther)	Gadiyal	Prefers to stay in spring fed rivulets and small streams	Omnivorous: mainly feeds on nymphs and larvae of insects, algae and diatoms, Bottom dweller	Breeds in July-August spawns in small streams
<i>N. zonatus</i> (McClelland)	Gadiyal	Prefers to stay in spring fed rivulets and small streams	Omnivorous: mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August ,spawns in small streams
<i>N. multifasciatus</i> (Day)	Gadiyal	Prefers to stay in spring fed rivulets and small streams	Omnivorous: mainly feeds on nymphs and larvae of insects, algae and diatoms, bottom dwellers	Breeds in July-August spawns in small streams
Family: Sisoridae				
<i>Glyptothorax madraspatmum</i> (Day)	Nau	Gets refuge under stones and rocks, common in monsoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in graveled bottom
<i>G. pectinopterus</i> (McClelland)	Nau	Gets refuge under stones and rocks, common in monsoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in graveled bottom
<i>G. cavia</i> (Hamilton)	Sipliya	Gets refuge under stones and rocks, common in monsoon	Insectivorous and feeds mainly on insects and nymphs and larvae	Breeds from April to August and spawns in graveled bottom
<i>Pseudecheneis sulctus</i> (Hamilton)	Mungrea	Bottom dwellers, hidden under stones	Insectivorous/ carnivorous and feeds only on insects and their nymphs and adults	Breeds from April to August in graveled bottom
Family: Schilbeidae				
<i>Clupisoma garua</i> (Hora)	Bare	Deep water pools and flooded water	Column feeder, omnivorous	Migratory and breeds during monsoon season

Schlosser (1982) observed that the physical structure of stream channel coupled with the hydrological cycle and energy inputs resulted in a consistent pattern of community structure and function along a stream. Habitat diversity (water depth, current, bottom substrates) were significantly correlated with the fish species diversity. Skud (1982) pointed out that dominant species or “keystone species” responded positively to factors that improved their survival and subordinate species negatively to the same factor. The Snow Trouts (*Schizothorax* spp. and *Schizothoraichthys* spp.) were the dominant species in the Upper Ganges.

Nowak and Zaleswki (1991) reported the highest fish diversity in the middle course of lowland part of the river Grabia. Further, they observed that space is a limiting factor for fish assemblage. This observation is in confirmation with the present observation in the Upper Ganges. Maximum density was found in the hyporhithronic stretch as the upper zones have limiting factor of space and volume of water.

There were few migratory fish species dwelling in the fluvial system of the upper Ganges. The important migratory fish species are *Tor tor*, *Tor putitora*, *Labeo dero* and *Schizothoraichthys progastus*, which migrate from downstream to upstream for breeding. The Mahseer (*Tor tor*; *Tor putitora*) migrates upstream from the foothills (Haridwar and its vicinity) in the month of March-April due to rise in temperature in the lower stretches of the fluvial system. These fish species stay in the higher reaches up to September-October and return in November, escaping from the cold water due to onset of winter (Sharma 1984b). The upstream migration of *Labeo dero* has also been recorded for spawning (Sharma 1984c). Local migration of *Schizothoraichthys progastus* is intended for the search of food and suitable feeding and breeding grounds in the fluvial system of the Upper Ganges.

Other Higher Vertebrates

The Upper Ganges also sustains few higher aquatic vertebrates other than fish. Smooth-coated Otter

(*Lutra perspicillata*) locally known as *Uud* was available in metarhithronic and hyporhithronic stretches. The ecological status of this aquatic mammal is vulnerable. It has been placed in Schedule-I of Wildlife Protection Act 1972 and Appendix-I of CITES.

However, the presence of this mammal is rare now-a-days in this stretch of the Upper Ganges. A water snake (*Xenochrophis piscicator*) also frequented the banks of the upper Ganges in the lower stretches. Few amphibians (*Rana cyanophylcyctis*, *R. blanfordiz*) had also been spotted near the banks of the Upper Ganges (Sharma 2011).

MICROBIAL DIVERSITY

Microbes are the most abundant and important biological component of aquatic ecosystem involved in the transformation and mineralisation of the organic matter in the ecosystem. The microbes of the upper Ganges play an important role in the riverine ecosystem. The microbial diversity dwelling the Upper Ganges was mainly represented by bacteria, fungi and actinomycetes.

The epirhithronic zone of Upper Ganges was mostly free from heavy pollution. Therefore, a limited number of microorganisms could thrive in the high altitude riffles, runs and rapids. The pathogenic bacteria also strayed in numbers in the erosional zone of the Upper Ganges.

However, in the metarhithronic and hyporhithronic zones, the microbial diversity and density increased from metarhithronic to hyporhithronic (Sharma 2009). An overall nine species of bacteria (*Bacillus circulans*, *Escherichia coli*, *Enterobacter aerogenes*, *Micrococcus* sp., *Microbacterium schleiferi*, *Pseudomonas aeruginosa*, *Pseudomonas fluorescens*, *Staphylococcus aureus*, *Streptococcus faecalis*) were present in the Upper Ganges.

Two genera of Actinomycetes (*Streptomyces clavifer*, *Streptomyces ragoon*, *Nocardia* Sp.) were also recorded in the fluvial system of the Upper Ganges.

Fungi were also common in the metarhithronic and hyporhithronic stretches of the Upper Ganges, represented by 10 genera (*Achyla* sp., *Alternaria* sp., *Asergillus flavus*, *Aspergillus niger*, *Cladosporium* sp., *Penicillium* sp., *Phoma* sp., *Trichoderma* sp., *Verticillium* sp.).

Seasonal variations in the physico-chemical environmental variables played an important role in distribution, periodicity and diversity of microbes. These parameters can be used to predict the occurrence of microbes in specific habitats. Bezuidenhout et al. (2002) observed that the surface water and rainfall are the environmental variables which affect the bacterial abundance. They also reported that the indicator micro-organisms (*Escherichia coli*; *Pseudomonas* spp. and *Enterobacter* spp.) were detected frequently during monsoon season. McDowell (1984) also found relationship between microbial abundance and water discharged flooding. The same observation was also recorded in the Upper Ganges. Maximum microbial diversity was recorded in hyporhithron stretch of the Upper Ganges during monsoon season. The minimum bacterial standard plate count was found to be (13,185 CFUml⁻¹) during winter season and maximum (36,410 CFUml⁻¹) during monsoon season. The bacterial density increase substantially with rise in temperature in summer and attains peak in the monsoon season (Sharma, 2009)

NATURAL AND ANTHROPOGENIC STRESSES ON BIODIVERSITY

The Upper Ganges is exposed to various natural stresses such as frequent flash floods, cloud bursts, river blockades due to massive landslides and earthquakes. Prominent flash floods and eco-disasters encountered with the fluvial system of the Upper Ganges were major Alaknanda flood in 1970; massive Bhagirathi flood in August 1978 caused due to river blockade; bursting of Gohna Tal in 1984; Uttarkashi earthquake of October 1991; Asiganga and Bhagirathi flash floods in 2012; and recent flash floods in Mandakini, Bhagirathi and Alaknanda in June 2013. All these natural eco-disasters

caused major geomorphic transformations in fluvial ecosystem of Upper Ganges and its biodiversity.

In addition to natural stresses, there are many anthropogenic pressures such as development of cascade of hydropower projects, construction and widening of roads and highways, excessive extraction of boulders, pebbles and sand from the riparian zones of the Upper Ganges. More than 71 hydropower projects have been planned at different stages (commissioned/ under construction/ under planning) on the Upper Ganges in Uttarakhand. The dams have deleterious effects on the river biodiversity including fish resources. Dams interrupt stream flow and generate hydrological changes along the integrated continuum of river ecosystems (Vannote et al. 1980; Junk et al. 1989).

The diversion of water for hydropower generation leads to reduction in flow downstream of the diversion site up to disposal of tail race out fall. This leads to the adverse impact on riverine ecosystem. The barrage/ dams also act as a barrier for migratory fish species. The construction activities of hydropower projects may also damage the preferred habitats of aquatic organisms including fish. The cumulative environmental impact of these hydropower projects on the aquatic biodiversity and integrity of the fluvial ecosystem of Upper Ganges may be much more.

Specific study of Tehri Dam construction on the biological production of Bhagirathi was undertaken by Sharma (1991). Responses of periphytonic diversity to the environmental stress caused by construction activities of Tehri dam has already been done by Sharma et al. (2008a). As a consequence of dam construction activities, some taxa were eliminated while others remained unaffected in the stressed environment of Bhagirathi. A deleterious effect on fish life was caused by Tehri Dam has also been noticed (Sharma 2003b). Macroinvertebrates diversity and the diversity of the nymphs and larvae of Ephemeroptera and Trichoptera were drastically influenced by the Tehri Dam (Sharma et al. 2008b).

Road widening and construction also has deleterious effect on riverine biodiversity of the Upper Ganges. Adverse impacts of widening of NH-58 and network of roads on the fluvial system, aquatic biodiversity and hyporheic biodiversity have also been reported (Sharma 2005, 2007, 2009).

Overall, these natural and anthropogenic pressures alter the flow regimes, hydraulics, stability of bottom substrates, aquatic river channel morphology, riparian vegetation, functional habitat, sediment flows and composition of biodiversity. Migration route, spawning sites and breeding grounds of fishes are also choked due to these stresses.

REMEDIAL MEASURES FOR CONSERVATION OF BIODIVERSITY

A host of suggestions have been made for minimising the adverse impact of natural and anthropogenic stresses on the river biodiversity of the Upper Ganges.

Restoration of Riparian Vegetation

Fishes and other aquatic organisms are benefitted in many ways by the availability of moderate level of plant cover in the riparian zone. Aquatic macrophytes and other riparian vegetation help in stabilising sediments and shoreline, reducing problems associated with erosion and turbidity. Riparian vegetation of the Upper Ganges has been adversely affected by several natural and anthropogenic activities. Therefore, an extensive programme for restoration of riparian vegetation on the mountain slopes of the watershed of the Upper Ganges will help in stabilising the river banks.

Proper Implementation of Muck Disposal Plan

A huge amount of muck is generated during the construction of hydropower projects. Most of the developers throw the muck along the bank of the rivers. This damages the lateral, longitudinal and vertical dynamic system of the river. Therefore, the muck should be disposed away from the river in a carefully identified site.

Restoration of Functional Habitats or Creation of New Habitats

It is possible to restore functional habitats or reconstruct new habitats with the help of gravel beds of large rocks near the base of rivers. Raising water level during the lean season often creates suitable spawning sites for nest building fish species.

Management of Downstream Ecology and Release of Appropriate Environmental Flows

Release of appropriate environmental flows with required water depth and velocity is necessary for maintaining the downstream ecology. Seasonal discharge limits can be established to prevent excessive damaging rate of flow releases. Limits can also be placed on the rate of change of flow sluicing (releasing of water through the sluice gate) turbine pulsing (releasing water through the turbines at regular intervals) and small turbines (capable of providing continuous generation of power using small flows) can be used to improve flows.

Establishment of Fish Hatchery

Establishment of fish hatchery in the vicinity of the hydropower projects can be one of the options for rehabilitation of migratory and endangered fish species. The THDC India Ltd. has already established a Mahseer hatchery in the vicinity of Tehri Dam Project for rehabilitation of the migratory endangered fish, Mahseer.

New Policy Interventions

New policy interventions are required for striking a balance between development and environment. Developmental activities (hydropower projects, road construction and widening) should be conducted ensuring minimal damage to the environment of riverine ecosystem and its biodiversity of the Upper Ganges

ACKNOWLEDGEMENTS

The author expresses his sincere thanks to the IUCN India office for providing an opportunity to contribute on biodiversity of the Upper Ganges.

Thanks are also due to Prof. R. K. Sinha for stimulating interaction on various aspects of river biodiversity.

Assistance rendered by the doctoral students of the author for preparing the manuscript is thankfully acknowledged.

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An Overview on the Threats of Aquatic Ecosystem in Upper Brahmaputra Basin

S. P. Biswas

Department of Life Sciences,
Dibrugarh University, Assam - 786004, India
E-mail: spbsdu@gmail.com, spbsdu@dibru.ac.in

ABSTRACT

The River Brahmaputra is the abode of over 300 species of fish and other mega fauna, notably the endangered Gangetic Dolphin, *Platanista gangetica gangetica*. Changes in the river morphology in the past hundred years indicated about 45 per cent widening of the river; simultaneously, the river becomes shallow and oxbow lakes are often formed.

High rate of siltation and erratic flood pattern experienced in recent years have a great bearing on the faunal composition of the Brahmaputra river system. The adverse changes to the riparian zone have impacted the habitats of a variety of food and ornamental species. An eco-hydrological plan for conservation of endangered and endemic fauna and also sustainable use of aquatic fauna including a methodology for the comprehensive assessment of proposed river dam projects with regard to impacts of ecosystem and alternative livelihood strategy for the rural people of the region have been highlighted.

Key words: Brahmaputra River, Gangetic dolphin, river dam, eco-hydrology

INTRODUCTION

The Brahmaputra drainage system having a combined length of 2906 kilometres and a catchment area of over 50 m ha, is one of the largest river systems in the world (Rao 1979). It flows through Tibet (China), India, Bhutan and Bangladesh. The Brahmaputra (*Zangpo* as it is known in Tibet), traverses 1625 kilometres eastward, and then suddenly cuts across the Himalayan mountains and reaches Indian territory.

The *Zangpo* changes its name to *Siang* or the *Dihang* after entering into Arunachal Pradesh. This reach of the river from the Indo-China border to Kobo in the Assam-Arunachal border covers a length of 268 kilometres and here the gradient of the river is relatively steep.

Apart from 47 major tributaries, over 3000 flood plain lakes, locally called *Beels*, are scattered throughout the Brahmaputra basin within Indian territory. The river system is sustained by snowmelt run-off, the ablation of glaciers and rain water. Being in a heavy rainfall zone and also blessed with innumerable snowed streams and rivers, the region is well-known for aquatic diversity, especially for fish.

However, this hitherto unpolluted river system suffered a gradual decline in habitat quality due to changes in “water regime” especially the seasonality and hydrograph of the river system. As a whole, the habitat reach of all the major tributaries and also the main river is unstable due to alluvial nature of the basin, frequent changes of river courses, high rate of bank erosion.

Deforestation in the catchments, construction of roads and embankments and blockage of feeder channels of floodplain lakes also contributed to the reduction of habitat complexity. The adverse changes to the riparian eco-tones have impacted the habitats of a variety of food and ornamental fish species.

Therefore, the major threats faced by the aquatic fauna and the importance of conserving eco-tone features and adopting an integrated eco-hydrological approach for restoration of riparian zone of the upper stretches of the Brahmaputra River is focussed upon here.

MATERIALS AND METHODS

Study Area

The present study has been restricted to only the upper stretch of the Brahmaputra within Assam from Saikhowaghat (95°35'07"E and 27°46'25"N) to Dhansirimukh (92°53'09" E and 26°38'19" N) comprising about 300 kilometres.

The study area was divided into four segments (zones) for sampling of fisheries and limnological data. The segments were as follows:

a) Saikhowa to Gujia b) Gujia to Disangmukh
c) Disangmukh to Janjimukh d) Janjimukh to Dhansirimukh.

Sampling was carried out from January 2010 to December 2011 on a seasonal basis. For collection of fish samples, the following landing centres were selected: a) Gujia (Tinsukia), b) Maijan (Dibrugarh), c) Dikhowmukh (Sivasagar), and d) Neematighat (Jorhat).

Maguri *Beel* (167.4 ha) is one of the largest floodplain lakes in upper Brahmaputra basin and lies between 27°33'79.5" to 27°34'35.7" N and 95°22'08.1" to E 95°22'19.0"E in the upper Brahmaputra basin within Tinsukia district and adjacent to the Dibru-Saikhowa National Park. A unique feature of this *Beel* is that the River Dibru, a tributary of the main Brahmaputra, flows through it. Maijan *Beel* (27°30'14.4" N and 94°58'04.8" E), located about 15 kilometres east to

Dibrugarh, the district headquarter, is an oxbow lake and covers an area of 134 ha. Potiasola (26°50'10.1" N & 94°12'17.4" E) is an "open" *Beel* formed by tectonic depression and is located in Jorhat District, about 14 kilometres north-east of Jorhat town. The area of the *Beel* is 66 ha having a variable seasonal depth (0.8 to 8.0m). Butikur *beel* (94°56' E; 26°75' N) is located along Dhemaji-Dhakuakhana road (area 15 ha) in the northern bank of the river.

METHODOLOGY

The limnological parameters selected for assessing riverine and wetland "health" was water temperature, pH, electrical conductivity, turbidity, alkalinity, dissolved oxygen (DO), free carbon dioxide (FCO₂). The assessment of the selected parameters was done by following the methodologies given by Michael (1984), and APHA (1998). Physico-chemical parameters of *Beel* water were recorded on a seasonal basis. Four distinct seasons — winter (Dec-Feb), pre-monsoon (Mar-May), monsoon (Jun-Aug) and post-monsoon (Sep-Nov) is prevalent in the upper Brahmaputra basin based on the intensity and duration of rainfall (Boruah and Biswas 2002).

The sampling of fishes was carried out following Gulland (1975). Fishes were collected using hired fishermen with cast net and monofilament gill nets of different mesh sizes. The fish samples were also collected from different fish landing centres such as Gujia Ghat (Tinsukia), Neemati Ghat (Jorhat), Dhemaji and Dibrugarh. The samples were immediately preserved in four per cent formaldehyde for taxonomic identification by following the keys of Talwar and Jhingran (1991).

The catch per unit effort (c.p.u.e.) for each fishing gear (widely used fishing net like cast net and gill net) was calculated following Biswas (1993). The fish catch (kg/ head/ hour) for each sampling station was recorded seasonally and statistical analysis (Bailey 1994) was done to find out whether there was any significant variation in fish catch between stations and seasons. Species diversity (Shannon and Weiner 1963); similarity and dissimilarity Indices

(Magurran 1988); fish species richness (Margalef 1957) were also calculated to find out the diversity of fish fauna at different stations.

RESULTS AND DISCUSSION

The Brahmaputra, being a large river, covers different climatic zones, landscapes and bio-geographic regions. The climate of the upper Brahmaputra valley varies from tropical through sub-tropical to temperate at the higher altitudes. Temperature varies from sub-zero degrees in the upper Arunachal Pradesh region to 38°C in the plains of Assam where relative humidity ranges more than 85 per cent.

The annual rainfall in the region varies from 1637 to 6317 millimetres (Barthakur 1986). Nearly 80 per cent of the rainfall occurs between May and October. The pre-monsoon rain experienced in April-May inundates the low-lying ground and recharges the wetlands, which provide an ideal habitat and breeding ground for a large number of fishes including Indian major carps (Biswas and Michael 1992).

Usually there are three or four “high floods” between May and October (Biswas and Boruah 2000a) and these annual floods have a great bearing on the faunal composition of a riverine system (Junk et al. 1989).

Geo-morphologically, the Brahmaputra basin is very unstable as it is located in a high seismic zone and is constituted by alluvial soil. The valley is rather narrow, the average width is only about 80 kilometres from foothill to foothill, and the river itself occupies six to 19 kilometres (WAPCOS 1993). During the rainy season (May-October), the river often floods to eight kilometres in width, it rises nine-12 metres and deposits the sediments carried down from the mountains.

The river is considerably fast flowing in Tibet and also in Arunachal Pradesh (the gradient ranges from 4.3 to 16.8 m km⁻¹), but between Kobo and Dibrugarh the gradient of the river is reduced to 0.09-0.17 m km⁻¹ (Goswami 1985). After Dibrugarh, the river basin is

flattened with an average gradient of 0.13 m km⁻¹ throughout its course of about 640 kilometres within Indian territory.

Further, the river carries one of the highest sediment loads in the world, about 332 million metric tons annually. Throughout its course, Brahmaputra is continuously shifting southwards and in some places may be migrating at rates as high as 800 m/ yr. The rate of aggradations is as high as 16.8 cm/ yr in the head reaches upstream from Dibrugarh (Varma and Rao 1996).

The banks of the river throughout are almost perpendicular (nearly 90° slope) and during floods, the loose texture of the soil, coupled with the strong current causes the erosion of the underside of the bank to produce an overhang that invariably collapses into the water.

A similar feature is very common in the entire River Brahmaputra (Biswas et al. 2000). The low gradient of the river bed coupled with the alluvial soil of the basin has resulted in a braided pattern to the river with frequent change of course, and it forms numerous sand bars (islands) throughout its course (Table 1).

Like the other physiographical features, the soil type of the region is varied and four types of soil – alluvial, laterite, red loam and red-yellow can be recognised. However, the soil of the region is mostly acidic (pH 4.5 to 5.9) in nature.

Hydrobiological Feature in the Upper Reaches of the Brahmaputra

Hydrobiological characteristics of the River Brahmaputra indicated that the abiotic parameters of water vary widely in open river and the adjacent floodplain lakes (Table 2). The variations were more prominent between wet and dry months.

Flood pulse and its associated sediment/ nutrients are identified as the most influencing factor for diversity and assemblage of fish fauna in the upper

Table 1: Habitat types at different segments in the upper reaches of the Brahmaputra

Physical Status	Segment A	Segment B	Segment C	Segment D
Bed Structure	Pebbles, partly sandy	Sandy & partly alluvial	Sandy & alluvial	Sandy & alluvial
Bank	Unstable	Unstable	Unstable	Unstable
Sand Bar	Present	Numerous	Numerous	Numerous
Major source of contamination	No prominent anthropogenic source	Tea garden & Oil field	Urban sewages	Urban sewages
Riparian habitat	Thin vegetation	Crop lands	Crop lands	Crop lands
Siltation	High sedimentation	High siltation rate inducing bank erosion	High siltation rate inducing bank erosion	High siltation rate inducing bank erosion

Brahmaputra basin. Erratic flood pattern experienced in recent years have a great bearing on the faunal composition of the Brahmaputra river system. The limnological parameters of the Brahmaputra were studied by various workers (Singh et al. 1988; Manna and Sarkar 2008) and almost similar trends were also observed by them.

Floodplain Lakes

It was observed that the open *Beels* received backflow water from the connecting river or from the huge catchment area following monsoon rains. Auto stocking of the open *Beel* was made by the influx of the flood water when many riverine species including the Indian Major Carps (IMC) entered in the *Beel* for spawning purpose.

However, *Beels* do have a “residential” fish population of which air-breathing forms such as *Channa*, *Clarias*, *Anabas*, etc. constitute about 40 per cent of the total. Besides, both “open” and “closed” *Beel* were rich in ornamental species such as *Botia*, *Chaca*, *Trichogaster* etc.

Flood pulses control population size and it has been found to be the strongest factor for species diversity in the riparian zones. Trophic structure is typically present in the *Beels* from surface dwelling to typical substrate dwelling species such as *Glossogobius giuris* to mud-dwellers such as *Monopterus albus* or burrower such as *Channa aurantimaculata*. Das and Biswas (2005) reported 70 species of ornamental fishes from the *Beels* of upper Assam, most of which

Table 2: Average physico-chemical parameters River Brahmaputra and its linked ecosystems

Habitat	Water Temp. (°C)	pH	Current Flow (m sec ⁻¹)	Transparency (cm)	DO (mg L ⁻¹)	F CO ₂ (mg L ⁻¹)	Alkalinity (mg L ⁻¹)	Conductivity (µS cm ⁻¹)	TDS (mg L ⁻¹)
Main River	18.5-27.8 (24.87 ±3.15)	7.2-7.7 (7.4 ±0.14)	0.09-0.82 (0.29±0.14)	17.9-45.8 (27.73 ±8.54)	8.6-11.1 (10.2±2.01)	3.4-8.4 (5.1 ±1.35)	50.0-77.6 (53.3±6.37)	94.0-136.6 (111.8±14.3)	79.0-133.5 (111.4±40.8)
Maguri Beel	13.8- 28.5 (21.6±4.6)	6.7-7.4 (7.1±0.2)	0.14-0.7 (0.4± 0.2)	25.1-68.2 (39.6± 12.4)	6.3-10.7 (8.1±1.4)	5.3-12.6 (8.2±2.5)	39.50-67.6 (55.7±9.1)	27-207 (97.6±28.67)	106.7-596.7 (326.7±168.0)
Maijan Beel	17.2-25.4 (21.6±0.68)	7.0-7.7 (7.3±0.14)	--	38.8-198.0 (124.42±7.49)	5.9-9.4 (7.78±0.68)	3.1-8.0 (6.55±0.76)	24-49.6 (34.96±3.06)	12.8-126.2 (69.54±17.4)	83.3-356.7 (235±33.98)
Potiasola Beel	18.2-27.3 (23.28±1.6)	6.9-7.7 (7.4±0.6)	--	25-172 (108.6±8.7)	4.33-7.43 (6.2±0.7)	2.45-8.28 (5.4±0.3)	50-130 (89.6±8.6)	10-110 (61.7±8.6)	21.3-230 (49.1±2.2)
Butikur Beel	18.0-30.0 (24.30 ±1.1)	7.0-8.6 (7.2 ±0.1)	--	72.0-161.0 (127.3 ±4.4)	4.0-10.4 (7.9 ±1.2)	4.0-90.0 (5.5 ±1.1)	25.0-110.0 (66.3 ±9.7)	7.0-170.0 (125.6±7.1)	29.7-109.0 (80.1 ±4.1)

have considerable commercial value in the domestic as well as overseas market.

Over exploitation of resources mainly fish from these wetlands coupled with indiscriminate killing of fish by using pesticides and other illegal devices are the major threats to the already depleted fishery resources of the flood plain lakes.

Fish Habitats

Based on the topography of the Brahmaputra river basin, five major types of fish habitat were identified:

- **Fast flowing river:** This section of the river has a shallow stony bed that harbours small stream fish genera such as *Nemacheilus*, *Garra*, *Barilius*, and *Danio* which hardly grow beyond 15 centimetres
- **Upstream pools:** These are the sluggish and deeper parts of the river. Species such as *Tor* spp., *Labeo pangusia*, *Bangana dero*, *Neolissocheilus hexagonolepis* and *Raiamas bola* inhabit this type of habitat
- **River meandering and confluence:** The eddy, counter-current system at the junction of two rivers (tributary and main river) is an ideal place for fish assemblages. The confluences are also the passageways for upstream fish migration. Similarly, the channel meanderings offer suitable habitats for a large number of fish species and river dolphins. Favorable hydrobiological conditions and proper habitat partitioning appear to be the key factors for the assemblage of species in river meandering areas
- **Open river:** The main river harbours a wide variety of fish species and other aquatic fauna including river dolphin
- **Beels** (floodplain lakes): *Beels* of the Brahmaputra basin are weed-infested shallow water bodies temporarily or permanently connected with the main river.

The fish assemblages in the River Brahmaputra along its length relate to physical factors of gradient,

current velocity and substratum as described by Wootton (1990). On the basis of the availability of fish in different seasons of the year, the fish species of the Brahmaputra may be categorised into the following groups:

Category I: This group of fishes is found round the year and do not have any preference for a particular physico-chemical variability of the water. They exhibit a mosaic type of distribution without any seasonal trend. *Wallago attu*, *Notopterus notopterus*, *Aspidoparia* spp., *Labeo* spp., *Mystus* spp., *Channa* spp., *Mastacembelus* spp., *Macrogathus* spp. and *Chela* spp. feature as prominent species among this group;

Category II: This group comprised of minnows and loaches is available in abundance during pre-monsoon and monsoon months. Notable in this category are *Amblypharyngodon mola*, *Esomus danricus*, *Salmostoma bacaila* and other planktophagus minnows which have a short life span.

Category III: The migratory forms such as giant Catfishes (*Sperata aor*, *Bagarius yarrelli*, *Silonia silondia*, and *Pangasius pangasius*), Mashers (*Tor* spp.) and Featherbacks (*Chitala chitala*) usually encountered during post-monsoon and winter months belong to this category.

Category IV: This group includes genera such as *Barilius*, *Danio*, *Lepidocephalus*, *Nemacheilus* which are sensitive to certain abiotic factors such as water velocity and dissolved oxygen and they prefer to live in clear, shallow or marginal area of the water body. Most of them are territorial or have a restricted home range.

Fishing was conducted in the main river throughout the year except during “closed season” (May 1 to July 15) and also during high flood and festival days. The normal fishing days in a year ranged between 260 and 285 days.

Biswas (1998) reported that fish catch intensity in the upper reaches of the Brahmaputra (Saikhowa Ghat to Neemati Ghat) ranged between 0.3 and 0.8 kilograms per head per fishing hour. The maximum

fishing, however, was done when the flood receded (usually in August-September).

In general, fish catch was on the higher side during winter and pre-monsoon months. During high flood, netting was difficult and the fish catch also dropped in all the stations surveyed. The average fish production in the open river was estimated to be 2.2 kg/ km/ day.

However, the catch composition varied from year to year even in the same landing centre and there were cyclical change in the recruit of individual species to fishery (Biswas and Michael, 1992; Biswas and Boruah, 2000a).

Although upper reaches of the Brahmaputra harbours a good number of fish species, but the value of diversity indices was quite different in different habitat types (Table 3). According to Lawson and Olusanya (2010), the diversity is partly a function of the variety of habitats; the more varied habitats tend to be inhabited by a large number of species than less variable ones. Secondly, the older and stable habitats usually contain more species than younger ones. Moreover, warmer temperatures, availability and stability of food result in high level of diversity along with latitudes and longitudes.

Anthropogenic effects including the changes in river management, heavy siltation causing loss of water cover for mega fauna are major concern for naturalists. Excessive boulder and sand excavation from river bed alters the micro-habitats of many hill-

stream fish species. Habitat alteration often leads to shallow channel dry up during non-rainy months.

Sand mining is common in some of the tributaries such as R. Burhidihing, R. Dikhow, and in R. Subansiri; but the amount of sand extraction from the river bed is not available. However, Islam (2012) reported that 18,000-24,000 cft of sand was excavated daily at Kukurmara during 2008-09.

The Upper Brahmaputra Valley has 15,196 ha area of wetland which is 15.01 per cent of the total 101,231.60 ha areas of wetlands in Assam, producing about 16,200t of fish annually (Purkayastha 2012). These wetlands are considered as fish granary of the state (Biswas and Michael 1992). They also act as feeding and breeding grounds for many riverine species (Biswas 1998).

Auto-stocking of the open *Beel* was made by the influx of the flood water when many riverine species including the Indian Major Carps (IMC) entered in the *Beel* for spawning purpose. The majority of the species in *Beels* enter the fishable stock in their first year life, as fishing pressure in the *Beels* is very high (Biswas and Boruah 2000b).

Das and Biswas (2005) reported 70 species of ornamental fishes from the *Beels* of upper Assam, most of which have considerable commercial value in the domestic as well as overseas market. The average fish production from the open *Beel* was recorded as 215.7kg/ ha/ yr and that of closed *Beel* was 107.6kg/ ha/ yr (Dutta 2002).

Table 3: Fish diversity indices in the upper reaches of the Brahmaputra

Fish Diversity Indices	Segment A	Segment B	Segment C	Segment D
Shannon Index (H')	2.70	3.27	3.14	3.13
Evenness Index (J)	0.71	0.95	0.95	0.96
Margalef Index (Ma)	1.85	5.17	4.26	4.44
Simpson's Index of Dominance (D)	0.31	0.04	0.05	0.05
Simpson's index of diversity (1 – D)	0.69	0.96	0.95	0.95

Over exploitation of resources mainly fish from these wetlands coupled with indiscriminate killing of fish by using pesticides and other illegal devices are the major threats to the already depleted fishery resources of the flood plain lakes (Biswas 1996; Sharma 2007).

The key issues identified in the basin are river bank erosion, siltation of natural water bodies and loss of livelihood for the riparian people especially the fisher folk. Maintenance of depth and flow of water is very important to sustain the riverine mega fauna and its dependent ecosystems but the frequent changes in the river's course coupled with heavy siltation has a great effect on the river's faunal composition.

During the twentieth century, the total amount of bank area lost from erosion was 868 square kilometres. Maximum rate of shift of the north bank to south resulting in erosion was 227.5 m/ year and maximum rate of shift of the south bank to north resulting in accretion was 331.56 m/ year (Sarma 2005). As the river widens each year due to heavy siltation and bank erosion, the average depth of the river continuously decreases and the water is distributed among numerous channels. As a result, water cover for large fish species and other mega fauna like the river dolphin becomes inadequate during the dry season.

Shrinkage of habitats (including loss of agricultural land due to sand deposition) and livelihoods, destruction and loss of dwelling houses were the three major concerns raised by several workers (Biswas et al. 1997; Biswas and Boruah 2000ab; Boruah and Biswas 2002, Sharma 2007). Siltation of wetlands, wanton killing of brood and juveniles, excessive weed infestation, lack of management plan and negative human interferences were identified as major contributory factors for the poor fish productivity in the wetlands of Assam resulting in poor livelihood status of the fishing community (Dutta 2002; Das and Biswas 2005; Hussain 2010). Further, Brahmaputra basin is the last refuge of the Gangetic Dolphin. Alteration/ reduction of water flow will have

an adverse impact on the survival and growth of the aquatic mega-fauna including dolphin (Biswas et al. 1997; Biswas and Boruah 2000b; Boruah and Biswas 2002). Sharing information among the riparian countries and environmental impact analysis (EIA) is highly essential before consideration of any river valley projects.

The enhancement of productivity to its potential level will considerably improve the livelihood status of the people providing additional scope to invest in education, health, housing and other basic needs to improve their overall socio-economic status. Eco-hydrology is highly effective in improving water resources, biodiversity conservation, socio-economic development and multiple ecosystem services (Boruah and Biswas 2002).

Remedial Strategy

Against this backdrop, it is now absolutely necessary to adopt an integrated approach, combining hydrology and ecology, thereby providing a new insight into the interrelationship of water and biota (Zalewski et al. 1997). This integrated approach, or eco-hydrological approach, creates a new background for the assessment and management of freshwater resources (e.g. river restoration) and accelerates the implementation of new ideas to sustainable development.

Potential development of phytoremediation technique using herbaceous plants for restoration of river basin processes for instance, reduction of bank erosion has been successful in an experimental site at Majuli Island (Biswas et al. 2000). Such an extension of phyto-techniques in the form of plantation of soil binding fast growing plants in the riparian zone will not only provide more stability to the bank areas and check erosion, but also lessen the turbidity of the river water to a great extent and consequently this helps in the increased productivity of the system. The locally available herbaceous plants have other economic utilities too. Some of these are used as firewood and at least one species is used for fencing in the *char* (island) areas (Biswas 1998).

The concept of integration of ecology and hydrology, with the twin objectives of reduction of threats and amplification of chances for sustainable development (Zalewski 1997) may be applied to the Brahmaputra ecosystem in the following manner:

1. An integrated (ecohydrological) approach is especially necessary for all proposed construction of dams and embankments.
2. To prepare an appropriate model for assessment of commercial fish stock especially the endangered species by GIS tools.
3. Ecological modelling with respect to the main river and its major tributaries should be made along with a strong database starting from the patch level.
4. Control of riverbank erosion by proper sloping of the identified bank areas followed by plantation of fast growing herbaceous plants.
5. To identify other important hydrological factor(s) which influence the migration of fishes.

ACKNOWLEDGEMENT

The author is grateful to the Dibrugarh University for giving the necessary permission to carry out the work.

Financial help from the Ministry of Environment and Forests, Government of India and logistic support rendered by Dr. A. Santoshkumar, Dr. S. Boruah, Dr. B. Bakalial, Dr. R. Bania, Dr. D. Baruah, Dr. L.P. Hazarika and Dr. M. R. Islam are also gratefully acknowledged.

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Identifying Stakeholders in the Ganges Basin to Reconcile Conservation and Competing Land Uses and Processes in the Landscape

Samir Kumar Sinha

Wildlife Trust of India,
Field Station: Valmiki Tiger Reserve, Valmikinagar,
West Champaran, Bihar - 845107, India
E-mail: samir.wild@gmail.com

ABSTRACT

The Ganges basin is the largest river basin in India. It is a source of surface water and other bio-physical resources and ecosystem services for socio-economic well-being in the basin.

Due to intensive agriculture and habitation use, and reduction in forest cover and water coverage, water, land and bio-resources are under tremendous pressure; biodiversity conservation and maintenance of ecological integrity in the basin has become a challenge. Fish resources are depleting and many wild animal species are under threat.

Landscape approach is considered as a suitable means to achieve conservation goals and meet the arduous task of feeding the population. The approach requires identification and analysis of stakeholders for a workable level of agreement among them.

The paper attempts to identify and analyse the stakeholders in the basin to achieve the goal of biodiversity and environment conservation in a multi-stakeholder scenario.

Keywords: Ganges basin, biodiversity conservation, landscape approach, stakeholder, stakeholder analysis

INTRODUCTION

Land-uses and Processes in the Ganges Basin

Ganges basin is the largest landscape in the country characterised by interacting ecosystems and human interference. It is the largest river basin in India in terms of catchment area (NRCD/ MoEF 2009). It is spread across approximately 1.09 million square kilometres in India, China, Nepal and Bangladesh. Rivers in the Ganges basin are not only an important source of surface water but also an array of bio-

physical resources and ecosystem services crucial for socio-economic well being of the inhabitants in eleven Indian states situated in the basin.

Approximately 79 per cent of the total basin (~0.86 million km²) extends only in India and occupies about 26 per cent of the total geographical area of the country. The region is densely populated (423 inhabitants km⁻²) and holds 478 million people of the total 1181 million population of India; some 100

million are directly dependent on the river and its tributaries (World Bank 2010; GRBEMP 2011). It has been estimated that human population in the basin would grow to over one billion by 2030 (Markandya and Murty 2000).

About 62 per cent land in the basin is cultivable land; 16 per cent is covered under forest, 14 per cent is not available for cultivation, and eight per cent is fallow land. In the Ganges basin states, areas under rivers and streams and riverine wetlands are 25236 and 736 square kilometre respectively. Drainage area of these water bodies is 861404 square kilometre (NWA 2011).

There are 27 national parks and 75 wildlife sanctuaries preserving the flora and fauna in-situ. As per 2001 census, there were 1949 towns and cities, of which 337 were under Class-I (population over 100000) and Class-II (population between 50000-100000) categories, located in the basin where approximately 124 million people reside (Anon. 2011). Of the country's total cultivable land, 46 per cent lies within the Ganges basin states which sustains 43 per cent population of the country; average cropping intensity is as high as 147 per cent against the national average of 139 per cent. Availability of irrigation sources and fertile soil are key factors behind this (Anon. 2011).

The quest for deriving high yield from the limited resources results in the exhaustion and overexploitation of resources on one hand and alteration of environmental conditions on the other. Environmental degradation further affects the socio-economic conditions in the basin. Intensive use of chemical fertiliser and pesticide in agriculture sector leads to high level of nutrients and pesticide residues into surface water bodies in the basin through agricultural runoff. It has been estimated that up to 15 per cent of the nutrients added to the soil reaches into surface water systems. Nutrients in surface water and ground water can affect human and aquatic organisms that rely on water for consumption and habitat (Easton and Petrovic 2004).

Water is withdrawn from the rivers for irrigation and energy generation through 12 major diversions/storage projects, and 11 hydroelectric storage projects, respectively (http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Water_Resources_Projects_In_India) in the basin. The water development projects both have direct and indirect impact on the basin's socio-ecological environment. It leads to inundation of forestland and loss of biodiversity; loss of soil fertility; displacement of people; development of seismicity etc. (Rahman et al. 2010).

Apart from withdrawal of water through these projects, rivers receive refuse from cities, towns, industrial houses in the basin (NRCD/ MoEF 2009). The river banks and floodplains are also encroached upon for quarrying, agriculture, establishment of brick kilns and illegal constructions on the floodplains of rivers. Satellite-based studies have revealed that the Ganges basin had been undergoing rapid land-use change; in the last three decades, agriculture and habitation use has increased while forest area has been reduced (Behera et al. 2014).

BIODIVERSITY CONSERVATION IN THE PRESENT LAND-USE SCENARIO

Rivers are central elements in many landscapes. They are important natural corridors for the flow of energy, matter and species, and are often key elements in the regulation and maintenance of landscape biodiversity (Malanson 1993).

Most of the activities and processes undergoing in the basin directly affect the goals of preservation of natural systems in general and biodiversity conservation in particular. Due to the increased rate of water abstraction, measurable shift in hydrology and water quality of the river, and over exploitation of fish resources, fisheries in the Ganges have diminished, fish catch has declined and fish species composition has changed (Vass et al. 2010).

As per CIFRI (1996), of the total landing of fish, only 29.8 per cent were sourced from riverine sources

while rest from other water bodies. Water abstraction projects have pronounced effect on the flow of rivers in the basin. Reduced flow lessens the silt carrying capacity of river resulting in enhanced sedimentation, which adversely affects the fish breeding grounds ultimately affecting fish catch and diversity.

Dams and barrages act as physical barriers and adversely affect migration of species. An anadromous fish such as Hilsa (*Tenualosa ilisha*), a commercially important Indian Shad, has registered a drastic decline in catch in middle reaches of the Ganges after commissioning of the Farakka Barrage in the lower reaches of the river in 1975 (Sinha et al. 1996). Recent construction of large number of hydroelectric projects on the rivers in the Himalayan region has resulted in habitat loss, barrier for movement of fish and other aquatic species, changes in sedimentation flows, alteration in environmental flows and changes in nutrient flows, affecting the biodiversity and natural processes critically important for maintaining them.

Rajavanshi et al. (2012) emphasised protecting the river segments with threatened fish species and critical habitats found nowhere else in the basin should be protected from dams or other potentially damaging civil works. All these interferences have made the riverine ecosystems most threatened among all the aquatic bodies in India (Singh and Singh 2007).

Due to forest loss, deterioration in water quality and flow, and other anthropogenic factors several species in the basin have become endangered. Royal Bengal Tiger (*Panthera tigris tigris*), Vulture (*Gyps* spp.), Gangetic Dolphin (*Platanista gangetica gangetica*), Gharial (*Gavialis gangeticus*), Ganges Shark (*Glyphis gangeticus*), River Terrapin (*Batagur baska*), Bengal Roof Turtle (*Batagur kachuga*), and Bengal Florican (*Houbaropsis bengalensis*) are struggling for survival in their habitat (MoEF 2011).

Shrinkage in forest cover and water expanse in the Ganges basin which leads to biodiversity loss is primarily due to increased agriculture and

urbanisation. It is evident from a recent study on changes in land-use class in the basin (Behera et al. 2014). According to the study, agricultural expansion and built-up land were the significant reasons for loss in forest area in the Indian portion of the Ganges basin during 1975 and 2010.

Coverage under forest plantations has increased but a marked decrease in natural forests, mangroves, scrubland, wasteland and water body has taken place. An increment of 45.03 per cent in built-up land class has been recorded during the period. Most of the forest cover has been converted to agriculture land and built up area.

KEY PROBLEMS AND WAY AHEAD

Food production to feed the burgeoning population is one of the key issues affecting the land-uses and environment worldwide. The problem is quite evident in the Ganges basin as discussed in the earlier section. Though, farming is the basis of civilisation, it is more damaging to nature than any other sector of human activity and expansion, and intensification of the sector threatens ecological goods and services (Balmford et al. 2012; MEA 2005).

It has been predicted that continuing population and food consumption growth will mean that global demand for food will increase till roughly the middle of the century and growing competition for land, water, and energy, in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment (Godfray et al. 2010). In the existing scenario in the Ganges basin, biodiversity conservation and environmental protection is a challenging task indeed.

In developed countries, biodiversity goals are achieved through a mix of total protection complemented by a broad spectrum of environmental restrictions on the use of non-protected land (Bennet et al. 2006). Conservation interventions are made across the entire landscape and conservation is just one among several management goals

(Philipps 2002). The composition of the portfolio of conservation approaches differs according to a country's stage of economic development, population density and culture (Sayer 2009). Similar, landscape approaches are now used to achieve conservation goals in developing countries where there is a need to address trade-offs between conservation and local livelihoods (Sayer and Campbell 2004).

These approaches assume that the landscape is the appropriate scale for reconciling these trade-offs. However, such approaches may not deliver effectively on either alleviating poverty or on conserving biodiversity (McShane and Wells 2004). Effects of climate change on regional crop production, competing demands on land for climate change mitigation, biodiversity conservation, and agriculture implies trade-offs, many of which are poorly understood and not easily resolvable (Lobell et al. 2011; Sandker et al. 2012). Thus, Sayer et al. (2013) opine that there is no single best answer to the problem, and societies will have to confront challenges that transcend traditional agricultural and environmental boundaries.

This necessitates that people and societies must make decisions, quality of which is a function of the process by which decision is reached, and achieving objectives is an ongoing process of negotiation, learning, adaptation, and improvement. This requires decision makings with landscape approaches, which have gained importance for searching solutions to reconcile conservation and development (Sayer 2009). The scope of the term 'Landscape' in the present days has changed from focused biophysical (Noss 1983) and visual/ scenic attributes (Franklin 1993) to an arena in which entities including humans interact according to physical, biological, and social rules that determine their relationships and it is defined in broader conceptual terms rather than simply as a physical space (Farina 2000).

The Convention on Biological Diversity (CBD 2011) recommends that the landscape level is an appropriate spatial scale for improving the

coordination between relevant policies and sectors, as multiple land-use forms such as settlements, transport infrastructure, agriculture, forestry, mining, hunting, and conservation often co-exist (and compete for limited natural resources) within the same landscape. It is also an important planning scale for considerations of ecosystem resilience (Thomson et al. 2009).

The US Department of Interior: Bureau of Land Management (http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/landscapequestions.html#howdef) explains "Landscape Approach" as an approach that looks across large, connected geographic areas to allow for recognition of natural resource conditions and trends, natural and human influences, and opportunities for resource conservation, restoration and development.

It seeks to identify important ecological values and patterns of environmental change that may not be evident when managing smaller, local land areas. Also, it provides a framework for integrating science with management and co-ordinating management efforts and directing resources where they are most needed. Sayer et al. (2013) provided 10 summary principles to support implementation of a landscape approach as it is currently interpreted.

These principles emphasise adaptive management, stakeholder involvement and multiple objectives, which differ from more traditional sectoral and project-based approaches. The multi-stakeholder principle, one of the 10 principles in Landscape Approach, requires engagement from a representative set of stakeholders, and negotiation towards a workable level of agreement among them about goals concerning issues and resources of common concern from the landscape and ways of reaching them.

Developing a stakeholder platform requires a patient iterative process of identifying stakeholders, their interests, building trust, empowering weak stakeholders and, for powerful stakeholders, to accept new rights and roles for other stakeholders (CBD

2011). In a landscape approach, all stakeholders need to understand and accept the general logic, legitimacy and justification for a course of action, and to be aware of the risks and uncertainties; building and maintaining such a consensus is a fundamental goal of it (Sayer et al. 2013).

Keeping in view the importance of stakeholder identification for landscape level solutions in the Ganges basin, the present paper attempts to identify the stakeholders which could be useful for developing strategies and mobilising activities for reconciliation of land uses competing with biodiversity conservation. The paper holds importance since very scanty information is available on stakeholder identification in the Ganges basin. The paper seeks to fill in such a gap.

MEANING AND IMPORTANCE OF STAKEHOLDERS

The Merriam-Webster dictionary defines “stakeholder” as: a person entrusted with the stakes of bettors; one that has a stake in an enterprise; and one who is involved in or affected by a course of action.

Grimble et al. (1995) defined the term as: “all those who affect, and/ or are affected by the policies, decisions and actions of the system. They can be individuals, communities, social groups or institutions of any size, aggregation or level in society.”

When the term implies in Landscape Approach, a stakeholder can be “an individual, group or institution having a specific stake in the landscape, and who is (in)directly affecting or affected by any decision concerning the landscape.”

Thus, stakeholders may not necessarily be physically present in the landscape. The stakes may include a product (fuel, timber, crop, fish, water, wood etc.), interest (benefit, profit, influence, power etc.), a service (recreation, biodiversity conservation, scenic beauty etc), or anything, to which a particular value is attached.

METHODS FOR STAKEHOLDER ANALYSIS

In policy development and natural resource management, stakeholder analysis is seen as an approach to empower marginal stakeholders to influence decision making processes (Reed et al. 2009). Lindenberg and Crosby (1981) suggested making an inventory of those who could have role in decision-making, gauging their importance through their level of influence and their interest for a particular outcome.

In the Landscape Approach, it is a methodology for understanding a landscape's dynamics by identifying the key actors directly or indirectly related to the landscape, and assessing their respective roles (interests, influences, rights, duties) in the landscape.

In the present paper, stakeholder analysis was used to better understand its perspective in the Ganges basin. Objectives of the analysis were to:

1. Identify the stakeholders, and
2. Categorise the stakeholders.

The overall purpose of the paper is to provide analytical support to an on-going process of uses, conflict resolution and management of resources crucial for biodiversity conservation in Ganges basin.

Methods followed to meet the objectives were as below.

- a. **Rich picture:** A hand drawn diagram (rich picture) was created to illustrate the main elements and relationships that need to be considered in trying to intervene to create improvement in biodiversity conservation prospects, and illustrate richness and complexity of the situation in the basin. Structures, people, land-use, natural elements, conflict and stakes in the basin were depicted using diagrams and words. While preparing the rich picture, due care was taken to avoid structuring the situation in a logic model or

process chain, and truly reflect the scenario as much as possible without privileging, predetermining, or presuming a particular point of view.

b. Identification and categorisation of stakeholders: Stakeholders in the Ganges basin were listed by analysing the rich picture, personal observations and experiences, literature review, and media reports. While identifying the stakeholders following guiding questions were kept in mind based on IIED (2005).

- Who are the potential beneficiaries?
- Who are adversely affected?
- Who has existing rights?
- Who is voiceless?
- Who resent to changes and mobilise resistance?
- Who is responsible for planning?
- Who has money, skill or key information?
- Whose behaviour has to change for success?

The identified stakeholders were first organised on the basis of macro to micro continuum to classify the stakeholders at different levels and identify their interest. Micro-level stakeholders are those who are immediate users and *de facto* managers of the basin resources, while macro-level stakeholders are the groups/ macro planners concerned with regional or national resource and development issues. The continuum levels, from macro to micro level, used in the study were global and wider society, national, regional, local off-site and local on-site (Grimble et al. 1995).

Stakeholders were further categorised into primary, secondary and tertiary depending on an assessment of whether they are immediately affected, or can immediately affect the biodiversity conservation in the Ganges basin. For this, top-down analytical categorisation of the identified stakeholders was done based on observations (Dryzek and Berejikian 1993). Stakeholders in different categories were

represented through a simple diagram of concentric circles.

Next level categorisation was done using Interest-Influence matrix displaying the attributes and interrelationship of the stakeholders. The analysis tried to identify the stakeholders with “interest” in and “influence” over the opinion making in the resource uses issues in the landscape.

Based on the analysis the stakeholders were classified into:

- a. Who can make difference (Key players)
- b. Who need to be made more responsible (Context setters)
- c. Bystander group (Crowd)
- d. Victim group (Subjects) (Eden and Ackermann 1998; De Lopez 2001).

RESULTS AND DISCUSSION

Rich Picture of the Ganges Basin

Rich picture of the Ganges basin illustrates main elements and their interrelationships in the basin. It also helped in identifying various goods and services connecting the biophysical attributes of the Ganges system and human benefits in the river basin (Figure 1).

The goods and services are not homogenously distributed over the landscape. The amount of service supply depends on location-specific and temporal landscape characteristics (Wiggering et al. 2006; Egoh et al. 2008). It also portrays the threat elements operational in the basin such as deforestation and dams in upper reaches, exploitation of biological resources, disposal of wastes, human settlements in the floodplains etc. As depicted, the landscape has multiple values (tourism, biodiversity, religious sentiments etc), goods (forests, fertile farmland, fishing ground, water for irrigation, human and industrial uses etc), and myriad of services (waterways, recharging of wetlands, dilution of pollutants etc).

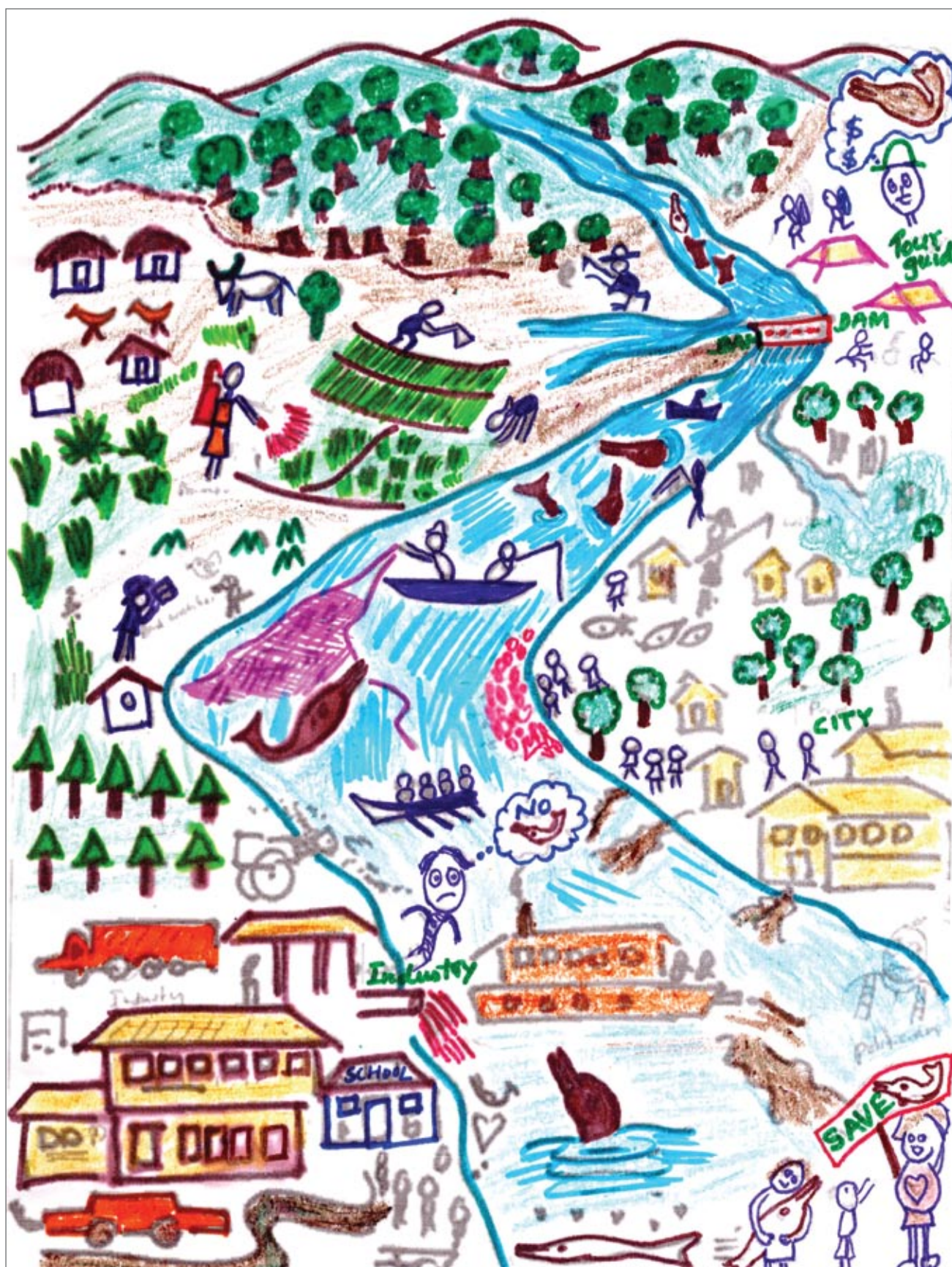


Figure 1: Rich picture of the Ganges basin and illustrating richness and complexity of the situation in the basin ©Samir Kumar Sinha & Enoka Priyadarshani Kudavidanage

Apart from these values, there exists a connectivity of systems (farming connected with river flow, wetlands connected with river, upland forests connected with lowland farming). The basin provides more than one service at a time viz. agricultural production, facilitating tourism and recreational activities, providing habitat for wildlife, supporting fisheries etc thus making the Ganges basin a multifunctional landscape.

STAKEHOLDER IDENTIFICATION AND CATEGORISATION

Stakeholders on a Macro-micro Continuum

The stakeholders were identified and organised on a macro-micro continuum. Interest of stakeholders

at local on-site continuum is in direct use of the basin resources, be it water, physical or biological resources or the aesthetic values attached with river and its floodplain, thus forming the micro continuum level, while the macro level continuum includes wider society like international agencies and common interested mass (Table 1). All stakeholders lie somewhere along the continuum mostly as per their interest in the uses of various resources or values of the Ganges basin.

Stakeholders at Different Levels

Based on the fact that whether a stakeholder will be immediately affected, or can immediately affect the biodiversity conservation in the Ganges basin, they were grouped into primary, secondary and tertiary.

Table 1: Ganges basin stakeholders on a macro to micro continuum

Continuum Level	Stakeholders	Interest of stakeholders
Global and wider society	• International agencies/ bodies like IUCN, CBD, CITES, World Bank etc. • Common interested mass	• Biodiversity conservation • Environmental sustainability • Livelihood of people • Cultural values
National	• Central government / agencies • National Ganga River Basin Authority (NGRBA) • National Mission for Clean Ganga (NMCG) • Researchers • Civil society organization (NGOs) • Politicians • Waterways authorities	• Tourism • Policy formulation • Ecosystem restoration • Biodiversity conservation • Advocacy and awareness • Policy for Water development work • Policy for Waterways development
Regional	• Government Departments (Water Resources, Fisheries, Mining, Urban Development) • Media • Agribusiness sector • Real estate sector • Protected areas	• Water use • Fish resource exploitation • Promotion of intensive farming • Issue identification and highlighting • Construction activities in floodplain
Local off-site	• Farmers • Wetland users • Fishermen societies • Religious institutions • Village institutions • Municipal bodies • Industries	• Water and land use • Regulating the resource uses • Conflict resolution • Water supply • Waste disposal
Local on-site	• Riverine fishing community • Sand miners • Water development sector • Tourism • Riparian farmers	• Sand and other physical resources • Fishing and aquaculture • Maintenance of water level • Water diversion and use • Cultural and natural scenic beauty sites

As per the analysis, sand miners, real estate sector, riparian farmers, water ways authorities, riverine fishing communities, tourists, industries, wetland users, municipal bodies and water development agencies are the primary stakeholders.

In addition to the primary stakeholders with rights, powers or direct impacts related to the river resources, the biodiversity conservation issues in the landscape have far-reaching impacts. Thus, the secondary stakeholders include the societal components having legitimate interest and long term effect (Figure 2). For example, to prevent the river from getting nutrient-loaded and ensure maintenance of the ecosystem, use of chemical fertilisers needs to be minimised, which will have long-term bearing on the agribusiness sector.

International agencies, National Ganga River Basin Authority (NGRBA), National Mission for Clean

Ganga (NMCG), politicians, common interested mass, government departments and religious institutions are tertiary stakeholders, with interest in biodiversity conservation and ecosystem functioning in the basin, but they are not the group who are directly or indirectly impacted by the measures undertaken for the conservation of the Ganges basin (Figure 2).

Interest and Influence of Stakeholders

Interest-influence matrix helped in categorisation of stakeholders (Figure 3) in the Ganges basin in a manner to engage them in meeting the objectives of the landscape approach of biodiversity conservation. “Interest” of the stakeholder was identified in terms of goods and services provided by the regulating, production, habitat, carrier, and information functions of the basin.

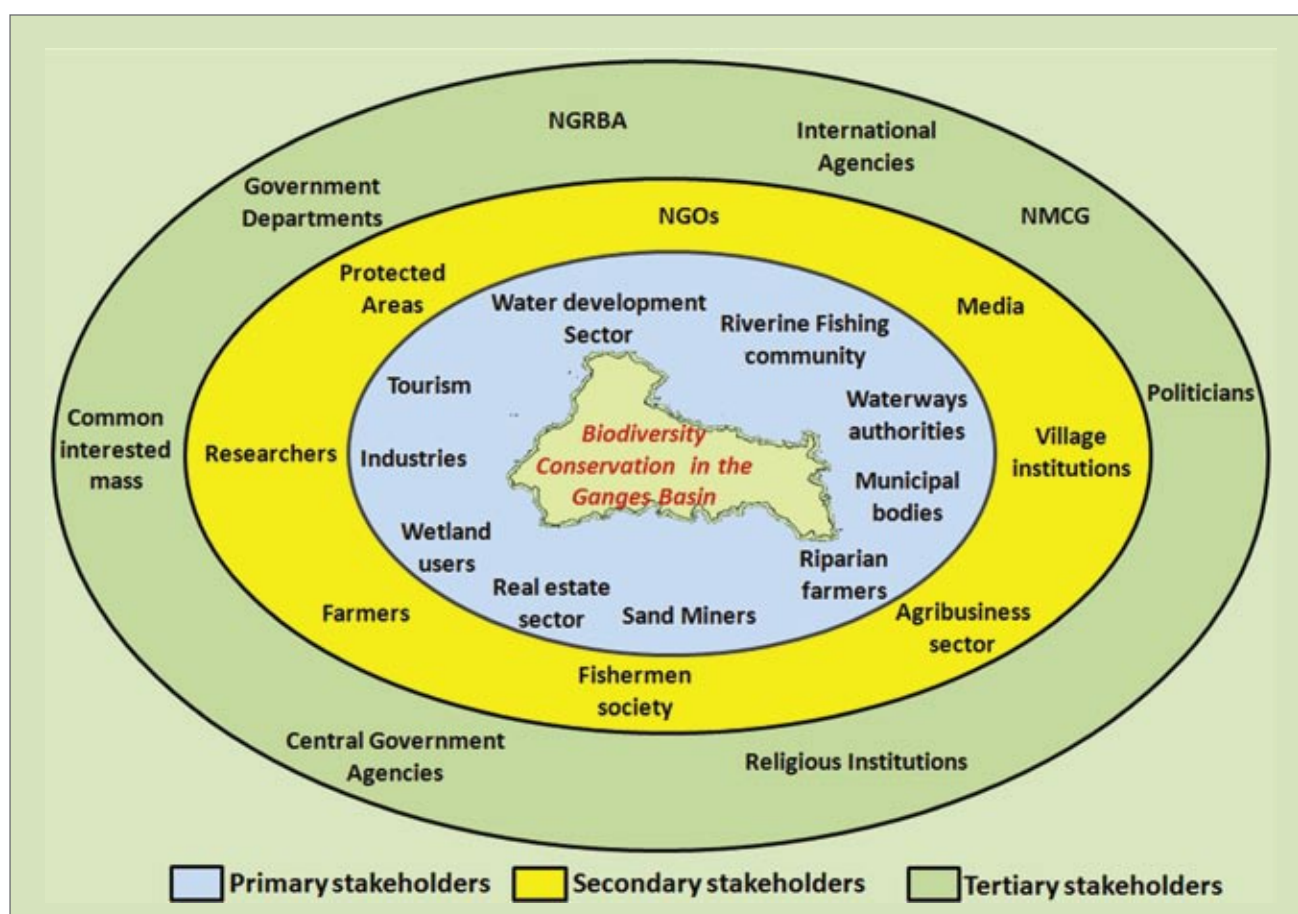


Figure 2: Levels of stakeholders in Ganges basin conservation

Since the capacity for “influence” is dependent on “power” (Nelson and Quick 1994) which could be coercive, utilitarian and normative (Etzioni 1964).

Galbraith (1983) described three sources of power: condign (influence through emotional, financial and physical threats and punishment), compensatory (influence through symbolic, financial and material rewards, such as salaries, bribes or gifts), and conditioning (works through manipulation of belief through cultural norms, education, advertising, propaganda).

The group of stakeholders having high interest and influence over the issues of conservation of the basin (international agencies, NMCG, NGRBA, politicians, central government agencies, researchers and protected areas) should be actively persuaded and used to address the cause. The group of stakeholders with high influence and little interest should be

monitored and managed through appropriate processes of negotiation and building consensus to use their influences to achieve the goals. For example, religious institutions have great influence over common masses and they have a large number of followers, but ecosystem conservation might not be their priority. Engaging them in conservation pursuit shall build opinion and kick off conservation actions involving the mass the institutions lead.

Victims are the groups having high interest but low influence, thus their impact is minimal. However, they can be empowered by developing alliance and complement other stakeholders' efforts (Reed et al. 2009). The stakeholders with low influence and low interest (waterways authorities, municipal bodies, farmers and riparian farmers) may not be taken much into account while engaging the stakeholders for desired change.

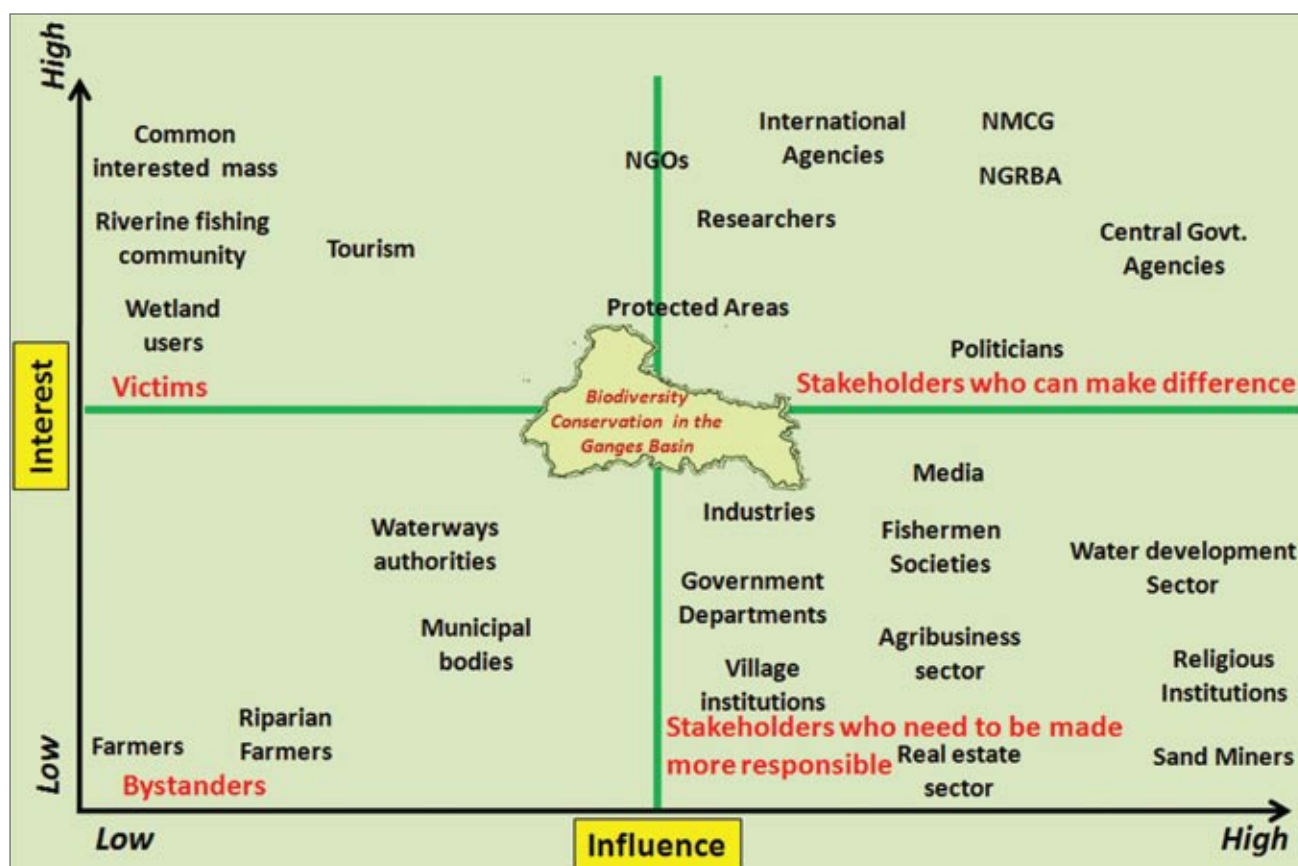


Figure 3: Stakeholders' interest-influence matrix for biodiversity conservation in the Ganges basin

CONSERVATION IMPLICATIONS OF LANDSCAPE APPROACH AND STAKEHOLDER ANALYSIS

As mentioned in earlier sections, landscape approaches seems to be an appropriate scale to achieve conservation goals in developing countries, but stakeholders, including conservationists, need to recognise that working at landscape levels inherently changes how we look at the outcomes of our interventions. The straightforward concepts of success and failure become ambiguous in a multiple-stakeholder context in which someone's gain is someone else's loss. Changes in one component of the landscape, even if desired, can have unintended and undesirable repercussions (Phalan et al. 2011).

Landscape approaches, therefore, demand an open-minded view of outcomes and acknowledgment of the tradeoffs likely to be involved in any system change (Sunderland et al. 2007). Such compromises require decision-makers to consider all stakeholders and to work towards their inclusion in the processes (Sayer et al. 2013).

Many efforts of environmental management fail because they pay inadequate attention to the various stakeholders involved and their particular interest. Stakeholder analysis helps us in understanding the objectives and interests of various stakeholders managing and using the environment (Grimble et al. 1995).

In a multiple stakeholder scenario, the stakeholders frame and express objectives in different ways as per their stake and interest. Failure to involve them in equitable manner in decision-making processes leads to sub-optimal, and sometimes unethical, outcomes. Thus, recognition and identification of concerns of stakeholders is much required in landscape approach (Sayer et al. 2013). However, in the Ganges basin most of the actions to restore the ecological integrity of the landscape are restricted to pollution abatement programs (NRCD/ MoEF 2009) and no detailed analysis of stakeholders has been done.

Recently, the National Ganga River Basin Authority, constituted in 2009 for comprehensive management of the river Ganges has developed Environmental and Social Management Framework for implementation of river water quality improvement project in selected states of India (Anon. 2011).

The framework has identified government departments, research institutions, and non-government and civil society organisations located in different states as key stakeholders for the project. Here, the stakeholder identification completely missed out the primary stakeholders who are the immediately affected or the first who affect the ecological integrity of the river (as described in earlier section of the paper). Effective participation of stakeholders is the key to success of such programmes.

The present paper endeavours to plug the gaps by identifying various stakeholders and analysing their concerns in a landscape perspective. This analysis shall help in looking at the issue of land-use pattern competing with the ecological integrity of the Ganges basin in a holistic manner.

The paper will also be useful further in identifying the stakeholders' relationship to sort out conflicting issues, developing communication strategies for them, strengthening their capacity, and also framing development and conservation goals to address growing pressure on natural resources in the Ganges basin and to accommodate the needs of present and future generations.

It is also highlighted here that stakeholders and their concerns are not static but dynamic, thus identifying stakeholders and recognising their concerns and aspirations is an iterative process. However, many agencies aspire to involve all stakeholder groups in decision making, but the transaction costs of doing this comprehensively can be prohibitive and total agreement can be elusive (Balint et al. 2011).

ACKNOWLEDGEMENT

I am thankful to Prof R. K. Sinha (Patna University), organising secretary of the International Symposium on River Biodiversity: Ganges-Brahmaputra-Meghna (GBM) River Basin for giving the opportunity to present the paper in the symposium.

I express my gratitude towards Mr P. R. Sinha, Country Representative, IUCN India for encouragements and support.

I owe much to Dr Cora van Oosten and Ms. Ilse Hennemann, Centre for Development Innovation, Wageningen UR, the Netherlands for giving the concept of Landscape Governance. Help rendered by Dr Enoka Priyadarshani Kudavidanage, Sabaragamuwa University, Sri Lanka in preparing the rich picture is duly acknowledged.

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Locating Fisheries and Livelihood Issues in River Biodiversity Conservation: Insights from Long-term Engagement with Fisheries in the Vikramshila Gangetic Dolphin Sanctuary Riverscape, Bihar, India

Sunil K. Choudhary¹, Subhasis Dey¹ and Nachiket Kelkar²

¹Vikramshila Biodiversity Research & Education Centre,
University Department of Botany, T. M. Bhagalpur University,
Bhagalpur - 812007, Bihar, India
E-mail: sunil_vikramshila@yahoo.co.in

²Academy of Conservation Science & Sustainability Studies,
Ashoka Trust for Research in Ecology & Environment, Jakkur,
Bangalore - 560064, India

ABSTRACT

River biodiversity conservation faces the complex challenge of reconciling diverse competing human interests. Floodplain rivers, such as in the Gangetic basin, are multiple-use socio-ecological systems supporting nearly 500 million people as well as endangered species such as the Ganges River Dolphin and gharial.

Fisheries are an important case where human livelihoods compete strongly with riverine species for resources and space. Although conservationists blame fisheries as the “big threat” to biodiversity, they seldom acknowledge and mainly ignore the difficult realities of the issue, resulting in ineffective protection and conflicts. Underlying this is over simplistic rhetoric: e.g. “including fisher communities” or “banning fishing”.

We challenge these ideas based on our 15-year long engagement with fisheries in a contested riverscape, the Vikramshila Gangetic Dolphin Sanctuary in Bihar, India. Based on insights derived, we provide a conceptual framework linking together ecology, political history, property rights and social equity towards a wider understanding of biodiversity-fisheries interactions.

FRESHWATER BIODIVERSITY AND THE CHALLENGE OF FISHERIES

Biodiversity conservation in open-access, multiple-use floodplain river systems involves inherent conflicts (Klug 2002; Allan and Flecker 2007). First, floodplain rivers are highly productive habitats on which many endangered species as well as millions of human users depend for diverse needs (Dudgeon 2000).

This leads to conflicting positions regarding the management aims for river resources. Further, ambiguous property rights and ownership due to their biophysical nature makes rivers open-access, unregulated systems. Also, river systems are dynamic, posing difficulties in defining their physical boundaries over space and time and hence, for meaningful conservation of riverine ecosystems and

biodiversity, which are globally the most threatened (Allan and Flecker 2007; Collen et al. 2008).

Despite the wide academic acknowledgement of this reality, on-ground conservation approaches targeted at protecting river biodiversity (ranging from terrestrial protected areas to community-based conservation) appear naïve and unbelievably over simplistic, and often merely instrumental and symbolic. There are many critiques of pitfalls of exclusivist paradigms of freshwater conservation, and yet we see limited engagements that churn the waters (literally) for alternatives.

Among the most difficult are issues related to reconciling human livelihoods such as river fisheries with biodiversity conservation (Kelkar et al. 2010). Fisheries are especially regarded as antagonistic to biodiversity, and multiple negative impacts (e.g. bycatch, overfishing, use of destructive gear) are cited as major problems (Smith and Smith 1998; Dudgeon 2000; Allan et al. 2005; Mansur et al. 2008; Raby et al. 2011).

Fisheries have historically interacted and competed strongly with species for resources and spaces, and are undeniably a major group to address. However, the instrumental approaches that conservation managers (as well as fisheries officers) take assume that these mechanisms are always treated as “a separate issue” to be tackled by “others” (authors, pers. obs.). We argue that such approaches often lie behind commonly seen ineffective conservation planning and strategies.

This creates serious resource conflicts between fisher groups and conservation managers. Therefore, there is an urgent need to understand and engage with the “fisheries problem” as a manifestation of deep-rooted historical, social, political, economic and cultural realities (Reeves 1995; Kelkar 2012; Kelkar and Krishnaswamy 2014).

Fisheries are not homogenous, but are in themselves layered systems with contested histories and

vulnerable futures for poor people. As such, they can neither be reduced to “threats to biodiversity” alone (Choudhary et al. 2006; Bashir et al. 2010) nor can they be simply assumed to “coexist” harmoniously with wildlife (Kelkar and Krishnaswamy 2014).

River conservation in the Gangetic floodplain riverscapes of the Indian subcontinent suffers from the lack of acknowledgement of all the above gaps in understanding processes critical for informing meaningful interventions and analyses. Based on the above background, we categorically discuss key lessons learnt by us from our efforts with a river biodiversity conservation programme targeted at river dolphins with the active involvement of local fishers over 15 years (Choudhary et al. 2006; Kelkar and Krishnaswamy 2014).

We neither claim success nor failure in this endeavour. Rather we aim to provide a conceptual framework for conservation biologists, fisheries managers and environmentalists to link multiple social-ecological processes together while dealing with issues of fisheries and biodiversity conservation.

We outline this conceptual framework with a detailed story of the contested case of the Vikramshila Gangetic Dolphin Sanctuary (VGDS) in Bhagalpur, Bihar, India.

FISHERIES AND BIODIVERSITY IN VGDS

The Vikramshila Gangetic Dolphin Sanctuary (VGDS) is a 60-68 kilometers stretch of the River Ganges between Sultanganj (25°15'15"N & 86°44'17"E) and Kahlgaon (25°16'54"N & 87°13'44"E) towns near Bhagalpur, Bihar, India (Choudhary et al. 2006).

VGDS, notified in 1991, remains the only protected area especially notified for Ganges River Dolphins. This region of eastern Bihar is located in the Ganga-Kosi interfluvium and is highly prone to extreme seasonal flooding, leading to annual movements of people to higher areas (Sharma 2006). Flood discharge is high over four-five months (July-

November) after which waters recede substantially until May-June. Thus, the landscape is constantly in a state of dynamic movement and flux.

The movement reconfigures the riverscape every year and that is critical for the maintenance of life histories of several species. VGDS has high densities of Ganges River Dolphins *Platanista gangetica gangetica* and Smooth-Coated Otters *Lutrogale perspicillata*, plus about six turtle species, c.200 bird species, 90 freshwater fish species and occasional sightings of Gharial *Gavialis gangeticus* and Mugger *Crocodylus palustris* crocodiles (Choudhary et al. 2006; Kelkar et al. 2010).

It must be mentioned here that since its declaration by the Bihar Forest Department in 1991, even today VGDS largely remains a “protected area” only on paper. Three large towns are situated along the intensively used river’s southern bank, and have high pollution impacts in terms of sewage and solid wastes. Inland waterways ships and local boat traffic are also frequent, and associated with considerable disturbance to the aquatic wildlife. The predominant land-use is agriculture, and villagers are engaged in farming, dairy, fisheries and pilgrimage-related activities. Socio-economic and law-and-order indicators of the region are poor, and organised crime is common.

Fishing is very common in the Sanctuary and it is easy to chafe at this state of affairs for conservationists.

Fishing within any protected area is illegal as per the Wildlife Protection Act (GoI 1972). In general, however, in all flowing waters of Bihar, fishing is free-for-all and open-access, thus allowable anywhere as per the State Fisheries Act (Government of Bihar 2006).

This contradiction is difficult to resolve given legal conflict and prioritisation problems. It needs dialogue on the field, between the state forest and fisheries departments (Kelkar and Krishnaswamy 2014). However, the lack of political will have consistently undermined such efforts (despite being initiated by members of fishing communities).

Departmental conflict is significant in that there is no action on the ground due to legal confusions about the state of tenure for fisheries on the one hand, and sanctuary space for conservation. In addition, the changing and shifting river channels cause incredible uncertainty in the boundaries of both the protected area and areas of fishery operations.

Given this state of multiple confusions, fishing has continued in the Sanctuary since its declaration. There is high spatial overlap between fishing activity and river dolphin distribution (75-85 per cent; Figure 1). Fishers and Ganges River Dolphins use similar river channel habitats with availability of small-sized fishes, and close contact with gill nets exposes dolphins to by catch-related mortality risk (Kelkar et al. 2010).

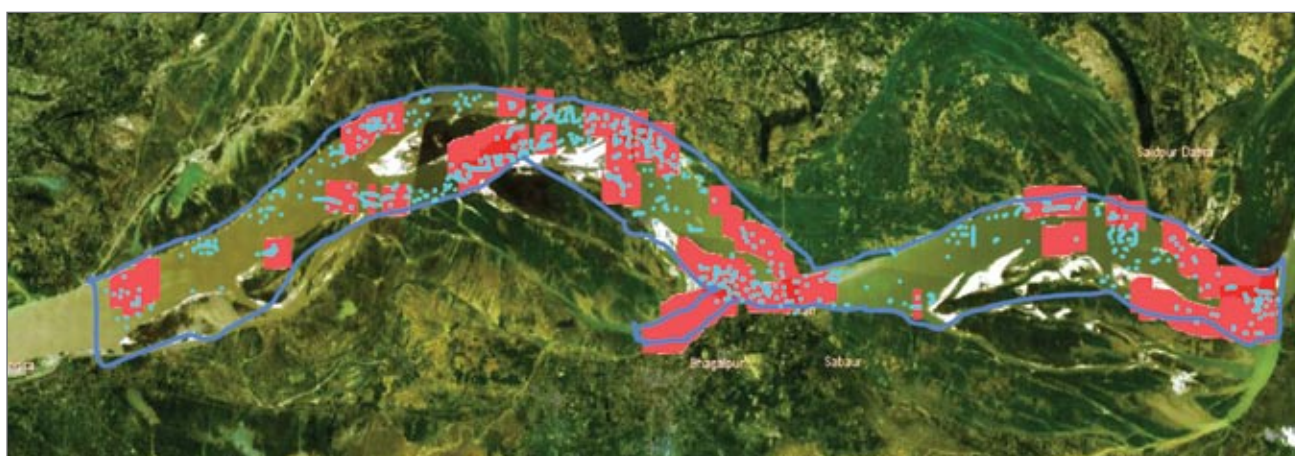


Figure 1: High overlap of fishing pressure with dolphin hotspots in the Vikramshila Sanctuary, Bhagalpur district, Bihar, India

In addition, turtle hunting has led to drastic declines in soft-shell turtle populations (fishers, pers. obs.). Bird populations (especially ducks and large waders) have shown an approx. decline of 50 per cent over the last 10-12 years, and an important factor seems to be hunting (authors, pers. obs.).

NEW LEARNINGS: LOOKING BEYOND BIODIVERSITY

The state-of-the-art discourse for the bona fide conservationist until the year 2000 was as follows: “Fishers fish ‘inside’ VGDS using ‘illegal’ nets, highly destructive fishing methods (e.g. mosquito nets, channel barricades and beach seines). They are overfishing and also hunting dolphins and other wildlife. This cannot be allowed inside a ‘protected area’. But since these people are poor, they need to be educated, and alternative livelihoods must be provided, by banning fishing in the area.”

When our team started working on dolphin conservation in the VGDS in 2000, this is where

we too began. However, it soon became clear that realities were far more complex as compared to this simplistic narrative. It was then that we came face-to-face with the poverty beneath the fisheries, the caste conflicts, and the destitution and vulnerability of fisher folk (Box 1). This complexity naturally forced us to look deeper into fisheries itself by keeping the proverbial “wildlife conservationist hat” aside. But are fishers alone really to blame? Who were these people who were, if at all, a “threat” to river dolphins?

Initially, we found during awareness and outreach programmes with fishers that they were “dead against” the idea of the Sanctuary itself, for the obvious reasons mentioned above. But despite entirely antagonistic turfs from which we were interacting, fishers pointed out that their real conflicts have been with decrees and laws regarding bans on fishing that criminalised and illegalised them, rather than with the protection of river dolphins and other riverine wildlife.

Socio-economic Profile of the Fishing Community Dependent on the Ganga in the VGDS

The fishing community (Mallah, Nishad castes and associated groups) belongs to one of the so-called low castes in the region, and also face severe socio-economic deprivation. Almost 500 families of traditional fisher community members (*Machhuara*, including a few castes) depend almost entirely on fisheries in this stretch (mainly from the village-clusters of Bhagalpur, Barari, Kahalgau, Nalgachia, Tintanga, Lailakh, Sultanganj and Janghira). These fishers identify themselves as *pushtaini* (traditional fishers or fishing through ancestry) as opposed to others (*gair-pushtaini*, ancestral occupations other than fishing). However, a much larger agricultural population regularly cultivates food crops on the bank areas of the Ganga in VGDS. Most fishers are landless and have no alternative livelihoods to river fishing, and almost 75 per cent depend entirely on rivers. There has been a substantial exodus of fisher folk for menial jobs, such as in unskilled labour and construction work in cities (Singh et al. 2011). Many work as rickshaw pullers or as local labourers. Education levels are very low (about 29 per cent literacy) and average drop out age is by the end of primary schooling. Incomes are extremely meagre, ranging between 20000/- and 30000/- INR per year per household. Monthly incomes and savings are between INR 500/- and INR 2000/- on average. Nearly 80-90 per cent of the fishers are BPL (below poverty line), yet many have not been accounted for in public distribution systems. Rampant corruption has caused many fishers to remain in impoverishment despite the presence of rural welfare schemes and cooperatives in Bihar (based on authors, pers.obs.; Choudhary et al. 2006; Kelkar and Krishnaswamy 2014). Traditional fishing people in the Gangetic basin region remain socially and economically marginalized (Jassal 2001), lacking livelihood security and material dignity. Despite a semi-legal monsoon fishing ban, meant to allow for protection of breeding fishes, fishers are not in a position to afford not to fish for three months, due to extreme poverty.

We began to sympathise, even if somewhat doubtfully, with the fishers' concerns and over time have formed close interpersonal relationships with fisher groups across some villages. This relationship has helped us attempt to understand the many complexities of the problem. In the process, our team convinced many fishers to stop poaching and killing of dolphins for oil (used as bait for *Clupisoma garua*, a Catfish species). Regular monitoring has since shown that targeted hunting of dolphins reduced, with three village clusters complying with our "request",

not "ban" (Box 2), and becoming part of monitoring activities for fisheries and river wildlife.

POLITICAL HISTORY OF THE FISHERIES IN BHAGALPUR DISTRICT

The periods of Mughal and British rule proved to be major watersheds in terms of changing patterns of resource access and social stratification in fisheries. Pre-colonial fisheries (until 1793) worked on the basis of a relatively benign "Sayar" tax, which was revenue generated from charging fishers for rights

A Civil Society Effort: The Vikramshila Biodiversity Research and Education Centre (VBREC)

The Vikramshila Biodiversity Research and Education Centre (VBREC) is an informal research and conservation team working under the aegis of the Bhagalpur University. VBREC has been funded in the long run by WDSC-UK and WCS. Conservation and awareness programmes by VBREC from 1999-2003 resulted in reduction of targeted illegal killing of river dolphins for blubber oil by fisher folk in this area. Along with this, VBREC has been pursuing high quality ecological research through multiple collaborations, and has published findings in several international peer-reviewed journals. A monitoring program has been running from 1999 till date and encompasses a wide range of variables, from socio-economic data on fishers, to river dolphin abundance, to hydrological profiles of river channels. Several fishers (n=c.200 households) of three major village clusters (at Barari, Kahalgaoon and Sultanganj-Janghira) have shown positive responses to these efforts, and many have become strongly integrated with monitoring activities (authors, pers.obs.). Of these, 15-20 have consistently reported illegal hunting and destructive fishing practices in the Sanctuary through informer networks. In all, nearly 15-20 incidents of illegal fishing practices (mosquito-nets and beach-seines) are still consistently being reported per month. Long-term monitoring data have been crucial in identifying broad trends in animal distribution and fisheries status. The monitoring has also help identify conflicts between fishers and animals. Despite these data, identifying the impacts of hunting or by catch on animals is tantamount to some conjecture. For instance, there are frequent cases of net and gear damage of fishers by otters (around four-five times per month in monitored areas during otter breeding in the dry-season). The losses by themselves are minor (a few hundred rupees) and mostly repairable. For poor fishers who continue to use damaged nets (unable to afford even this cost), even these can sometimes be significant, running into a few thousands per net lost. Fortunately, this situation has not led to serious conflict perceptions against otters, owing to positive attitudes and favorable cultural perceptions (authors, pers.obs.). However, it has been a struggle to translate statistical inference from data to on-ground change. The big lesson we have learnt has been that our monitoring and research efforts, despite being thorough, robust and conducted in tough conditions, may have still been marginal given the root problem. The overall conditions of fishing communities in the landscape haven't changed much still, with poverty, threats from criminals, destructive fishing, corruption, social disparity and conflicts. Even if our work has benefited biodiversity to a small extent, direct tangible benefits accruing to fishers are still wanting. Until such benefits come about in a sustained fashion and provide socio-economic security, political identity to fishers, soliciting their long-term support for river wildlife conservation remains an uncertain issue.

of trespass and fishing for very short periods of time, and based on their expected income from the fish-working (Reeves 1995).

This idea was based on riparian law regarding ownership of water by the owner of the neighbouring land, but use rights were given free of much sanction (Puthucherril 2009). However, with the Permanent Settlement of Bengal (1793) and associated Tenancy Acts, the British formalised feudal systems with the Zamindars (landlords) for maximising revenue extraction (Reeves 1995; Robb 1997; Tsai and Youssof-Ali 1997; Sharma 2006).

The passing of these Acts involved assignment of complete, exclusive and rivalrous property rights to landlords owning riparian stretches (Reeves 1995, 2002). This system was the *Jal kar* (literally translated to “Water Tax”), which became a form of water lording (called *Panidari*, like *Zamindari*), and traditional fishers worked now as labourers to the *Panidars* (or the new Water lords).

River reaches within provincial boundaries were owned by the biggest Zamindari estates, and systems of sub-letting stretches for fisheries also prevailed. The Bhagalpur district *Panidari*, notified from Sultanganj to Pirpainti, was under the *Zamindars* Mahesh Ghosh and Musharaf Hussain, for over 300 years, until 1991 (Sharma 2006).

The *Jalkar*-based management was further maintained through multiple laws and acts, notably the Bengal Ferries Act (1885) (Government of Bihar 2011), whereby landlords could levy taxes even on users of ferry-ghats; especially Dalits and other “lowly” castes were charged heavy fares (Sharma 2006). Over the years, not surprisingly, the feudal system turned oppressive, and local power relations and caste inequalities deepened, at the cost of fisher livelihoods.

Despite *Zamindari* abolition in India (legally arrived in 1952), the feudal *Panidari* system of river fishing contracts prevalent in this region was abolished

only between 1987-1991 (Gupta 1993), following repeated efforts by the *Ganga Mukti Andolan* and *Jal Shramik Sangh*, a social-political movement springing from traditional fishers of Kahalgaon, against the shackles of oppression and for protecting the riverine fisheries.

Freeing all rivers or “flowing water” from contract systems, for everyone to fish in was a major political advantage to the socialist ruling party (Kelkar and Krishnaswamy 2014). In *Panidari*, the oppressive landlords who owned a segment of the river, would grab a large chunk of what fishers would fish there.

Needless to say, the *Panidars* would harass, beat up, or even kill fishermen and their families who refused to work on the contracts or pay up the “fish tax” (Choudhary et al. 2006; Sharma 2006; Kelkar and Krishnaswamy 2014).

But the abolition of *Panidari* also meant that fishing in the river became a “free-for-all” open-access, an unmanaged commons. The year 1991 was also when the Sanctuary was declared. The *Ganga Mukti Andolan* also became strongly opposed to the Sanctuary, identifying it as yet another form of state imposition on fishing rights (authors, pers.obs).

In fact, here the new symbolic boundary perceived by the fishers became: “the Sanctuary will ban fishing, and it is just a new form of *Panidari* in the form of state control”.

WATER TENURE, RIGHTS AND FISHERIES INSTITUTIONS

In dynamic river floodplains, land and water tenures are inherently conflicted, as, due to an impossibility of definition, the “default” situation is of ill-defined property rights (Begossi 1998; Neil Adger and Luttrell 2000; Sharma 2006). In such a situation, many questions arise: Who gets the right to fish? On what terms? Who gives these rights? How are fishing rights used and abused? (Begossi 1998; Neil Adger and Luttrell 2000; Lam and Pauly 2010).

Mismatches between biophysical, political and state processes create conflicts (Kelkar and Krishnaswamy 2014) as political history interacts with uncertain river boundaries. This is evidenced in VGDS: through the intermeshing of conflicting interests of state-led protected areas, private mafia control, state-led “cooperative management” and politico-legally prescribed unregulated open-access (Reeves 1995; Reeves 2002; Sharma 2006; Katiha et al. 2013).

In response, constant effort emerges, to create clearer boundaries over the existing haze. Fisher community groups have been arguing for exclusive “club-good” property rights based on traditional (caste) lines.

However, many people within the community still believe that “free” fishing (open-access) is needed. We believe that parcelling of water at scales manageable for fisher community groups will be inevitable for adaptive fisheries management. This would serve to curb illegal practices employed by non-fishing castes and improve conditions for biodiversity (fishers, pers. comm.). An instance of fishing conflicts over ambiguous tenure is as follows: Fishing is not allowed as per State Fisheries Department Guidelines on channels connected to the river main stem up to 100 metres (*kol*s). But this is relaxed for oxbow lakes and overbank impoundments (*dhabs* – where fishing contracts are leased out even to non-fisher castes) (Government of Bihar 2006).

For officials who rarely visit the field, it is near impossible to even define *kol*s and *dhabs*. Also, given alterations in flows, *kol*s might change to *dhabs* and vice versa. Managing tenure claims in such a situation becomes virtually impossible. Further, lack of political organisation of fishers and of local institutions compounds the problem. Locally rooted, strong fisheries management institutions can significantly help mediate market pressures and social conflicts (Johnson 1998; Marshall 2001; Gerber et al. 2008).

Alternatives do not seem to be working. Between 1967 and 1970, fishery cooperatives were set up across several areas in Bihar. Cooperative extension schemes have either become defunct or corrupted by elite capture (Sharma 2006; Kelkar 2012). This has relegated them to pseudo-institutions with no meaningful function or structure, with no benefits transferred to intended communities. Landlords have enforced claimant fishers to become wage labourers on their own pond entitlements.

Conflicts over fisheries have turned violent over the last four decades in particular (Sharma 2006). This has led to continued disillusionment of fishers about prospective community-based management systems (Bennett et al. 2001; Ahmed et al. 2006). The change in institutional control, from the formal tender-based private contract system with inbuilt exploitation, to an open-access free-for-all situation of harassment and lawlessness, has now forced fishers to rethink alternatives (Kelkar 2012).

Recent surveys indicate that many fishers (almost 65 per cent, n=95), lacking knowledge of any other system, now perceive the days of contract as better than the present operation, and mention that the *Panidari* afforded some protection to them because of “bonded” labour.

Both private and open-access arrangements have failed to work, and what remains to be tested are participatory common-property management regimes (authors, unpubl., pers.obs.). However, fishers’ participation will be predicated on a systemic social and political change to improve trust and transparency between management interests (Marshall 2001; Zanetell and Knuth 2004; Campbell 2007). The fact is that the state of fisheries is downgraded everywhere, across Bihar, so the Sanctuary is not the only driver for conflicts. But also, we daresay that species protected under the declaration of the Sanctuary are found commonly even in unprotected areas (Figure 2), and interact with fisheries regularly even there.

This brings us back to the larger question of fisher livelihoods vis-a-vis biodiversity conservation, and suggests that we need to question the nature of conservation approaches we often take as granted.

SOCIAL CONFLICTS

Due to open-access fishing there has been no scope for the settlement of fishing rights (Kelkar and Krishnaswamy 2014). Criminal gangs operate regularly through a fishery mafia ring in the Sanctuary area (as well as outside) and illegally extort fish catch from these fishermen at gun point, killing anyone who refuses or defies them.

Our monitoring data suggest that nearly 75 per cent of fishers (n=300 approx.) in the area have personally been threatened. Further, their stated risk of fish grabbing and rent-seeking related harassment may be as high as once in every four days of fishing. The fishing mafia use destructive fishing practices to capture small fishes in the river to cater to a huge market at Siliguri in northern West Bengal (fishers, pers.comm.).

Destructive netting practices (e.g. barricading of confluences with mosquito nets), cause mass mortality of larval and juvenile fishes, reducing recruitment to the main river and suppressing viability of fish populations (Kelkar 2012; Dubey and Ahmad 1995). These threats have ousted both traditional fishermen and river dolphins from their preferred fishing/foraging locations.

Mosquito nets (*kapda jal*) and beach-seines (*kachaal jal*) are excessively operated, up to 20 times a month in side-channels at seven-eight locations by fishers and other villagers with the protection/ support of criminals. These nets are operated in the vicinity of productive confluence habitats and in floodplain wetlands marginally connected to the main river channel. New gears are also being increasingly used, such as shore-trap nets built over stakes using very fine mesh of 1 millimetres, which does not spare even fish larvae.

These nets are called *bahuwa jaals* and these are also creating similar problems, bringing in control of criminals over fish catch and its packaging and sale in markets in Siliguri. Establishing wholesale fish centres near river banks makes monitoring of catches from these nets very difficult. These easily-accessed centres have made the whole boom-and-bust business lucrative.

Sustaining traditional means of fishing is becoming increasingly uncertain and difficult for fishers. As conservationists, our limitations to negotiate with the fishery mafia inevitably make trust building uncertain among fishers (fishers, pers. comm).

Due to the open access, many “non-fishing” castes have plunged into fishing, including dominant landholder classes such as Bhumihars and Rajputs, to other marginalised floodplain castes. Recently, Mandals (Gangota castes), mainly floodplain



Figure 2: Distribution of Ganges River Dolphins within and outside the arbitrary boundaries of the Vikramshila Sanctuary

people involved in animal husbandry, have also been enlisted in Bihar as traditional fishers (fishers, pers. comm.).

In a state where caste plays an important role in determining almost any action, free fishing has also caused caste-based conflicts, and includes massacres of fishers and allied (lower) castes living on floodplains (Sharma 2006). Apart from large social conflicts, other monumental catastrophes of the past haunt the present fisheries.

ECOLOGICAL HISTORY: CHANGES AND CATASTROPHES

The Farakka Barrage built in 1972-73 (downstream on the Ganga in West Bengal) almost entirely destroyed the commercial Hilsa *Hilsa¹ ilisha* fishery in the upstream reaches of Bihar and Uttar Pradesh (Banerjee 1999; Kelkar 2012). The Hilsa, highly valued across the region for its taste, and as a seasonal delicacy, had been a commercially invaluable resource for the fisher populations and a crucial seasonal prey-base for wildlife. Studies have estimated 99 per cent reductions in availability of Hilsa up river, since the Barrage was built (Payne and Temple 1996). This decline reflects to a large extent, the collapse of many important fishes in India's inland waters.

Barriers to movement imposed by dams, pollutant loads, spawning habitat degradation and overfishing have led to declines in native commercial carp species (Rohu/ Rui, Katla), and catches are gradually being replaced by "trash" species, mainly small catfish, barbs and gobies (Payne and Temple 1996; Tsai and Youssof-Ali 1997; Norman-Lopez and Innes 2005; Rahman and Rahman 2008; Vass et al. 2010; Kelkar 2012).

Pond-cultured carps and catfishes from Andhra Pradesh and West Bengal dominate the markets across Uttar Pradesh and Bihar (making up for 70-

95 per cent of the sold fish catch) (Kelkar 2012). For river fisheries as a whole, over 90 per cent fishers reported serious declines (>80-90 per cent) in natural population of prized major carps Rohu/ Rui (*Labeo rohita*), Katla (*Catla catla*) and Mrigal [*Cirrhina mrigala* (according to law of priority)] (*Cirrhina mrigala*) (Tsai and Youssof-Ali 1997; Rahman and Rahman 2008; Kelkar 2012).

The species composition of fishery landings at Bhagalpur in VGDS show a shift from major carps and large Catfishes to trash species (Choudhary et al. 2006; Montana et al. 2011). Average fish sizes available and caught in fishing in these reaches indicate mostly juveniles and small-sized adults, which is another indication of ecosystem-level fisheries collapse (Payne and Temple 1996).

The fisheries department rules specify that fishing with gill nets less than 40 millimetre in diameter is illegal anywhere in the Ganga's main channel, even if outside the sanctuary (Government of Bihar 2006). Thus, almost 80 per cent of the existing fishing in the sanctuary becomes therefore, illegal and destructive to river dolphins and fish populations.

Artisanal fisheries, being target-specific and inflexible in capture efficiency, have been predated by over-exploitative commercial fishing practices (Tsai and Youssof-Ali 1997; Kibria and Ahmed 2005). The diversity of fishing gears and practices is getting homogenised in the wake of mechanisation of fisheries. This has ushered in use of imported nylon monofilament gill nets instead of traditional cotton fiber nets, among other harmful, non-selective fishing techniques (Kibria and Ahmed 2005).

The mesh size of gill nets has since shrunk multifold: the average mesh-size used today is around 20 millimetres which is a decline of almost four-five times in 30-40 years. Due to fishers targeting small fishes, competition and conflict with dolphins have

¹ The Ganges Shad/ Padma Shad is *Hilsa ilisha* and not *Tenualosa ilisha*. The Ganges Hilsa/ Ilish is smooth bodied and spotless whereas *Tenualosa* is spotted (nomenclature based on Bhuiyan 2009).

likely intensified over the years (Kelkar et al. 2010). It is evident in the regular reporting of five-six cases/year of accidental entanglement and death of dolphins in gill nets.

Apart from the collapse of the once-resilient river fisheries, multiple contemporary problems of great seriousness continue to haunt fisheries production and sustenance. These include poor and altered river flows, erratic releases of water from upstream dams, extreme river pollution and climate change impacts (Sinha and Khan 2001; Vass et al. 2009; Orr et al. 2012).

Fish disease, juvenile mortality and toxicity of fishes are other grave problems, which need consideration in fisheries policy (Dubey and Ahmad 1995). There have to be large-scale attempts at river flow improvement, restoration, maintenance of water quality, productivity and hydrological connectivity, and overall ecosystem rehabilitation for fisheries (Dudgeon 2005).

When the resource base itself is so degraded, talking about last-ditch digs at biodiversity conservation by involving fisheries seems superfluous. As it is inadequate to talk about river biodiversity without considering the social side of fisheries, the reverse is also true. Social change without ecological river restoration may not achieve long-term fisheries improvement. Maintenance of ecological river flow regimes, protection of fish breeding sites and reduction of river pollution are also required along with strengthening local fisheries management.

MARKET PRESSURES AND SHIFTING BASELINES IN FISHING PRACTICES

The state of river fisheries directly indicates the biophysical, ecological and social integrity of the river basin (Welcomme 1995). Existing in-river fisheries contribute merely about five to 10 per cent of overall inland fish production, and fisheries in the Gangetic basin has been labeled a “failed economic sector”, with current production highly unsustainable (Gol (Planning Commission) Report 2010; Gol -

Department of Animal Husbandry, Dairying and Fisheries 2007; Datta et al. 2010; Gol 2011).

In Bihar, boom-and-bust fishing operations are entirely illegal (Government of Bihar 2006), but still go on because of zero monitoring of fisheries. The fisheries now represent trophic downgrading. The fish market is now like a market that scrapes these remains and continues generating even more pressure on rivers, and more “trash fish”.

It is obvious that unsustainable fisheries leads fishers to take even more desperate measures (Smith et al. 2005; Norman-Lopez and Innes 2005; Datta et al. 2005; Kasulo and Perrings 2006). Fisheries policy and statistics appear to misrepresent this condition. The recent boom in artificially managed pond aquaculture and wetland fishing especially in Andhra Pradesh and West Bengal has changed the nature of supply radically (Gol - Department of Animal Husbandry, Dairying and Fisheries 2007; Gol 2011). This has contributed to India becoming one of the largest producers of inland freshwater fishes in the world, but, one may note, of this river fisheries’ contribution is negligible (Kumar et al. 2003; Datta et al. 2005; Miao et al. 2010).

Although net aquaculture production shows increases, the collapse of in situ river fisheries that still support thousands of poor people who don’t get access to aquaculture, get totally ignored under such swamping. River fisheries thus need urgent attention not just in ecological but economic terms.

ALTERNATIVE LIVELIHOODS

For immediate concerns of livelihood sustainability, alternative livelihoods need to be made available to fishers through informed choice. Co-operative land leases for development of pond fisheries that are managed by family groups or settlements of fisher folk is an idea being proposed by many fishers in floodplain belts (Das 2006; Dey and Prein 2006).

It is necessary to create systems where better community control on well-defined water bodies

(e.g. tanks, wetlands, floodplain pools, oxbow lakes) is possible. If planned well, these systems could help in fostering socially equitable and profitable fisheries management alongside biodiversity conservation (Folke et al. 2005; Hoggarth et al. 1998). This can help link fisheries with floodplain agriculture, rather than antagonise them over water sharing.

River fisheries need adaptive management that utilises fishers' traditional local knowledge while securing livelihoods and conserving biodiversity (Folke et al. 2005; Berkes et al. 2008; Kingsford et al. 2011). Through gradual, active river restoration and fisher support, "biodiversity-friendly" fisheries could be developed through monitoring standards of zero-entanglement or setting of species or size-specific targets.

Fisher communities can help protected area authorities in monitoring neighbouring river stretches. The fishers' own use of resources also needs critical scrutiny. Monitoring of the following parameters both from within and from outside the community is essential: 1) Net mesh-sizes used 2) Fishing in ecologically sensitive areas or regulated zones, 3) Hunting of wildlife in rivers, especially turtles, gharials, Ganges River Dolphins, Smooth-Coated Otters, muggers, birds or any other species mentioned in the Wildlife Protection Act ((GoI (WLP) 1972) with amendments in 1991, 2002, 2006, 2011), and 4) Density of people fishing in different areas and laying claims based on flowing or impounded water areas.

Rural labour programmes and food security acts in India could enhance both nutrition and wage rates of fishers, providing protection to livelihoods without adverse impacts on fisheries (Kelkar and Krishnaswamy 2014). Improved social security could also potentially create opportunity for involving fishermen in small-scale ecotourism around riverine protected areas such as the VGDS. Finally, the quest for sustaining fisheries in the Ganga River Basin will require integration on multiple fronts: ecological restoration of rivers, biodiversity conservation, and

socially just management of traditional fisheries systems.

SOCIAL, CULTURAL AND MATERIAL WELL-BEING OF FISHERS

We will conclude with one last point: that the social, cultural and material well-being of fishers is also an important goal unto itself that should not be overlooked by managers and conservationists. Community cohesiveness, identity, dignity and security can in themselves be empowering forces as they enable fishers to take decisions in a self-reliant manner (Stewart et al. 2004; Smith et al. 2005; Ahmed et al. 2006; Deacon 2012).

Creating such an environment in itself can take practitioners beyond the rhetorical confines of "inclusive conservation". We stress that it is now much needed on the part of conservationists to clarify what exactly they mean by saying "we must involve fishing communities in conservation".

There is a need to identify meaningful, realistic, objective and tangible objectives and practices that are beyond rhetoric. First, there is a need to communicate on-ground fisheries problems through sustained dialogue between local government departments, fishers and conservationists. There has to be appreciation of the livelihood values of fisheries at higher levels of policy and government authority.

In our case, the Bihar Forest and Fisheries Departments need to actively engage with fishing communities together to understand the complexities than blindly following their standard managerial mandates. At present, due to pettiness and power abuse on the side of the departments there is mistrust, fear and suspicion on the fishers' side. The existing tension appears to be beyond immediate resolution.

There are constant breaches of decided actions, as forest officials often take the wrong action against non-errant bonafide fishers using small nets (while

leaving the bigger mafia scot-free), and this can potentially erode support for conservation built by our long-term efforts considerably (authors, pers. obs.). The acknowledgement that livelihood security of fisheries and biodiversity conservation are inextricably intertwined issues, by itself equalises the otherwise polar debate.

Fishers are certainly worthy of receiving conservation benefits in the form of legally recognised rights but one need not ignore that by the nature of their livelihood itself, they will also always be exploiters of biodiversity (Kelkar and Krishnaswamy 2014). Hence, though we need not essentialise traditional fishers either as “noble savages” or “destroyers of nature”, we will have to be cautious in promoting systems of dignity and equity by ensuring compliance to biodiversity conservation.

We have still been struggling to ensure complete compliance from the fishers’ side towards biodiversity conservation – the reason for this being that they don’t perceive any benefit of doing so. After the Ganges River Dolphin was declared India’s national aquatic animal (GoI 2010), Bihar has taken some measures, such as the appointment of “dolphin *mitras* (friends)” from local fishermen who will monitor illegal fishing and intentional killing of dolphins (Kelkar and Krishnaswamy 2014). However, this has the danger of getting reduced to symbolic cash incentives and may not be enough, particularly in the absence of sustained funding and governmental interest. Nevertheless the scheme can, if well supported, be developed as a means for conservation, through economic gains to complying fishers, and mobilise their support in surer ways (van der Ploeg et al. 2011).

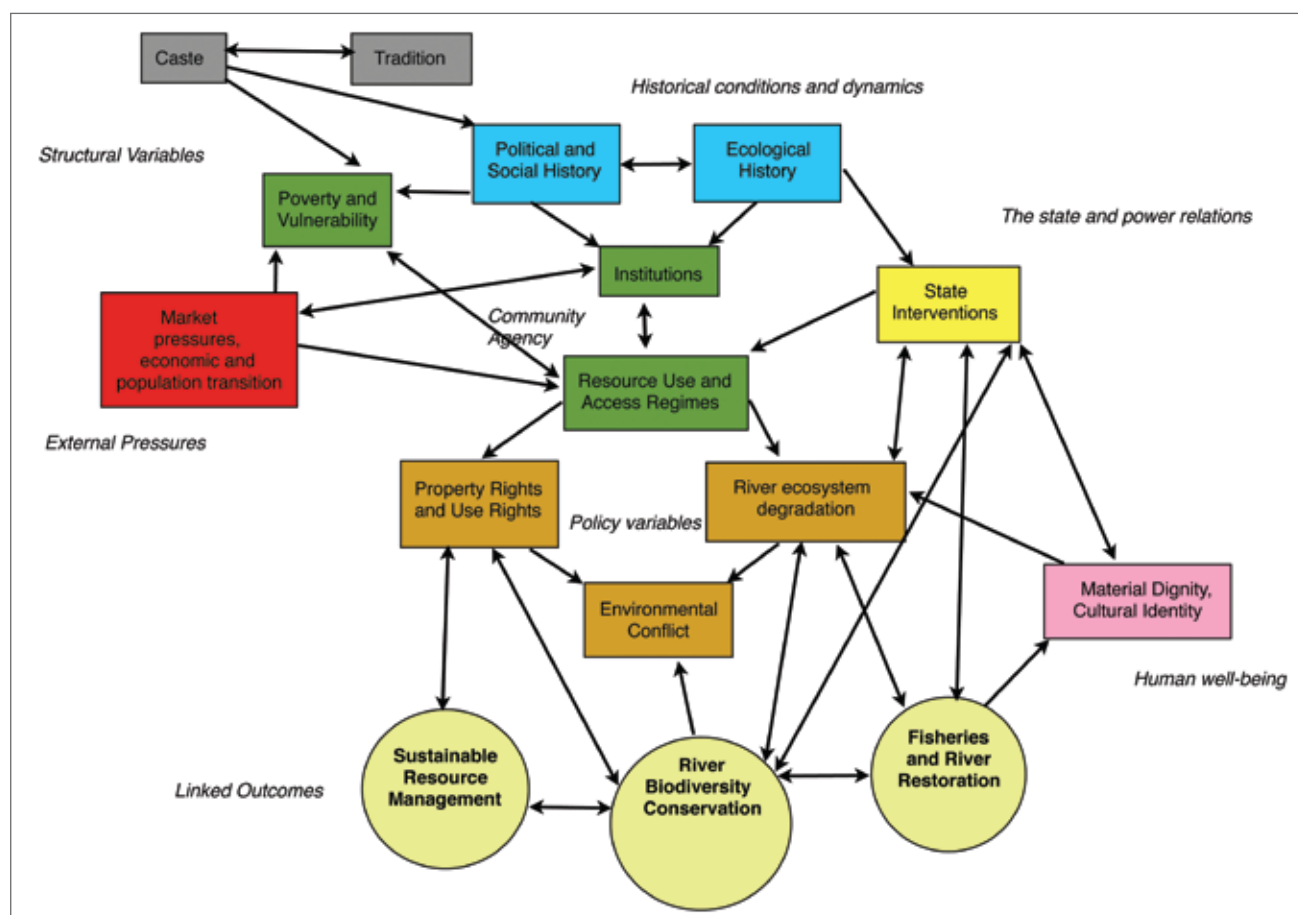


Figure 3: Conceptual framework to link variables and outcomes of interactions between social, political, historical and economic drivers of fisheries with ecological conservation

Fisher compliance to ecologically conducive practices for biodiversity conservation can be incentivised through recognition and positive reinforcement via “entitlements” provided to fisher community groups (Leach et al. 1999). It is equally important to recognise the whole issue in terms of identity of fisher communities (“fisher folk”).

Fisheries need attention as an independent socio-cultural system, on an equal plane as with an agrarian system. Fisher identity has remained a poorly acknowledged issue, but we stress that the political space for river fisheries can spring only from rightful assertion of local identity and organisation (Stewart et al. 2004).

From the above synthesis, we provide a conceptual framework for linking variables and issues in fisheries and biodiversity conservation together in a coherent manner for the consideration of conservationists (Figure 3). We regard empowering community agency, rights and local institutions as central to conservation planning, supported by state interventions and river ecosystem restoration programmes.

With this, the goals of sustainable resource management, fisheries restoration and river biodiversity conservation appear complementary rather than antithetical. This means that secure fisheries might naturally lead to conservation of river biodiversity because of overall improvements in their human condition.

In a nutshell, conservation and fisheries management have to be mutually reinforcing. We hope to realise this aim for the complex and curious riverscape of Vikramshila, by developing understanding useful to integrating such thinking across resource conservation and management in dynamic systems (Bengtsson et al. 2003).

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THEME

Higher Vertebrates

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2.	D. N. Choudhary, T. K. Ghosh ¹ , J. N. Mandal and T. K. Pan ² , Department of Zoology, T. N. B. College, Bhagalpur (India), ¹ PG Department of Zoology, T. M. Bhagalpur University, Bhagalpur (India), ² PG Department of Botany, T. M. Bhagalpur University, Bhagalpur (India)	Study of Breeding Behavior of Greater Adjutant in Kosi River Floodplains of Naugachia in Bhagalpur, Bihar, India	99
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6.	Sandeep Kumar Behera ¹ , Hari Singh ² , Viveksheel Sagar ³ and Rupak De ⁴ , ¹ Ministry of Water Resources, River Development and Ganga Rejuvenation (NMCG), New Delhi (India), ² ARNI University Katgarh Indora, Kangra, Himachal Pradesh (India), ³ Society for Conservation of Nature, Etawah, Uttar Pradesh (India), ⁴ Lucknow, Uttar Pradesh (India)	Current Status of Ganges River Dolphin (<i>Platanista gangetica gangetica</i>) in the Rivers of Uttar Pradesh, India	139
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Avian Diversity of the River Ganges and Gandak in the Stretch of Bihar, India

Anupma Kumari, A. K. Singh, G. P. Purusharthi, S. K. Sinha¹ and R. K. Sinha

Environmental Biology Laboratory, Department of Zoology,
Patna University, Patna - 800005, India

¹Wildlife Trust of India, Field Station: Valmiki Tiger Reserve,
Valmikinagar - 845107, India
E-mail: anupmakumari10@yahoo.com

ABSTRACT

River Ganges between Sahebganj and Chausa near Buxar (app. 526 kilometres) and River Gandak between Gandak-Ganges confluence at Patna to Tengrahi ghat near Mangalpur in Gopalganj (app. 152 kilometres) were surveyed during October to December 2012 to assess avian diversity in the rivers.

The birds sighted in the river channel and along the bank as well were recorded. Avifauna of the River Ganges was represented by 90 species belonging to 66 genera and 29 families. The species included one endangered, seventeen rare, two vulnerable and seven near-threatened species. The highest encounter rate was for the barn swallow (10.42 ± 57.69 individuals km^{-1}).

Out of the 90 species of birds recorded in the Ganges, 43 were resident, 36 were migratory and 11 were winter visitors. Altogether 39 species of birds belonging to 31 genera and 18 families including three rare species and three near-threatened species were recorded in the Gandak. Of the species recorded in Gandak, the resident, migratory and winter visitor species were 23, 12 and four respectively.

Sand bars were the most preferred habitat. Most of the species show aggregated distribution, the most common type of species dispersion in nature. This study is an attempt to generate baseline information on the avian diversity in the the two rivers — Ganges and Gandak — in Bihar.

Key words: Ganges River, Gandak River, Avian diversity, Rare species, Near-threatened Species, Vulnerable, Endangered species

INTRODUCTION

Biological monitoring, for example using birds, is advantageous over non-biological monitoring because it detects environmental changes which cannot be observed by measuring a set of physico-chemical parameters. Also, biological monitoring helps in detecting cumulative and non-linear consequences of environmental changes acting simultaneously (Koskimies 1989).

Birds serve as useful biological indicators because they are ecologically versatile and live in diverse habitats, and possess different habits as herbivores, carnivores and omnivores (Jarvinen and Vaisanen 1979). Moreover, diversity of avifauna is one of the most important ecological indicators to evaluate different habitats, both qualitatively and quantitatively (Furness and Greenwood 1993) because they are very sensitive to the slightest of

environmental changes and are important indicators of the ecological conditions and productivity of an ecosystem (Newton 1995; Desai 2007).

India has a rich avian diversity as it provides wide variety of wetland habitats that act as ideal wintering grounds for migratory birds. The basin of River Ganges, which has very high cultural, heritage and religious values, drains about 1,060,000 kilometres and is the fifth largest in the world (Welcomme 1985). The basin is also home to a variety of life forms ranging from phytoplankton to the Ganges River dolphin, thus signifying its biological and ecological importance.

The geo-morphological features in the basin of River Ganges provides varieties of habitats in the form of mid channel Island, channel between Islands, sand bars, flood plains and a large number of floodplain wetlands which attract thousands of resident and migratory birds. The River Gandak, a major Himalayan tributary of the River Ganges, is also identified as an Important Bird Area (IBA) site (Islam and Rahmani 2004).

The riverine ecosystem of India have suffered much from intense human intervention resulting in habitat loss and degradation particularly in the Ganges basin, where heavy demand is placed on freshwater. The entire river basin is densely populated — around 750 million people were estimated to be living in the entire river basin (Bandyopadhyaya 2014) and this number is expected to grow to one billion by 2030 (Markandya and Murty 2000).

Heavy population pressure and poor socio-economic condition of the population along the river are posing serious threats to the river system, which directly affect the avifaunal diversity. Poaching is the biggest threat to avian fauna in the rivers and the adjoining wetlands (Sinha et al. 2012). Besides, shrinking wetlands, heavy use of pesticides, river traffic with mechanised boats/ vessels, extensive farming in flood plains and loss of riparian vegetation are other important threats.

Keeping in mind the importance of birds as an indicator of the river system and changes occurring at species and habitat level, a study was conducted in the Ganges and the Gandak rivers in the middle reaches of the Ganges in Bihar to generate baseline data for bird monitoring programme in the river stretches.

The study was conducted with following objectives:

- (1) To prepare a checklist of birds in the Ganges and Gandak rivers in the state of Bihar, India.
- (2) To assess the conservation status of avifauna frequenting in the region.
- (3) To estimate relative abundance of the recorded birds.

MATERIALS AND METHODS

Study Area

The study was conducted in the mainstream of the lower middle reaches of the river Ganges between Sahebganj (25° 14'55", 87° 38'31") and Chausa (25° 32'29", 83° 54'56") covering a distance of 526 kilometres and in the river Gandak in a 152 kilometres stretch from Gandak-Ganges confluence at Patna (25°39'23", 85°10'40") to Tengarahi ghat (Mangalpur) near Gopalganj (26° 32'55", 84° 26'42") in the state of Bihar (Figure 1).

The floodplains all along the studied stretch are highly fertile and are under intensive agriculture. The river banks and flood plains are dotted with sporadic trees, shrubs, herbs and grasses mainly dominated by *Saccharum bengalensis* and *Saccharum spontaneum*.

Field Survey

Survey was conducted from October to December 2012 using a motorised country boat in day light hours. Average boat speed in Ganges was 6.45 km hr⁻¹ and it took nine days to cover the whole stretch. In River Gandak, the survey was completed in five days (average boat speed was 3.93 km hr⁻¹). Standard field guides (Ali and Ripley 1987; Grimmett et al. 2001) were used for identification of birds.

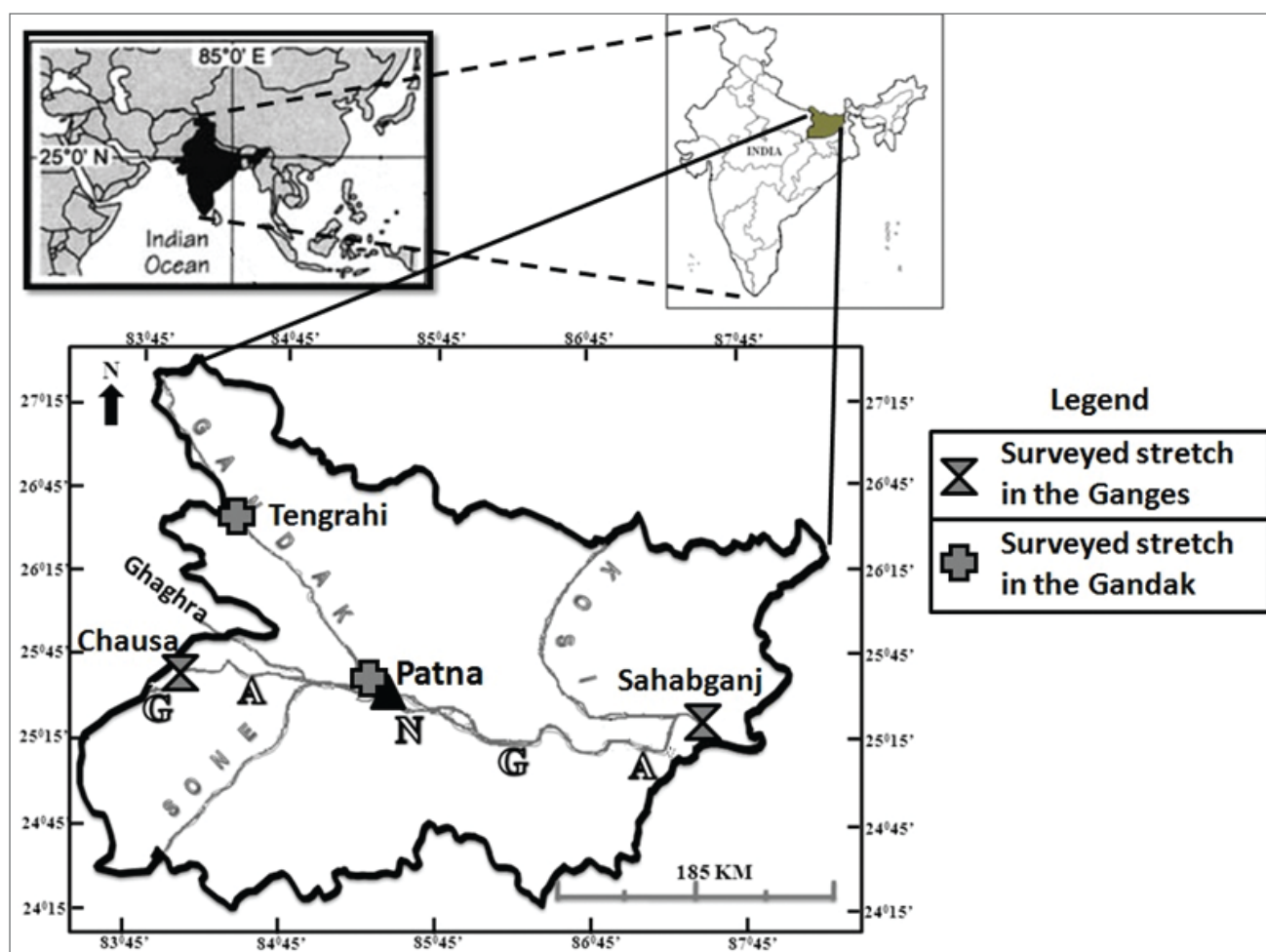


Figure 1: Map showing the study area

An SLR 400 mm tele lens (Nikon D 300 S), Swift ultralite binoculars (10 x 42), Model no. 762 were used for visual documentation and identification of birds. Geographical coordinates were recorded using GPS receiver (Magellan GPS 315). We calculated encounter rates (number km⁻¹) of species recorded during boat surveys and also generated information on their habitat heterogeneity such as river course, Islands (sand bars, mid channel Island and channel between Islands), river bank characteristics, anthropogenic activities along the banks etc.

Birds sighted during the study period were categorised according to their residential status as residents 'R' (species which are found in the study area throughout the year), winter visitors 'W' (species which are found in the study area only during winter and mainly resident of Himalayas) and migratory

birds 'M' (species which are migrated from outside the Indian subcontinent and are found in the study area only during winter), following Grimmett et al. 2001.

Encounter rate of species (number of birds sighted per unit distance) was considered as surrogate to relative abundance of species. Additionally, sighting frequency during the survey and available literature (R. K Sinha, unpubl.) was used as abundance status of the species in the region. Bird species were categorized as Very Common (VC), Common (C), Moderately Common (MC) and Rare (R) based on the frequency of sighting during different seasons (February, June, October, December) of the year 2005, 2006, 2007, and 2012). The data were analysed to give the abundance status class to each species for relative abundance on the basis of frequency of

sighting, following Mc Kinnon and Philips (1993) and Saikia and Saikia (2000). Abundance classification was done as below:

Abundance status	Criteria	
	River Ganges	River Gandak
Very Common (VC)	Sighting: > 10 times, throughout the study area in good numbers	Sightings: > 7 times and, throughout the study area in a good number
Common (C)	Sightings: 7-9 times and throughout the study area during most of the visits	Sightings: 5-6 times and throughout the study area during most of the visits
Moderately Common (MC)	Sightings: 3-6 times, encountered less frequently	Sightings: 3-4 times, encountered less frequently
Rare (R)	Sighting: 1-2 times, in low number	Sighting: 1-2 times, in low number

Feeding habits were classified as per direct observations and available literature (Ali and Ripley 1987). The threatened status of bird species was ascertained as per the IUCN list of Threatened Taxa (Birds Life International 2013). The following formula was used for determining percentage of occurrence of families (Basavarajappa 2006).

$$\% \text{ occurrence} = \frac{(\text{No. of species of each family})}{(\text{Total no. of different species})} \times 100$$

RESULTS AND DISCUSSION

Species Richness and Conservation Status

In the river Ganges, 90 species of birds belonging to 66 genera and 29 families were recorded (Table 1). Anatidae was the richest family represented by 12 species followed by Ciconiidae (10 species), Ardeidae, Accipitridae and Scolopacidae (eight species each) (Table 1, Figure 2). Scolopacidae was the dominant family in the Mahi river, Gujarat (Pandya et al. 2010).

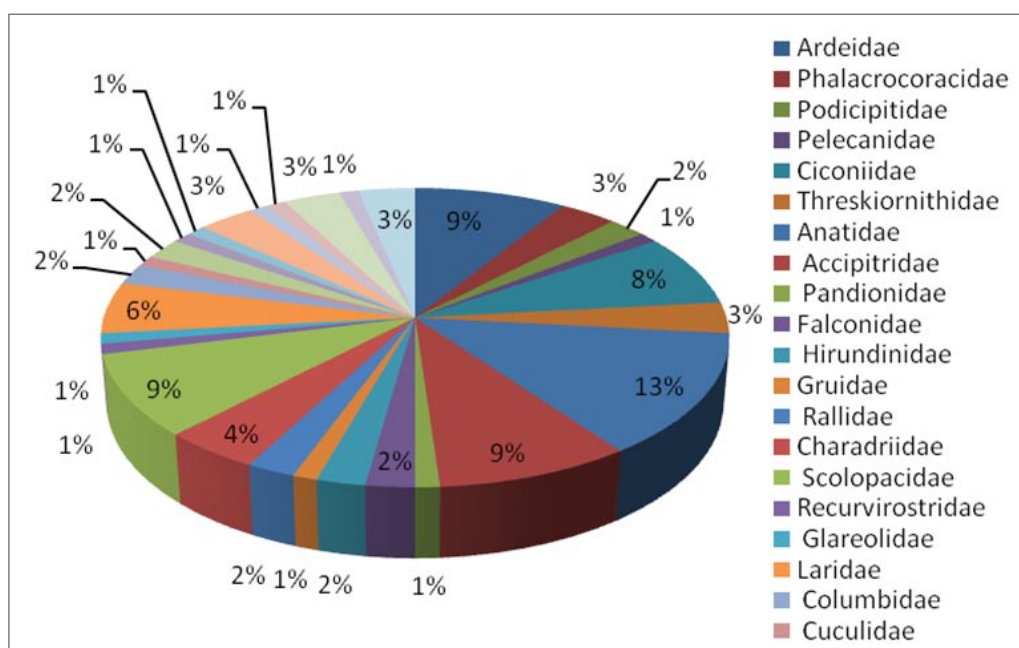


Figure 2: Family wise percentage of species in the river Ganges

Table 1: List of birds sighted in the river Ganges & Gandak during October-December 2012

S. N.	Common Name	Scientific Name	Encounter (per Km $\pm$ S. E)%	Pop. Status (A)	Pop. Status (B)	IUCN 2013	F.H.
1. Family: Ardeidae							
1	Intermediate Egret#	<i>Mesophoyx intermedia</i>	0.01 $\pm$ 0.06 / (0.04 $\pm$ 0.24)	C	C	LC	P
2	Little Egret#	<i>Egretta garzetta</i>	0.002 $\pm$ 0.01 / (0.02 $\pm$ 0.12)	C	C	LC	P
3	Grey HeronI #	<i>Ardea cinerea</i>	0.25 $\pm$ 0.46 / (0.5 $\pm$ 0.88)	VC	C	LC	P
4	Purple HeronI π	<i>Ardea purpurea</i>	0.004 $\pm$ 0.02	R	C	LC	P
5	Great Egret#	<i>Casmerodius albus</i>	0.004 $\pm$ 0.02 / (0.033 $\pm$ 0.20)	C	C	LC	P
6	Cattle Egret#	<i>Bubulcus ibis</i>	0.01 $\pm$ 0.08 / (0.11 $\pm$ 0.64)	VC	VC	LC	P
7	Indian Pond Heron#	<i>Ardeola grayii</i>	0.004 $\pm$ 0.02 / (0.047 $\pm$ 0.20)	MC	VC	LC	P
8	Black-crowned Night-Heronπ	<i>Nycticorax nycticorax</i>	0.28 $\pm$ 1.72	R	MC	LC	P
2. Family: Phalacrocoracidae							
9	Little Cormorant#	<i>Phalacrocorax niger</i>	0.33 $\pm$ 1.23 / (0.053 $\pm$ 0.32)	C	C	LC	P
10	Indian Cormorant#	<i>Phalacrocorax fuscicollis</i>	0.06 $\pm$ 0.24 / (0.13 $\pm$ 0.80)	MC	MC	LC	P
11	Great Cormorant#	<i>Phalacrocorax carbo</i>	0.01 $\pm$ 0.09 / (0.01 $\pm$ 0.08)	VC	C	LC	P
3. Family: Podicipitidae							
12	Little Grebeπ	<i>Tachybaptus ruficollis</i>	0.002 $\pm$ 0.02	MC	VC	LC	P
13	Great Crested Grebe*#	<i>Podiceps cristatus</i>	0.006 $\pm$ 0.03 / (0.027 $\pm$ 0.12)	MC	MC	LC	C
4. Family: Pelecanidae							
14	Great White Pelican*** π	<i>Pelecanus onocrotalus</i>	0.004 $\pm$ 0.02	R	MC	LC	P
5. Family: Ciconiidae							
15	Painted Stork#	<i>Mycteria leucocephala</i>	1.11 $\pm$ 3.64 / (0.006 $\pm$ 0.04)	C	C	NT	P
16	Asian Openbill#	<i>Anastomus oscitans</i>	0.02 $\pm$ 0.14 / (0.08 $\pm$ 0.48)	VC	C	LC	C
17	Black Stork**#	<i>Ciconia nigra</i>	0.004 $\pm$ 0.02 / (0.053 $\pm$ 0.18)	R	MC	LC	C
18	Woolly-necked Stork π	<i>Ciconia episcopus</i>	0.01 $\pm$ 0.07	VC	MC	NA	P
19	Black necked Stork π	<i>Ephippiorhynchus asiaticus</i>	0.004 $\pm$ 0.02	MC	UC	NT	P
20	Lesser Adjutant π	<i>Leptoptilos javanicus</i>	0.002 $\pm$ 0.01	R	UC	VU	C
21	Greater Adjutant π	<i>Leptoptilos dubius</i>	0.002 $\pm$ 0.01	R	R	EN	C
6. Family: Threskiornithidae							
22	Black-headed Ibis π	<i>Threskiornis melanocephalus</i>	0.002 $\pm$ 0.01	MC	C	NT	O
23	Black Ibis π	<i>Pseudibis papillosa</i>	0.11 $\pm$ 0.30	VC	MC	LC	C
24	Eurasian Spoonbill#	<i>Platalea leucorodia</i>	0.20 $\pm$ 0.62 / (0.02 $\pm$ 0.12)	MC	MC	LC	O

S. N.	Common Name	Scientific Name	Encounter (per Km $\pm$ S. E)%	Pop. Status (A)	Pop. Status (B)	IUCN 2013	F.H.
7. Family: Anatidae							
25	Lesser Whistling Duck π	<i>Dendrocygna javanica</i>	0.28 $\pm$ 1.72	C	C	LC	O
26	Greylag Goose*#	<i>Anser anser</i>	0.95 $\pm$ 5.75 / (0.02 $\pm$ 0.12)	MC	C	LC	H
27	Bar-headed Goose***#	<i>Anser indicus</i>	0.57 $\pm$ 3.45 / (0.26 $\pm$ 0.79)	MC	C	LC	H
28	Ruddy Shelduck***#	<i>Tadorna ferruginea</i>	0.12 $\pm$ 0.35 / (0.57 $\pm$ 1.21)	VC	C	LC	O
29	Common Shelduck*#	<i>Tadorna tadorna</i>	0.004 $\pm$ 0.02 / (0.013 $\pm$ 0.08)	R	R	LC	O
30	Gadwall*#	<i>Anas strepera</i>	9.57 $\pm$ 57.47 / (0.59 $\pm$ 1.69)	VC	VC	LC	H
31	Mallard *** π	<i>Anas platyrhynchos</i>	0.04 $\pm$ 0.23	MC	MC	LC	H
32	Northern Pintail * π	<i>Anas acuta</i>	0.02 $\pm$ 0.13	VC	VC	LC	H
33	Common Teal * π	<i>Anas crecca</i>	0.02 $\pm$ 0.14	C	VC	LC	H
34	Red-crested Pochard*#	<i>Rhodonessa rufina</i>	0.01 $\pm$ 0.07 / (0.027 $\pm$ 0.11)	MC	MC	LC	H
35	Ferruginous Pochard *** π	<i>Aythya nyroca</i>	0.03 $\pm$ 0.23	R	MC	NT	O
36	Tufted Duck* π	<i>Aythya fuligula</i>	0.03 $\pm$ 0.18	MC	VC	LC	O
8. Family: Accipitridae							
37	Black Kite π	<i>Milvus migrans</i>	0.01 $\pm$ 0.06	VC	VC	LC	C
38	Black-shouldered Kite π	<i>Elanus caeruleus</i>	0.002 $\pm$ 0.01	MC	C	LC	C
39	Brahminy Kite π	<i>Haliastur Indus</i>	0.002 $\pm$ 0.01	R	MC	LC	C
40	Eurasian Marsh Harrier* π	<i>Circus aeruginosus</i>	0.002 $\pm$ 0.01	R	MC	LC	C
41	Pied Harrier***#	<i>Circus melanoleucos</i>	0.002 $\pm$ 0.01 / (0.06 $\pm$ 0.04)	R	UC	LC	C
42	Long-legged Buzzard*** π	<i>Buteo rufinus</i>	0.002 $\pm$ 0.01	R	C	LC	C
43	Greater Spotted Eagle* π	<i>Aquila clanga</i>	0.002 $\pm$ 0.01	R	MC	VU	C
44	Booted Eagle*** π	<i>Hieraaetus pennatus</i>	0.002 $\pm$ 0.01	R	MC	LC	C
9. Family: Pandionidae							
45	Osprey #	<i>Pandion haliaetus</i>	0.02 $\pm$ 0.04 / (0.02 $\pm$ 0.07)	MC	MC	LC	P
10. Family: Falconidae							
46	Common Kestrel π	<i>Falco tinnunculus</i>	0.002 $\pm$ 0.01	MC	C	NA	C
47	Peregrine Falcon II π	<i>Falco peregrines</i>	0.002 $\pm$ 0.01	R	UC	LC	C

S. N.	Common Name	Scientific Name	Encounter (per Km ± S. E)%	Pop. Status (A)	Pop. Status (B)	IUCN 2013	F.H.
11. Family: Phasianidae							
48	Grey Francolin#	<i>Francolinus pondicerianus</i>	0.02±0.09 / (0.03±0.16)	C	C	LC	O
12. Family: Gruidae							
49	Common Crane* π	<i>Grus grus</i>	0.01±0.07	MC	MC	LC	H
13. Family: Rallidae							
50	White-breasted Waterhen π	<i>Amaurornis phoenicurus</i>	0.02±0.09	C	VC	NA	O
51	Common CootII π	<i>Fulica atra</i>	0.002±0.01	MC	VC	LC	O
14. Family: Charadriidae							
52	Little Ringed Plover II π	<i>Charadrius dubius</i>	0.002±0.01	MC	VC	LC	I
53	Kentish Plover *** π	<i>Charadrius alexandrinus</i>	0.004±0.02	MC	C	LC	I
54	River Lapwing#	<i>Vanellus duvaucelii</i>	0.02±0.090 / (0.05±0.25)	C	C	NT	I
55	Red-wattled Lapwing#	<i>Vanellus indicus</i>	0.01±0.050 / (0.06±0.26)	C	VC	LC	I
15. Family: Scolopacidae							
56	Black-tailed Godwit* π	<i>Limosa limosa</i>	0.01±0.05	R	C	NT	O
57	Eurasian Curlew*#	<i>Numenius arquata</i>	0.08±0.37 / (1±0.63)	MC	C	NT	I
58	Common Redshank*** π	<i>Tringa tetanus</i>	0.05±0.29	MC	VC	LC	I&M
59	Marsh Sandpiper* π	<i>Tringa stagnatilis</i>	0.01±0.07	MC	C	LC	I&M
60	Common Greenshank*#	<i>Tringa nebularia</i>	0.14±0.57 / (0.8±0.48)	MC	VC	LC	I&M
61	Green Sandpiper* π	<i>Tringa ochropus</i>	0.02±0.14	MC	VC	LC	I&M
62	Common Sandpiper *** #	<i>Actitis hypoleucos</i>	0.01±0.050 / (0.27±0.09)	MC	VC	LC	I&M
63	Temminck's Stint* π	<i>Calidris temminckii</i>	0.01±0.03	MC	VC	LC	I&M
16. Family: Recurvirostridae							
64	Pied Avocet ** π	<i>Recurvirostra avosetta</i>	0.02±0.14	MC	MC	LC	I&M
17. Family: Glareolidae							
65	Small Pratincole π	<i>Glareola lacteal</i>	1.89±11.49	MC	C	LC	I
18. Family: Laridae							
66	Pallas's Gull* π	<i>Larus ichthyaetus</i>	0.01±0.03	C	MC	LC	P&I
67	Brown-headed Gull** π	<i>Larus brunnicephalus</i>	0.09±0.38	C	C	LC	O

S. N.	Common Name	Scientific Name	Encounter (per Km $\pm$ S. E)%	Pop. Status (A)	Pop. Status (B)	IUCN 2013	F.H.
68	Black-headed Gull** π	<i>Larus ridibundus</i>	0.08 $\pm$ 0.36	C	C	LC	O
69	Caspian Tern*** π	<i>Sterna Caspia</i>	0.01 $\pm$ 0.05	R	C	LC	P
70	Common Tern*** π	<i>Sterna hirundo</i>	0.002 $\pm$ 0.02	MC	MC	LC	P&I
19. Family: Columbidae							
71	Rock Pigeon π	<i>Columba livia</i>	0.004 $\pm$ 0.02	C	VC	LC	G&F
72	Eurasian Collared Dove#	<i>Streptopelia decaocto</i>	0.01 $\pm$ 0.03 / (0.013 $\pm$ 0.08)	MC	VC	NA	G&F
73	Spotted Dove€	<i>Streptopelia cbinensis</i>	0.027 $\pm$ 0.16	VC	VC	LC	G&F
20. Family: Cuculidae							
74	Greater Coucal#	<i>Centropus sinensis</i>	0.004 $\pm$ 0.02 / (0.013 $\pm$ 0.08)	C	VC	LC	C
21. Family: Alcedinidae							
75	White-throated Kingfisher #	<i>Halcyon smymensis</i>	0.01 $\pm$ 0.03 / (0.02 $\pm$ 0.09)	C	VC	LC	P
76	Pied Kingfisher #	<i>Ceryle rudis</i>	0.01 $\pm$ 0.03 / (0.087 $\pm$ 0.21)	VC	C	LC	P
77	Common Kingfisher €	<i>Alcedo attbis</i>	0.013 $\pm$ 0.06	MC	VC	LC	I
22. Family: Upupidae							
78	Common Hoopoe#	<i>Upupa epops</i>	0.004 $\pm$ 0.02 / (0.013 $\pm$ 0.08)	MC	C	NA	I
23. Family: Hirundinidae							
79	Plain Martin π	<i>Riparia paludicola</i>	0.03 $\pm$ 0.18	MC	VC	LC	I
80	Barn Swallow*** π	<i>Hirundo rustica</i>	10.42 $\pm$ 57.69	C	VC	LC	I
24. Family: Motacillidae							
81	White Wagtail #	<i>Motacilla alba</i>	0.01 $\pm$ 0.05 / (0.013 $\pm$ 0.08)	MC	VC / C	LC	I
82	Yellow Wagtail π	<i>Motacilla flava</i>	0.01 $\pm$ 0.03	MC	VC / C	LC	I
83	Paddyfield Pipit π	<i>Anthus rufulus</i>	0.004 $\pm$ 0.02	C	C / MC	LC	I
25. Family: Turdinae							
84	Common Stonechatl π	<i>Saxicola torquata</i>	0.002 $\pm$ 0.01	MC	C	LC	I
26. Family: Passerinae							
85	House Sparrow π	<i>Passer domesticus</i>	0.02 $\pm$ 0.14	C	VC	LC	G&I
27. Family: Sturnidae							
86	Asian Pied Starling π	<i>Sturnus contra</i>	0.01 $\pm$ 0.06	C	C	LC	O
87	Common Myna π	<i>Acridotheres tristis</i>	0.02 $\pm$ 0.06	C	C	LC	O

S. N.	Common Name	Scientific Name	Encounter (per Km $\pm$ S. E)%	Pop. Status (A)	Pop. Status (B)	IUCN 2013	F.H.
88	Bank Myna π	<i>Acridotheres ginginianus</i>	0.14 $\pm$ 0.63	VC	C	LC	O
28. Family: Dicruridae							
89	Black Drongo#	<i>Dicrurus macrocerus</i>	0.01 $\pm$ 0.03 / (0.04 $\pm$ 0.24)	C	VC	LC	O
29. Family: Corvidae							
90	Rufous Treepie π	<i>Dendrocitta vagabunda</i>	0.004 $\pm$ 0.02	C	C	LC	O
91	House Crow#	<i>Corvus splendens</i>	0.08 $\pm$ 0.23 / (0.11 $\pm$ 0.50)	VC	VC	LC	O
92	Large-billed Crow#	<i>Corvus macrorhynchos</i>	0.09 $\pm$ 0.33 / (0.15 $\pm$ 0.64)	VC	C	LC	O

A = Population status as per the present study and unpublished data: R. K. Sinha.

B = Population status as per Kazmierczak, 2000. EN = Endangered, VU = Vulnerable, NT = Nearly threatened, LC = Least concern, NA = Not assessed

VC = Very common, C = Common, MC = Moderately common, R = Rare, UC = Uncommon

* = Migratory Birds, ** = Passage Migrant, *** = Migratory Birds which Breeds in Indian Subcontinent; † = Resident in Himalayas and Winter Visitors to Plain; †† = Resident of all over India and Winter Visitors to Rest of Sub-continent

= Bird Sighted in the Rivers Ganges and Gandak; π = Bird Sighted in the River Ganges; € = Bird Sighted in the River Gandak

% = In Parenthesis, Birds Encounter per km in and along the river Gandak

F. H. = Feeding Habit; H = Herbivores, C = Carnivores, O = Omnivores, P = Piscivores, I = Insectivores, I & M = Insectivores & Molluscivores, P & I = Piscivores and Insectivores, G & F = Graminivores and Frugivores, G & I = Graminivores and Insectivores

However, the present survey recorded lesser number of birds as compared to the study by Sinha et al. (2012), who reported 162 species of birds between Buxar and Mahinari Ghat, Katihar (500 kilometres) during continuous surveys in the Ganges in 2003-2007. The reason may be attributed to the short duration of the present study (October-December 2012). Bashir et al. (2012) reported 55 species of birds along a 165 km stretch of the upper Ganges between Bijnor and Narora barrages, Uttar Pradesh. Thapa et al. (2008) recorded 100 species of birds around Bagmati river.

Greater adjutant (*Leptoptilos dubius*) was the only endangered species sighted in the Ganges. However, the study recorded two vulnerable (lesser adjutant, *Leptoptilos javanicus* and greater spotted eagle, *Aquila clanga*), and seven near threatened species — Black Necked Stork, *Ephippiorhynchus asiaticus*; Black-Headed Ibis, *Threskiornis melanocephalus*; Ferruginous Pochard, *Aythya nyroca*; River Lapwing, *Vanellus duvaucelli*; Black-Tailed Godwit, *Limosa limosa*; Eurasian Curlew, *Numenius arquata*, and Painted Stork, *Mycteria leucocephala*.

The River Gandak, was represented by 39 species belonging to 31 genera and 18 families including three near threatened species; Painted Stork (*Mycteria leucocephala*), River Lapwing (*Vanellus duvaucelli*), and Eurasian Curlew (*Numenius arquata*). (Table 1). Anatidae and Ardeidae was the richest family represented by six species each in the River Gandak (Table 1, Figure 3). Sharma et al. (2009) reported 29 bird species along the River Gandak.

Abundance Status

In the Ganges, encounter rate (Individuals km⁻¹ $\pm$ Standard error) was highest (10.42 $\pm$ 57.69) for Barn Swallow (*Hirundo rustica*) followed by Gadwall (*Anas strepera*) (9.57 $\pm$ 57.47), which was the most encountered species (0.59 $\pm$ 1.69), followed by Ruddy Shelduck in the River Gandak.

Roy et al. (2014) reported Ruddy Shelduck as the most abundant species in the River Brahmaputra in Dibrugarh, Assam. In the upper reaches of the Ganges between Bijnor and Narora in Uttar Pradesh, the Little Cormorant was the most encountered (3.16 $\pm$ 0.290 individuals km⁻¹) species (Bashir et al. 2012).

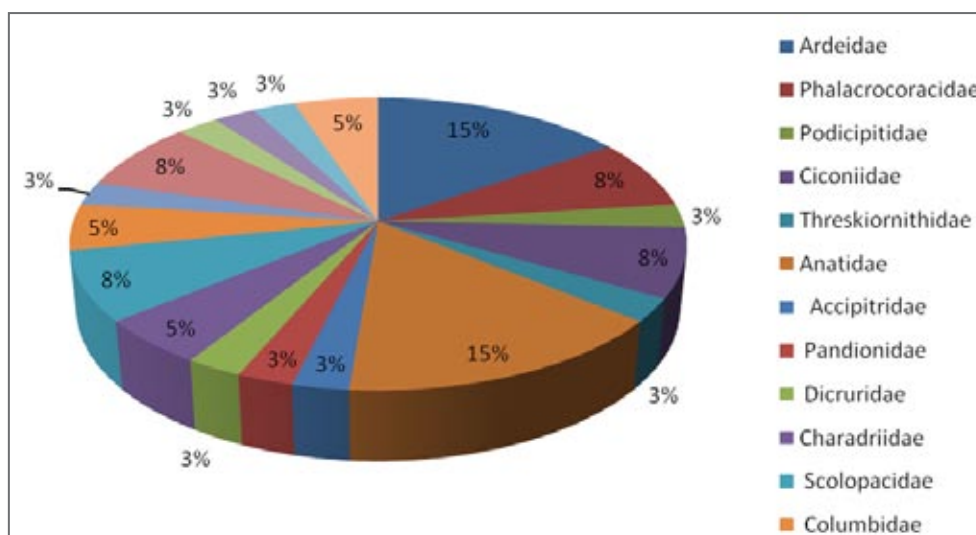


Figure 3: Family-wise percentage of species in the river Gandak

Of the species recorded in the Ganges, sighting of 17 species was rare. Very common, common, and moderately common species in the Ganges were 14, 24 and 35 respectively (Table 1). In the Gandak, only three species — Pied Harrier (*Circus melanoleucos*), Black Stork (*Ciconia nigra*) and Common Shelduck (*Tadorna tadorna*) were rare. Among the rest of the species, 11 were very common, nine were common, and 16 were moderately common (Table 1).

Residential Status

Out of the 90 species of birds recorded in the Ganges, 43 were resident, 36 migratory and 11 were winter visitors (Table 1). Most of the migratory birds belong to the families Anatidae, Scolopacidae, Laridae and Accipitridae. Black Stork (*Ciconia nigra*), Pied Avocet (*Recurvirostra avosetta*), Brown-Headed Gull (*Larus brunnicephalus*), and Black-Headed Gull (*Larus ridibundus*) were passage migrants. Flock of six individuals of Common Crane (*Grus grus*) were observed in the survey.

The species starts arriving in the Gangetic plains from mid-October and they stay here till April. Out of 36 species of migratory species, 15 species have their breeding place in Indian subcontinent (Kazmierczak, 2000). Brown-Headed Gull (*Larus brunnicephalus*), Common Tern (*Sterna hirundo*) and Bar-Headed

Goose (*Anser indicus*) breed in Ladakh; Great White Pelican (*Pelecanus onocrotalus*) and Caspian Tern (*Sterna caspia*) breed in Gujarat; Pied Harrier (*Circus melanoleucos*) breeds in Assam while rest of the birds breed in the Himalayas (Kazmierczak 2000).

In the Gandak survey of the 39 recorded species, 23 were resident, 12 were migratory and four were resident and winter visitors. Most of the migratory birds belong to the family Anatidae and Scolopacidae (Table 1). Breeding place of Bar-Headed Goose (*Anser indicus*), Ruddy Shelduck (*Tadorna ferruginea*), Pied Harrier (*Circus melanoleucos*), and Common Sandpiper (*Actitis hypoleucos*) were found in the Indian subcontinent (Kazmierczak 2000).

In the Gangetic plains, floodplains of the rivers are used as a feeding and roosting ground for thousands of migratory birds. They arrive in winter and disperse to nearby flood-plains and wetlands in Bihar. This could be the possible reason why the highest number of species were recorded in winter (more than 70 species) as compared to the summer in June (R K Sinha, unpubl.). If habitats in the Gangetic basin are conserved, it may provide special habitat for winter and migratory birds and number of species visiting the area may increase.

Feeding Habit

Analysis of feeding habit of the recorded birds reflects that in the Ganges majority of the species were omnivores (22.2) and piscivores (21 per cent) and very few were graminivores and frugivores (Table 1). In the River Gandak also, majority of the species were piscivores (33.3 per cent) and omnivores (17.9 per cent).

Habitat Use by Species

More than 50 per cent of the recorded species occupied sand bar or mid-channel Islands. Most of the species occupying these habitats belonged to families Ardeidae, Ciconiidae, Anatidae, Laridae and Phalacrocoracidae. Members of Acciptridae and Scolopacidae families were sighted on the banks of the river. Nests of Bank Myna (*Acridotheres ginginianus*) and Barn Swallow (*Hirundo rustica*) were also observed along earthen river banks. It was also observed that most of the birds show aggregated distribution which is the most common type of dispersion found in nature. This reflects patchiness of resources in the environment.

Although each bird species responds to its environment in an individual way (Gaud et al. 1986), species with similar ecology are likely to react in a similar manner, and by grouping them, data can be interpreted more reliably (Zonneveld 1983).

Monitoring of bird populations makes it possible to recognise the environmental changes and evaluate their significance more precisely than monitoring only a few species (Koskimies 1989). The present study provides a baseline for future monitoring of the riverine habitats. However, when using bird species as indicators of certain environmental changes, the indicator species must be chosen on the basis of specific habitat factors which must be monitored (Szaro and Balda 1982).

Occurrence of major proportion of water birds is also an indicator of good habitat quality. But increasing agricultural activities and percentage of cultivated

land of riparian wetlands have been suggested to affect bird communities by decreasing bird diversity (Mensing et al. 1998).

The present study was done for a very short period, but more intensive studies will definitely enrich our knowledge on avifaunal diversity in the region. A systematic long term monitoring of avian diversity in the basin would help in assessing the changes occurring in the river ecosystem.

ACKNOWLEDGEMENTS

The authors extend their sincere thanks to all members of Environmental Biology Laboratory, in general and Dr Dilip Kumar Kedia in particular for helping in data analysis.

The boatmen deserve special thanks for untiring field work.

The work was financially supported by the Department of Environment and Forests, Government of Bihar.

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Plate

Vulnerable and near threatened species of birds recorded during the study



Lesser Adjutant (Vulnerable) (Photo by Fernando Trujillo)



Painted Stork (Near threatened) (Photo by Fernando Trujillo)

Migratory birds recorded during the study



Great White Pelican (Photo by Fernando Trujillo)

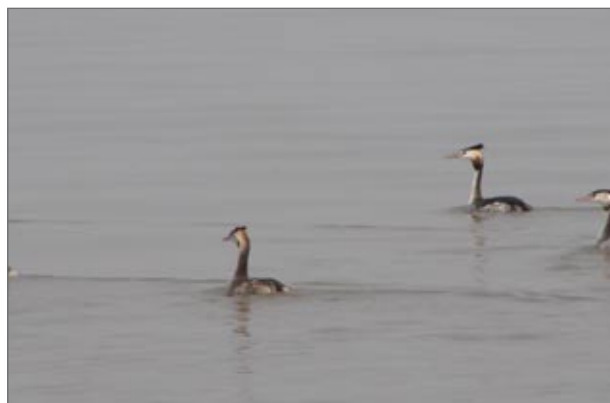


Gadwall (Photo by G. P. Purusharthi)

Birds in different habitat types



Eurasian Curlew in mid-channel Island
(Photo by G. P. Purusharthi)



Great Crested Grebe in river channel
(Photo by G. P. Purusharthi)

Study of Breeding Behavior of Greater Adjutant in Kosi River Floodplains of Naugachia in Bhagalpur, Bihar, India

D. N. Choudhary, T. K. Ghosh¹, J. N. Mandal and T. K. Pan²

Department of Zoology, T. N. B. College, Bhagalpur - 812007, India

¹PG Department of Zoology, T. M. Bhagalpur University, Bhagalpur - 812007, India

²PG Department of Botany, T. M. Bhagalpur University, Bhagalpur - 812007, India

E-mail: dnc_gopal08@rediffmail.com

ABSTRACT

The Greater Adjutant (*Leptoptilos dubius*) is a large sized endangered wetland bird belonging to family Ciconidae. The present work includes the study of nesting and other behaviors shown by the chicks and parent adjutants in different diara villages of Kadwa and Khairpur panchayats located in Kosi river floodplains under Naugachia block of Bhagalpur district, Bihar (India) during 2011-2014.

A total of 75 nests were recorded in 2014. A considerable increase in the number of nests and number of birds was found compared to the previous years. Behaviors shown by the chicks and their parents during the breeding period were also recorded. Nesting trees recorded were Peepal (*Ficus bengalensis*), Pakar (*Ficus glomerata*) Semal (*Salmelia malaberrica*) and Kadamb (*Anthocephalus cadamba*).

Key Words: Greater Adjutant, breeding, nesting, River Kosi, floodplains

INTRODUCTION

There are around 1300 species of birds found in India. Out of them around 22 per cent are totally dependent on wetlands (BirdLife International 2007). One such wetland dependent group whose population is declining alarmingly comprises storks (Istiaq 2001). There are 19 species of storks found in the world, of which 15 are regionally threatened. Tropical Asia and Africa have the largest concentrations of storks (Istiaq 2001).

The Greater Adjutant (*Leptoptilos dubius*) is a large sized wetland bird of stork family belonging to order Ciconiformes (Ali and Ripley 1987). It mainly feeds on fishes, crabs, crustaceans, mollusks, snakes and sometimes carcasses. This stork has long legs,

long and stout beak, a gular pouch hanging from the neck and grayish black wing with a long white band on the outer side, which differentiate this from the "Lesser Adjutant" and other storks (Grimmett et. al. 1999; Ali and Ripley 1987). It has been categorised as endangered by BirdLife International (2014).

Presently, the global population of this threatened stork is around 1100-1200 and over 50 per cent population is found in India (Rahmani 2012). At the beginning of the 20th century, the Greater Adjutant was found often in large number in South and South East Asia from Pakistan through Northern India, Nepal, Bangladesh, Vietnam and Cambodia. But now their global number has decreased alarmingly. This sharp decline is due to the effects of pollutants

and the continuous reduction in the availability of nesting and the quality of feeding sites (Islam and Rahmani 2002).

There are reports about the occurrence of Greater Adjutant from different parts of Bihar i.e. from Vikramshila Gangetic Dolphin Sanctuary (VGDS) Bhagalpur, (Choudhary et al. 2004) and from the wetlands of Katihar and Khagaria districts (Choudhary and Ghosh 2004) and also about their breeding (Mishra et al. 2010, Choudhary et al. 2011). The present work is a study of breeding and the breeding behavior of Greater Adjutants during 2011-2014.

MATERIALS AND METHODS

Seven *diara* (floodplains) villages (Pratapnagar-Katitola, Thakurji Kachahari Tola, Kashimpur, Khairpur Middle School, Ashram Tola, Gola Tola and Lachhminia Tola) of two Panchayats i.e. Kadwa and Khairpur, located in River Kosi floodplains under Naugachia block of Bhagalpur district in Bihar, were selected for the present study, because of their frequent sighting in these areas.

Data were collected on number of nests, number of live chicks, breeding behavior of parents, other activities of chicks, and also about the nesting trees during October 2011-April 2014 successively as their breeding period is October to January, varying locally with early or late cessation of the rains (Ali and Ripley 1987; Grimmett et. al. 1999) and was summarised in Table 1.

All the activities were studied visually from a closer distance without disturbing the birds. Sometimes binoculars (Minolta 10 x 30) were also used to record the activities. We visited the sites regularly, every fortnight from October to April during the study period. Main observations were listed accordingly. Photographs were also taken during their breeding and related behaviors.

RESULTS AND DISCUSSION

A total of 75 nests (with two-three chicks in each nest) and 169 live chicks were recorded in the year 2014 from the selected seven *diara* villages of Kosi floodplains under Naugachia block. This year, one new nesting site — the Thakurji Kachahari tola was also recorded where we could sight seven nests with a total of 18 chicks on three separate Kadamb trees (*Anthocephalus cadamba*), located adjacent to each other.

In the year 2012, 23 nests and 53 chicks were recorded from four *diara* villages namely Pratapnagar-Kati Tola, Kashimpur, Khairpur Middle School and Ashram Tola only whereas in the year 2013, a total of 49 nests and 111 chicks were raised successfully at six *diara* villages of Pratapnagar, Kashimpur, Khairpur Middle School, Ashram Tola, Gola Tola and Lachminia Tola of the same Panchayats. It clearly showed a significant increasing trend of the number of nests and numbers of chicks raised in comparison to the previous years.

This shows an increasing trend in the number of nests and number of live chicks as recorded earlier (Table 1). Greater Adjutant generally prefers building their nests on large wide-branched trees with thin foliage cover of Peepal, Pakar, Semal and Kadamb. In 2014, most of the nests were observed on Kadamb trees at a height of 13-14 metres (ocular estimate). All the nests looked like spherical baskets made up of plant twigs and were 1-1.5 m in diameter at the tree top. One fallen nest was measured to be 1.3 metre in diameter. The parent birds gradually increase the diameter of the nests by adding plant twigs as the chicks grow. The parent birds also collect green delicate leaves from nearby trees for cushioning the nest.

The main source of food and water for this Greater Adjutant are the tributary of River Kosi and the wetlands surrounding the said villages as most of the time the birds were found foraging in these areas.

Table 1: Nesting sites and litter size of Greater Adjutants in studied diara villages of Kosi floodplains of Naugachia

S. N.	Breeding sites	Village/ tola	Number of Nests			Number of Chicks (Litter size)			Number of chicks died			Number of chicks survived			Nesting Trees
			2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	
1	A	Pratapnagar Katitola (Kadwa) 25°5'40"NL & 87°3'16"EL	07	08	07	15	24	20	0	01	02	15	23	18	Kadamb ⁴ tree
2	B	Thakurji Kachharitola (Kadwa) 25°5'42"NL & 87°3'14"EL	0	0	07	0	0	18	0	0	02	0	0	16	Kadamb ⁴ tree
3	C	Kashimpur (Kadwa) 25°5'43"NL & 87°3'15"	6	10	15	14	23	37	0	01	04	14	22	33	Kadamb ⁴ tree
4	D	Khairpur Middle School Guruthan (Khairpur) 25°5'46"NL & 87°3'17"EL	07	16	24	16	35	58	0	01	05	16	34	53	Peepal ¹ Kadamb ⁴ & Semal ³ tree
5	E	Ashramtola (Khairpur) 25°5'46"NL & 87°3'19"EL	03	08	12	08	20	30	0	01	03	8	19	27	Pakar ² tree
6	F	Golatola (Khairpur) 25°5'47"NL & 87°3'19"EL	0	02	03	0	06	06	0	0	0	0	06	06	Peepa ¹ tree
7	G	Lachminia tola (Khairpur) 25°5'47"NL & 87°3'21"EL	0	05	07	0	11	18	0	04	02	0	07	16	Peepal ¹ tree
Total			23	49	75	53	119	187	0	8	18	53	111	169	

1 *Ficus bengalensis*, 2 *Ficus glomerata*, 3 *Salmelia malabarica*, 4 *Anthocephalus cadamba*

Both the parent birds alternately shared incubation and protection (guarding) of chicks after hatching. Parental care is well developed in Greater Adjutants as observed. They also rearrange their nesting material (plant twigs), nurse the chicks by preening and shading by spreading their wings above the chicks during rains and sunny days.

Parents feed their young ones more actively during the middle of the day. They collect the food materials (mainly fishes and snakes) from the nearby rivers and wetlands, store them and regurgitate the entire food item on the nest floor after returning. The juvenile birds beg for food by moving their heads up and down with a humming sound or sometimes show bill chattering movement as the parents approach them.

Juvenile birds (90-100 days old) were observed leaping into the air from the nest floor fluttering their wings vigorously. Sometimes the juvenile birds took short flights from branch to branch or from tree to tree or in the air and returned to the nest. We noticed that the breeding period of Greater Adjutant in Bihar is during October to March. Nest construction begins between October 10-15 and the chicks start fledging around first week of March; the nests were deserted around April 10-16.

Choudhary et al. (2004) reported the occurrence of Greater Adjutant from Vikramshila Gangetic Dolphin Sanctuary (VGDS) in Bhagalpur while Choudhary and Ghosh (2004) reported their presence (small flock of 7-10 birds) in the wetlands near Pasraha (Khagaria district), Kursela (Katihar district), Bihpur and Naugachia (Bhagalpur district) of Bihar. However the largest assemblage of 53 individuals was recorded on the bank of River Ganges within Vikramshila Gangetic Dolphin Sanctuary in May, 2006 along with 57 painted storks and other water birds (Choudhary and Mishra 2006).

The sighting of such a large number of Greater Adjutants and painted storks was the main impetus to look for their resting and breeding sites in the nearby

area initiated us to be more vigilant. In the month of January 2009, two Greater Adjutants were recorded roosting with seven Lesser Adjutant storks on a large Banyan tree at Koabari village under Taiyabpur railway station of Kishanganj district (Choudhary et al. 2011).

So far their breeding is concerned, we recorded altogether 13 nests at two *diara* villages i.e. Kashimpur and Ashram Tola of the same locality in the year 2006 (Choudhary et al. 2011). Presently, the number of live nests reached up to 75 along with 169 live chicks, raised by the birds successfully.

The total number of Greater Adjutants (breeding and non-breeding) in this locality (Naugachia block) may be around 350-400 as per our survey. The number is increasing every year in this area. This rapid increase in their number may be due to availability of plenty of food and water from the nearby River Kosi and its tributaries, suitable climate, security provided by the local villagers and presence of large nesting trees such as Peepal, Semul, Banyan, Pakar and Kadamb.

Mass awareness created by the members of a local NGO, Mandar Nature Club of Bhagalpur, towards the conservation and protection of these endangered storks may be another important factor for the increasing population of these birds particularly in this locality (Mishra et al. 2010; Choudhary et al. 2011) is certainly a matter of great concern.

Maximum nesting (21) was recorded on a single Peepal tree this year near Khairpur Middle School and it is a permanent breeding site of these birds since last six-seven years is probably due to security provided by the school teachers, employees and students. As we noticed that birds are roosting and breeding on this Peepal tree without any hindrance even in the presence of large number of students below the tree, showing a good example of proto cooperation.

Nest reorientation, i.e. rearrangement of plant twigs on the nest, nest cushioning by delicate leaves, preening and proper nursing and feeding of chicks timely by both the parent birds were also recorded showing the phenomenon of sincere parental care (Choudhary and Ghosh, 2004; Choudhary et al. 2010).

CONCLUSION

The Greater Adjutants are breeding successfully in Bihar and their number is increasing every year in the Naugachia block of Bhagalpur district. According to a recent report, their number is decreasing in Assam and Combodia while their number is increasing in the area. It reveals that the River Kosi floodplains, particularly Kadwa and Khairpur Panchayats of Naugachia, have become the potential breeding ground for these endangered storks. Tolerance of villagers towards the birds and awareness created by the members of Mandar Nature Club helps in their successful breeding. Traditional beliefs of farmers combined with relatively simple awareness programs to ensure villagers retain pride can aid to improve number of species that are of global conservation concern.

ACKNOWLEDGEMENTS

Authors are thankful to the villagers of Kadwa and Khairpur Panchayats for their active cooperation and help provided to us during our field work.

We are also indebted to the teachers of Khairpur Middle School for raising awareness among students on protecting these eco-friendly birds.

We also extend our sincere thanks to Mr Arvind Mishra, IBCN Coordinator of Bihar and Jharkhand and the members of Mandar Nature Club, Bhagalpur for their valuable suggestions.

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Figure 1: Adult with three juveniles



Figure 2: Nest cushioning by adults



Figure 3: Wing stretching



Figure 4: Nest guarding by an adult



Figure 5: Flying practice



Figure 6: Chick feeding



Figure 7: Shading the chicks

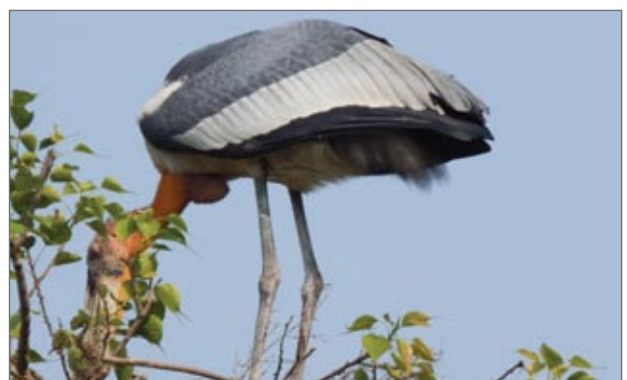


Figure 8: Nest reorientation by an adult

(All photographs are © of D N Choudhary)

Overview of Higher Vertebrates in the Ganges-Brahmaputra-Meghna River Basin: Their Status, Threats and Conservation

Ravindra Kumar Sinha, Dilip Kumar Kedia, and Anupma Kumari

Environmental Biology Laboratory,
Department of Zoology, Patna University,
Patna - 800005, India
E-mail: rksinha.pu@gmail.com

ABSTRACT

The Ganges-Brahmaputra-Meghna (GBM) river basin is one of the world's most biodiverse freshwater ecosystems. Some of the higher vertebrate species such as Ganges River dolphin, *Platanista gangetica gangetica*; Smooth-coated Otter, *Lutrogale perspicillata*; gharial, *Gavialis gangeticus*, and turtles, *Nilssonia gangetica* and *Lissemys punctata* are rare, endemic, threatened charismatic mega-fauna of the GBM basin.

Most of the higher vertebrate species are facing considerable threats throughout the distribution range in the river systems due to various anthropogenic stresses. Based on our own studies and literature review this paper presents details of the non-avian higher vertebrates, mainly Ganges River dolphin, Smooth-coated Otter, *Gavialis* and some turtles in the GBM river basin including their current status and causes of decline. Recommendations for conservation of these endangered species have also been suggested.

Key words: River Biodiversity, Ganges-Brahmaputra-Meghna River Basin, Ganges River Dolphin, Smooth-Coated Otter, Gharial, Turtles

INTRODUCTION

The major rivers of the Ganges-Brahmaputra-Meghna Basin drain the Himalaya and are amongst the world's most biodiverse freshwater ecosystems, but they are increasingly under threat due to declining flow and pollution as the range countries scramble to harness hydropower and provide water for expanding agrarian economies.

Hundreds of new dams, irrigation barrages, run-of-the river hydroelectric schemes, river linking schemes and other water development projects are planned or being implemented in the rivers of the basin (Dutta 2010; Verma et al. 2009; Sinha and Kannan 2014). Rivers in the Himalayan region will

soon have the highest concentration of dams in the world (Dharmadhikary 2008). The combined effects of these activities are predicted to cause rapid and escalating hydrological change and habitat fragmentation that will negatively impact riverine biodiversity and ecosystem services (Dudgeon 2000; Ziv et al. 2012). The Ganges Basin has an extraordinary variety in altitude, climate, land use and biodiversity (O'Keeffe et al. 2012) which is favourable for diverse faunal diversity including the higher vertebrates.

Freshwaters are experiencing declines in biodiversity far greater than those in the most affected terrestrial ecosystems (Braulik et al. 2012). Construction of

dams and barrages as well as embankments mainly in Ganges basin both in India and Bangladesh have dramatically increased habitat fragmentation and loss of lateral connectivity with other freshwater bodies such as wetlands etc.

The critically endangered species of the Ganges include Ganges dolphin (*Platanista gangetica gangetica*), gharial (*Gavialis gangeticus*), River Terrapin (*Batagur baska*), Red-crowned Roofed Turtle (*B. kachuga*) and Gangetic Shark (*Glyphis gangeticus*) (MoEF 2011).

River dolphins are iconic species that can serve as charismatic flagship for conservation of freshwater ecosystems but it is poorly understood and increasingly threatened (Braulik et al. 2014). In the recent past, the Ganges dolphin's range in substantial portions of the Ganges system, especially in upper reaches and smaller tributaries, has shrunk due to various anthropogenic stresses including indiscriminate abstraction of river water leading to decline in flow; pollution from various sources, construction of embankments, dams and barrages, siltation etc. Smooth-coated Otter, *Lutrogale perspicillata*, once very common, is one of the rarest and endangered species of the GBM Basin. This species has been pushed on the verge of extinction due to over-exploitation and habitat degradation. *Gavialis gangeticus*, a fish-eating crocodile, is an endemic and critically endangered fauna of the Ganges basin in India and Nepal and probably in Bangladesh.

The Ganges system supports a rich and diversified turtle species. There is rampant poaching of most of the turtles in Uttar Pradesh, Bihar and West Bengal as their eggs and meat are in high demand for human consumption especially in West Bengal, Bangladesh and other neighbouring countries. Their egg laying spaces on the river banks are also being encroached upon for crop cultivation and other development activities. Based on our own researches and review of published papers, the species dealt in this paper are: Ganges River dolphin

(*Platanista gangetica gangetica*), Smooth-coated Otter (*Lutrogale perspicillata*), Gharial (*Gavialis gangeticus*), River Terrapin (*Batagur baska*), Red-crowned Roofed Turtle (*B. kachuga*), Three-keeled Tricarinata Hill Terrapin (*Melanochelys tricarinata*), Ganges Soft-shelled Turtle (*Nilssonina gangetica*), Indian Peacock Soft-shelled Turtle (*N. hurum*), Spotted Northern Indian Flapshell Turtle (*Lissemys punctata andersoni*), Indian Roofed Turtle (*Kachuga tecta*), Spotted Black Terrapin (*Geoclemys hamiltoni*) and Indian Narrow-headed Soft-Shell Turtle (*Chitra indica*).

GANGES-BRAHMAPUTRA-MEGHNA RIVER BASIN

The Ganges-Brahmaputra-Meghna (GBM) river basin (Figure 1) is a trans-boundary river basin with a total area of just over 1.7 million square kilometres (Table 1), distributed among India (64 per cent), China (18 per cent), Nepal (nine per cent), Bangladesh (seven per cent) and Bhutan (three per cent).

The Ganges-Brahmaputra-Meghna (GBM) basin constitutes only 0.12 per cent of the world's land mass which is the home to about 750 million people (>10 per cent of world's population) (Bandyopadhyay 2014), and the basin drains significant parts of both the South and North aspects of the Himalaya. Many of their tributaries are also of a trans-boundary nature (Biswas 2006). The GBM river system is the third largest freshwater outlet to the world's oceans, being exceeded only by the Amazon and the Congo River systems (Chowdhury and Ward 2004).

Silt and sediments are integral part of the river ecosystem. River Kosi, one of the largest tributaries of the Ganges, is the second highest carrier of silt load after the River Huang-Ho of China. River Kosi carries 172 million tons or 2774 tons/ square kilometres suspended load whereas Huang-Ho carries 1887 million tons or 2804 tons/ square kilometres besides, the average annual suspended load of Ganges is 1451 million tons, i.e. 1518 tons/ square kilometres (IUCN 1980).

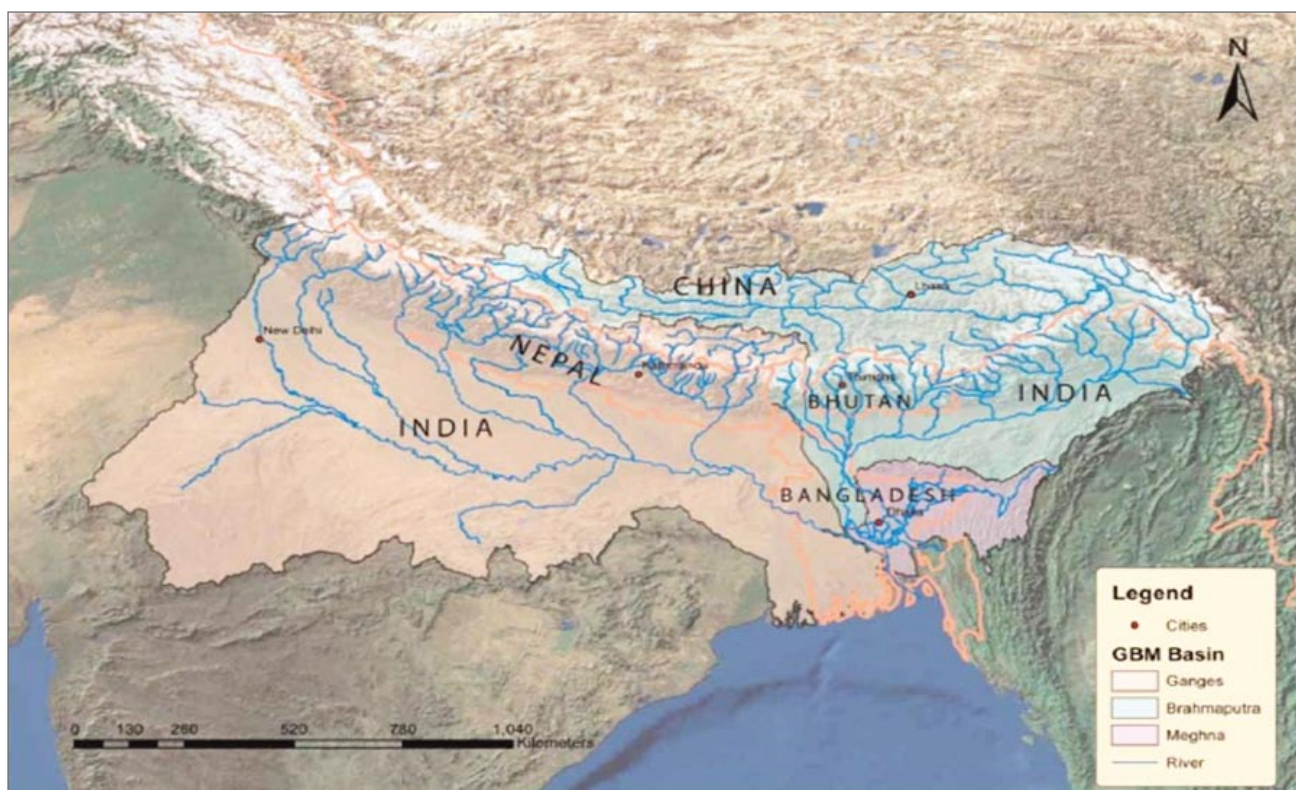


Figure 1: Map of the Ganges-Brahmaputra-Meghna river Basin. (Golam Rasul 2014)

Without suspended solids rivers cannot maintain hydro-geo-morphological complexities which are essential for creating diversified micro/ macro habitats for sustenance of rich and diversified biota. Not much is known about role of sediments in river ecology, however, it was noticed that “silt free water” from Farakka Barrage to the River Bhagirathi through a 38.2 kilometres long Feeder Canal has very badly affected the ecological integrity of the river for about 175 kilometres up to Katwa.

The condition in the River Bhagirathi improves only after discharge of the River Ajay which carries a large amount of sediments and silt into the Bhagirathi at Katwa in Burdwan District of West Bengal (Sinha and Kannan 2014). Gopal (2000) also opined that 90 per cent of the sediments are retained in the basin and the remainders are carried to delta.

The deposition of sediments in the reservoir behind the barrages has not only created a large sand bar (three kilometres x 0.3 kilometres) but led to less

flow of sediments through the Bhagirathi-Hooghly River System at the mouth of the Ganga resulting in increase in coastal erosion. The sea is likely to advance towards the mainland accompanied with salinity ingress. The Inter-Governmental Panel on Climate Change 4th Assessment Report says that one million people will be affected by coastal erosion due to decreased sediment delivery by the rivers.

The main River Ganges is the combination of two rivers, the Bhagirathi originating at Gomukh from Gangotri glacier and the Alaknanda originating at Satopanth glacier in Garhwal Himalayas. The two rivers flow separately for about 200 kilometres and receive several small tributaries before they merge at Dev Prayag where it attains the name of Ganges. In the plains, the Ganges receives many tributaries such as Ramganga, Gomati, Ghaghara, Gandak and Kosi on its left bank. The Mahananda, another major tributary, joins Ganges in Bangladesh. Besides, many tributaries such as Yamuna, Tons, Son, Punpun, Kiul and Ajay join Ganges at its right

bank. River Damodar, Rupnarayan and Haldi join the Ganges downstream Kolkata. The total length of the Ganges from Gomukh to its mouth at Sagar Island in the Bay of Bengal is 2715 kilometres (Parua 2001). The Ghaghara has maximum annual runoff (about 94400 million m³) (Rao 1979).

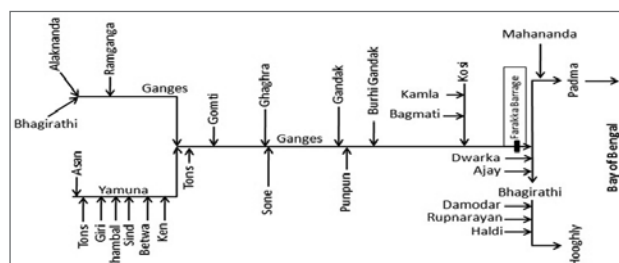


Figure 2: Flow diagram of River Ganga

The River Brahmaputra originates in the Kailas range of the Himalayas at an elevation of 5150 metres in China under the name of Yalung Zangbo. After flowing for 1700 kilometres parallel to the main range of the Himalayas, it enters India and after passing through 720 kilometres in Assam, it enters Bangladesh below Dhubbri and after traversing for 279 kilometres joins the Ganges (Padma) at Goalundo in Bangladesh (Rao 1979).

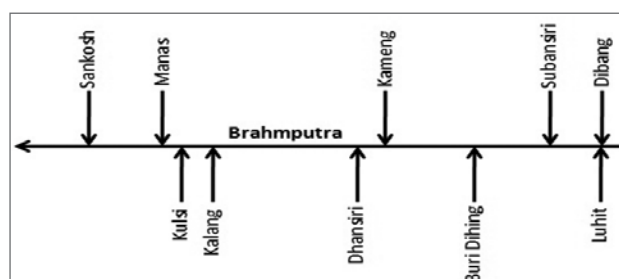


Figure 3: Flow diagram of River Brahmaputra

The Barak River originating from Manipur hills flows westward up to Badarpur, when it bifurcates into Surma, the northern branch and Kushiara, the southern branch in Assam. The Surma enters Bangladesh next to Sylhet town and joins Meghna river near Kular Char and the Kushiara merges with Meghna near Ajmiriganj in Bangladesh. Meghna carries total flow of 1110.60 km³ including that of the Ganges-Padma and Brahmaputra and finally discharges into the Bay of Bengal.

HIGHER VERTEBRATES

The Ganges River Dolphin

Current Status

Ganges River dolphins, commonly known as Susu, *Platanista gangetica gangetica*, are distributed throughout the Ganges-Brahmaputra-Meghna (GBM) and Karnaphuli-Sangu river systems of Nepal, India, Bangladesh, and potentially Bhutan (Mohan et al. 1997; Sinha et al. 2000; and Smith et al. 2001) from the deltas to as far up the rivers are navigable.

The river dolphins prefer areas of eddy counter currents, such as small islands, sand bars, river bends, and convergent tributaries. In the monsoon season, Ganges dolphins disperse locally to floodplains and tributaries and return to larger river channels in the dry, winter season (Sinha et al. 2000; Sinha and Sharma 2003a, 2003b; Smith 1993; Smith et al. 2004) The dolphins have been reported to move along the coast of the Bay of Bengal when monsoons flush freshwater out in the Bay of Bengal (Moreno 2003) as it has been sighted in the River

Table 1: Catchment area of Ganges-Brahmaputra-Meghna River Basin in different countries

Catchment Areas of Major Rivers in GBM Basin					
Total Catchment Area (km ²)	Catchment Area (km ²)				
	India	Nepal	Bhutan	China	Bangladesh
552000	195000	-	47000	270900	39100
1087300	860000	147480	-	33520	46300
82000	47000	-	-	-	35000
1721300 (100%)	1102000 (64.02%)	147480 (8.57%)	47000 (2.73%)	304420 (17.69%)	120400 (7%)

Budha Balang in Orissa, approximately 300 km south west of mouth of the Ganges, which has never been part of the GBM river basin.

The dolphins were recorded from Dev Ghat in the River Narayani in Nepal, 250 metres above the mean sea level (Kasuya 1972). Nine susus were also sighted in the Barak River in 2006 at Silchar in Assam (Pawlen Singha, pers. comm., Email: thpawlensingha@gmail.com) in India. The current estimated population of the Ganges dolphin in different rivers of GBM Basin is 3607 (Table 2) including 3025 in India, 532 in Bangladesh, and about 50 in Nepal (Sinha and Kannan 2014).



Surfacing of *Platanista gangetica gangetica* in River Ganges in Bihar photo by Fernando Trujillo

Many rivers in India, Nepal and Bangladesh are yet to be surveyed. In Bihar many rivers north of the Ganges, such as Mahananda, Mechi, Bagmati, Kamala, Balan, Burhi Gandak, and their tributaries are also to be surveyed. The rivers such as Teesta, Manas, and their tributaries, ultimately joining the Brahmaputra have not been surveyed. Most of the rivers in Bangladesh are un-surveyed.

The frequency of dolphin sightings remains high in the middle and lower reaches of the main stem of the Ganges, as the river has more hydro-physiographic complexity and greater hydraulic refuge as induced by minor geomorphic features. The distribution of prey is likely to be one of the most important factors that influences the distribution of river dolphins; however, habitat selection is frequently assessed

in terms of physical habitat characteristics, as these are the primary determinants of prey distribution and are more easily measured (Gregar and Trites 2001; Cañadas et al. 2002; Davis et al. 2002; Bearzi et al. 2008).

Threats

The major threats to the Ganges Dolphin in its entire distribution range include incidental and directed killings, use of dolphin products mainly dolphin oil, and habitat loss or degradation due to unsustainable abstraction of river water for irrigation and other purposes, noise pollution and chemical pollution in rivers both from point and non-point sources



(Kannan et al. 1993, 1994, 1997; and Senthilkumar et al. 1999), siltation, river resource extraction like stones, sand (Mohan et al. 1997) and woody debris (Smith, 1993), increasing river traffic, depletion of prey base, construction of dams, barrages (Sinha 2000), and embankments as water development projects and flood control measures.

Conservation Status

The Ganges dolphin has been categorised as Endangered by the IUCN (IUCN 1996), included in Schedule I in the Indian Wildlife (Protection) Act 1972, and in the Appendix I of CITES, and in the Appendix II of the CMS. The species has been given status of the *National Aquatic Animal* by Government of India in October 2009, a formal notification was issued in May 2010.

Table 2: Status and distribution of Ganges River dolphins in the Ganges-Brahmaputra-Meghna River Systems

River	Segment (with channel length)	No. of Dolphins	Year	Reference
Ganges	Between Haridwar and Ganga Sagar Island (2489 km)	1518	1993-95 to 2012	Sinha et al. 2010a; Sinha et al. 2000; Sinha 1999; Sinha 1997; Behera 1995; Sandeep Behera, pers. comm; and Gopal Sharma, pers. comm.
Yamuna	From confluence of Chambal river to Yamuna-Ganga confluence at Allahabad (250 km)	31	2012	Sandeep Behera, pers. comm.
Girwa	India/Nepal border to Girijapuri Barrage (approx. 20 km)	39	2012	Sandeep Behera, pers. comm.
Ghaghara	Girijapuri Barrage to Deorighat (505 km)	295	2006	WWF Nepal 2006
Rapti	15 - 20 km	8	2012	Sandeep Behera, pers. comm.
Saryu	22 km	16	2012	Sandeep Behera, pers. comm.
Chambal	Rajghat to Panchnada (approx. 550 km)	85	2012	Sandeep Behera, pers. comm.
Sone	From Uttar Pradesh/ Bihar border to its confluence with Ganges about 35 km upstream Patna in the state of Bihar (approx. 300 km)	0	2001	Sinha and Sharma 2003b
Sone	Between Bicchi in Madhya Pradesh to Banjari (130 km)	10	1998	Sinha et al. 2000
Sarda	Sarda Barage to Palia (approx. 100km)	0	1994	Sinha and Sharma 2003a
Kosi	Between Kosi Barrage to Kursela (approx. 200 km)	85	2001	Sinha and Sharma 2003b
Gandak	Gandak Barrage to Gandak-Ganges confluence at Patna (approx. 320 km)	257	2010	Choudhary et al. 2012
Ken	Confluence with Yamuna to Sindhan Kalan village (30 km)	8	1998	Sinha et al. 2000
Betwa	Confluence with Yamuna to Orai (84 km)	6	1998	Sinha et al. 2000
Sind	Confluence with Yamuna to 110 km upstream	5	1998	Sinha et al. 2000
Rupnarayan	Gadiara to Mankur (42 km), West Bengal	18	2006	WWF Nepal 2006
Brahmaputra	Arunachal Pradesh/Assam to India/Bangladesh border (856 km)	583	2012	Abdul Wakid, pers. comm.
Subhansiri	Katai Sapor to its confluence with the Brahmaputra at Jamuguri (94 km)	35	2012	Abdul Wakid, pers. comm.
Kulsi	From Gharamara to its confluence with the Brahmaputra at Nagarbera (76 km)	17	2012	Abdul Wakid, pers. comm.
Barak (Meghna in Bangladesh)	At Silchar (about 15 km)	09	2006	Pawlen Singha, pers. comm.

River	Segment (with channel length)	No. of Dolphins	Year	Reference
River system and Sundarbans area in Bangladesh	Kushiyara (113 km) - 43 dolphins Karnaphuli-Sangu (165 km) - 125 dolphins Sundarbans (1488 km) - 225 dolphins Burhi Gandak (17 km) - 11 dolphins Jamuna (83 km) - 74 dolphins Padma (110 km) - 54 dolphins	532	1998-2012	Smith et al. 1998, 2001, 2006,; Alam and Sarker 2012; and S.M.A. Rashid et al. 2014, unpubl.
Karnali River and tributaries - River Mohana and Pathariya; and River Koshi in Nepal	In discrete segments	>50		Bhojraj Shreshtha, pers. comm.; and Kevin Denlay, pers. comm., Dec. 2013
Total		3607		

Conservation Measures

Successful strategies to facilitate the recovery of depleted populations, reverse trends of population decline and habitat deterioration, and to ensure that robust populations with high quality habitat are secure will need to be multifaceted, adaptable, and tailored to particular local or regional conditions (Reeves et al. 2003). Among the elements needed for an effective management scheme are abundance estimation and reliable demographic knowledge of how many animals are being removed. Following conservation strategies will help in saving the Ganges dolphin for long:

- Developing and encouraging alternative fishing techniques (Sinha 2000).
- Reducing incidental mortality through rescue and release efforts (Braulik 2000).
- Managing future dolphin-oriented tourism which is a potential sustainable income source for fishermen and locals.
- Habitat protection and restoration.
- Researches on various aspects of Ganges Dolphin and reducing pollution load in rivers.

Indian Smooth-coated Otter

Current Status

Smooth-coated Otters inhabit several major river systems in south and south east Asia, and their

environmental requirements link them to food and water security issues as the region is so densely populated by humans. Its distribution is continuous from Indonesia, through Southeast Asia, and westwards from southern China to India and Pakistan, with an isolated population in Iraq (Pocock 1941; Hussain 1993). Its presence has been confirmed in Pakistan, India, Nepal, Bhutan, Bangladesh, Southwest China, Myanmar, Thailand, Vietnam, Malaysia, Sumatra, Java and Borneo (Mason and Macdonald 1986).

Khan et al. (2014) reported presence of *Lutrogale perspicillata* from the River Alaknanda from Rudraprayag to Rishikesh and also from the Ganges in Hastinapur Sanctuary between Bijnor and Narora. A small family of about five-six Indian Smooth-coated Otter, *Lutrogale perspicillata*, was encountered in the main stem of the Ganges in the Vikramshila Gangetic Dolphin Sanctuary (Sinha 2013). We sighted several families of the species in the River Karnali in Nepal and the Girwa in India in February-March, 1993. We did not record otters while conducting continuous dolphin surveys in River Sarda in Uttar Pradesh; River Gandak, River Kosi, River Son in Bihar in the last two decades.

Because of their secretive and nocturnal behaviour of the Smooth-coated Otter, reliable estimates of its

population are not available. In Southeast Asia it is found in large groups (Foster-Turly 1992; Hussain 1993; and Hussain 1996) where the basic family group consisted of adult female and her offspring, father and older siblings often join the group (Lekagul and McNeely 1988). The group size of otters varies considerably between months and seasons, the group being large during the monsoon (Hussain 1996).

to chase fish into fishing nets. This fishing technique is currently used by about 300 fishermen, with an additional 2,000 people indirectly dependent on the technique for their livelihood (Feeroz et al. 2011).

Threats

This species is threatened by a combination of habitat destruction and hunting. The expansion of agriculture has led to the destruction of huge areas



Smooth-coated otters in the Ganges in Vikramshila Gangetic Dolphin Sanctuary photo by R. K. Sinha

Along the Chambal river in Central India the group size ranges from one to nine individuals (mean = 4.62). During a study conducted in the Corbett Tiger Reserve, in North India an estimate of 41 individuals (35 adults and 6 juveniles) with a mean of 5.1 ± 1.55 was recorded from the 85 kilometres of river stretch within the Reserve (Nawab 2007).

The Smooth-coated Otter is predominantly a fish eater, but supplements its diet with shrimp/ crayfish, crab and insects, and other vertebrates such as frog, mudskippers, birds and rats (Prater 1971; Foster-Turly 1992; and Hussain and Choudhury 1998).

Along the major rivers in India they eat more fish, often making up to 94 per cent of the total diet (Hussain and Choudhury 1998), while along the coast in mangrove habitats and in rice fields it ranges between 75-100 per cent (Foster-Turly 1992; Melisch et al. 1996). Smooth-coated Otters are used for commercial fishing in southern Bangladesh. These otters are bred in captivity, trained, and used

of natural habitats, including forests, grasslands and wetlands, in nearly all regions of the world (Ottino and Giller 2004).

The expansion and development of urbanisation and riverfront infrastructural developments, such as the construction of dams, has broken the continuum of natural habitats into small fragments (Nawab 2007) and these patches of suitable habitat may be too small to support a breeding pair or a functional social group. It may be noted that area sensitive species (Lambeck 1997) like otter, that have a low dispersal capacity, are unable to re-colonise such patches following extinction (Collinge 1996).

Intentional otter trapping is prevalent in GBM basin in India, Nepal and Bangladesh (Hussain 1993; Melisch et al. 1996; and Hussain 2002). Although quantitative data on population sizes or trends are lacking, it is suspected that the global population of the Smooth-coated Otter has declined by >30 per cent over the past 30 years.

As per IUCN, main threats are habitat destruction by loss of forests in general, and riparian vegetation in particular, pollution, and hunting for certain body parts believed to have medicinal properties, and international trade for skin; the main exporting country Bangladesh, main importing country Germany (Foster and Turley 1992).

Conservation Status

Since 1977, *Lutrogale perspicillata* is listed on CITES Appendix II. It is a protected species in almost all the range countries, which prohibits its killing. But most range countries are not able to control the clandestine trade leading to extensive poaching. Smooth-coated Otters are protected in India under the Wildlife (Protection) Act, 1972, Schedule II, Part II, and are listed as “Endangered” as per IUCN criteria.

Gharial

Current Status

The gharial (*Gavialis gangeticus*) is the rarest freshwater fish-eating crocodile in the world. Gharial is the only surviving member of the Gavialidae family (Maskey 1989). It lives in deep fast-flowing rivers (Shah and Tiwari 2004) and prefers clean water and sand banks/ bars where they find their food, bask and make nests, respectively.

Any modification of either of these habitats is extremely dangerous for the gharial. Gharials return every day to the same place to bask, making it prone to poaching. Its long snout is the most impressive characteristic; it permits the animal to hold struggling preys as fishes (CSG 2000) and to swim and move under water with a very low water resistance.

This snout is terminated for the mature males by a large protuberance similar to a *ghara*, a traditional pot in India and Nepal. Apparently the animal got its name gharial from the word *ghara*. Male matures sexually after 13 years, the female at 16 years when the individuals are about three metres long (Whitaker 1987).

A male has a harem and will mate with all the females of the harem. The mating period lasts for two months between November and January; nests takes place between March and May in hole digging on sand banks along the river (Groombridge 1987). Clutch size is 30-50 eggs, and the eggs are the largest of any crocodilian (average 160 grams) (Stevenson and Whitaker 2010).

Historically, the gharial was present in several countries of Southeast Asia — Pakistan, Bhutan, Myanmar, India, Nepal and Bangladesh. In the 1940's, gharial population was estimated to be 5000-10000 individuals. It declined to 150-200 individuals in the 1960's principally due to habitat destruction and uncontrolled exploitation. Current population is about 2000 individuals in India and 81 in Nepal.

Currently, three widely separated breeding sub-populations are left in India (Chambal River, Girwa River and Son River) and in Rapti/ Narayani River and Karnali River in Nepal. Wild breeding population of gharial in the rivers is now expected to be less than 200 individuals. We recorded a small resident population of about 25 gharials in the River Gandak in Bihar, in December 2012. Stray individuals are reported from River Ganges/ Padma near the India-Bangladesh border.

In a survey conducted in 156 kilometres stretch of River Gandak upstream its confluence with the Ganga at Patna, 22 adults, one hatchling, and two sub-adults (total 25) were sighted in December 2012 (Sinha 2013). One thousand and eighty eight gharials were sighted in the River Chambal (435 km) in February 2014 (R. K. Sharma of M. P. Forest Department, pers. comm.), and 24 nests were found in River Girwa at Katernia Ghat in 2012 (Sandeep Behera of WWF-India, pers. comm.).

In 2014, captive bred gharials have been released in Ghaghra and Gandak rivers in India. Gharial conservation began in 1971 in Nepal with the help of the Frankfurt Zoological Society. It consists of population reintroduction by egg collect, gharial



Gavialis gangeticus in River Gandak. Photograph photo by Samir K. Sinha

breeding and juvenile release. Nearly 700 individuals were released in four different rivers of Nepal (Andrews and Mc Eachen 1994). Despite all these efforts, gharial population is very low — 81 gharials were counted in the whole country in 2008 (Kadkha et al. 2008). The gharial is believed to be extinct in Bhutan. Stray individuals are reported occasionally in Bangladesh, however, surveys are needed to prove whether there is a breeding population of gharial.

Threats

Threats are not completely understood and identified but some of them are known which are as follows:

Poaching: It has been clearly identified and is still continuing in its entire distribution range. Usually this species is confused with crocodile by the common people who kill it. Use of the *ghara* (narial excrescence in adult male gharial), penis and fat for medicines has been traditional and is still reported from Nepal and occasionally in India. Gharial eggs are sought by tribal people to eat.

Pollution: No threat for gharial was clearly identified but some mark of pollution was observed in the different rivers: foam, dead fishes, health problem

after drinking water of these rivers in Nepal. The 2007/ 2008 die-off of 113 sub-adult and adult gharials along the Chambal from what has been identified as a nephrotoxin(s) (Whitaker et al. 2008) serves as a harsh warning. It might have happened due to sudden discharge of the toxic chemicals into the river from some industries. But the real cause of death was never disclosed.

Dams and barrages: Large barrages were built in all major rivers at India-Nepal border and also in the other rivers in India (Smith et al. 2000), where gharials live, to divert river water for various purposes. The barrages allow gharials to go downstream, but once below the barrage they cannot return upstream the barrage.

Incidental and intentional killing by fishing activities: Most of the rivers are traditionally used by local population for fishing. Gharials are killed both incidentally and directly. When gharials are caught in the net, they are not able to escape due to their weak muscles.

Loss of breeding ground: The rivers harbouring gharials are facing intense human pressure. Sand

mining activities are very common in the breeding ground areas. The river banks are also used for farming and crop cultivation. Besides the above threats, gharials are facing acute shortage of freshwater in the rivers as there are competing demands for freshwater for irrigation and also by other stakeholders. Many perennial rivers are getting dry in the lean season. Climate change is likely to aggravate situation. The intense fishing pressure is also dwindling the prey base for gharial.

Conservation

The gharial is listed in the Schedule I of the Indian Wildlife (Protection) Act 1972. Gharial Conservation Project was started in India since early 1970s. India established two breeding centres: at Kukrail in Lucknow in Uttar Pradesh, and at Morena in Madhya Pradesh. Since this date, about 3000 young gharials were released in 12 different rivers; the major release programme was done in River Chambal (India) where 1718 individuals were released during the period 1979-1993 (Ross 1998). About 400 kilometres stretch of the River Chambal was declared as protected area, National Chambal Sanctuary, for protection and conservation of gharial.

Katarnia Ghat Gharial Sanctuary, another protected area, was declared in about 25 kilometres stretch of the River Girwa at India-Nepal border. Sone Gharial Sanctuary is in Madhya Pradesh. This animal has been listed as *protected species* in Nepal also.

Reintroduction of gharials in rivers has not given the desired result due to scarce conservation funds and human resources (Choudhury et al. 2007). The gharial is listed on CITES Appendix I and on CMS Appendix I. It is categorised as *Critically Endangered* as per 2009 IUCN Red List.

Suitable habitat in the rivers harbouring gharial must be protected. Pollution control, infrastructure development and fishing activities need special attention. Periodical monitoring of existing population is important for conservation of the species. Involvement of local people is must in conservation

and management planning for the species. Research activities should focus on key management issues such as the gharial's role in the ecosystem, fish ecology, relationship between gharial and mugger (*Crocodylus palustris*), ensure minimum water flow needed for the survival of gharial and other river fauna as well as investigate the genetic relationship of remnant populations.

Socioeconomic studies are needed to understand the impact of local anthropogenic pressures on the habitat in a better way (Stevenson and Whitaker 2010).

Turtles

Twenty Nine species of freshwater turtles and tortoises occur in India. Northeastern India has highest species diversity with 21 species (Ahmed and Das 2009). The Ganges system supports 18 species of turtle fauna (Choudhury and Bhupathy 1993). The Ganges and Brahmaputra drainages have been identified as world's highest priority freshwater turtle conservation area (Buhlmann et al. 2009). Almost all species in the Ganges and Brahmaputra basin are facing serious threats of over exploitation for meat and eggs.

The Indian soft-shell turtle, *Nilssonina gangetica*, and Indian flap-shell turtle, *Lissemys punctata punctata*, act as scavenger in the river as they feed on carcasses and cadavers, but unfortunately they are facing extinction due to rampant poaching for their meat. As the turtles are facing threats of extinction, following turtles of Schedule I and *Chitra indica* of Schedule II of the Wildlife (Protection) Act 1972, have been described herewith:

1. River Terrapin (*Batagur baska*): The Northern River Terrapin, *Batagur baska* (Family Geoemydidae), is a large (carapace length up to 59 centimetres) critically endangered river turtle that previously occupied most rivers and estuaries of South Asia (India, Bangladesh, and Myanmar) (Das 1986). Exceptionally large concentrations of this species that resided in the Hooghly River of West Bengal in

India and the Ayeryawady Delta in Myanmar during the 19th and early 20th centuries are now extirpated. *Batagur baska* was included as one of the 100 most endangered species by IUCN in 2012. The Terrapin's demise has resulted from extensive exploitation of its flesh and eggs, and habitat alteration and destruction (e.g., sand-mining, dam building, water projects, and pollution) that have degraded the turtle's nesting areas and feeding habitat.

2. Indian Roofed Turtle (*Kachuga tecta*): Found in Pakistan, India (Ganges, Brahmaputra and Indus River drainages), Bangladesh and Nepal. This is a quiet-water turtle, occurring in quiet streams, canals, oxbows, ponds, and man-made water tanks. It also occurs in brackish coastal waters. A soft bottom and abundant aquatic vegetation are preferred conditions. Their basking sites include river banks, floating trunks and partially submerged vegetation. It is non-aggressive in nature, as they do not bite on being handled.

This species is seldom exploited for food, being generally too small. Some numbers are caught for the pet trade in the west (Das 1991). It is listed under Schedule I of the Indian Wildlife (Protection) Act 1972, Schedule I of the Bangladesh Wildlife (Preservation) Act 1974 and Appendix I of CITES.

3. Three-keeled Tricarinate Hill Terrapin (*Melanochelys tricarinata*): Its distribution extending from the Garhwal Himalayas in Uttarakhand in India,



Nilssonis hurum (Photo by Gopal Sharma)

eastward through the northern India, southern Nepal and northern Bangladesh, to Arunachal Pradesh in North-eastern India (Das 1991; Busack 1994). The species is terrestrial and lives in riverine grasslands besides in forests. It is reported to be rare in Bangladesh (Rashid and Khan 2000). As per IUCN 2008 Red List, it is a vulnerable species. Also, it is included in Appendix I of CITES; Schedule 1 of the Indian Wildlife (Protection) Act, 1972; and Schedule III of Bangladesh Wildlife (Protection) Act, 1974.

Threats to the species include destruction of forests along the plains of the Ganges and Brahmaputra rivers, exploitation by Chakma tribesmen of Bangladesh and also by aborigines of Northeastern India. Subsistence utilization was reported from Assam and Bihar (Choudhury and Bhupathy 1993) and Dudhwa National Park in Uttar Pradesh in North India (Javed and Hanfee 1995).

4. Ganges Soft-shelled Turtle (*Nilssononia gangetica*) (*Syn. Aspideretes gangeticus*): It lives in the Ganges, Indus, and Mahanadi river systems in Pakistan, northern India, Bangladesh, and southern Nepal. This large soft-shell turtle inhabits deep rivers, streams, and large canals, lakes and ponds with mud and sand bottoms. Immature turtles have dark eyespots on the carapace which are indistinct or absent in adults. Major threat to this species is trade in East Asian markets at volumes of 30–40 tons/week. It is listed in CITES Appendix 1 (IUCN 2000), and in Schedule 1 of Indian Wildlife (Protection) Act, 1972.

5. Peacock Soft-shelled Turtle/ Indian Peacock Soft-shell Turtle (*Nilssononia hurum*): It is found in Nepal, India, Bangladesh and Pakistan. It is listed on the IUCN Red List as a "Vulnerable" species. In India it is found in Assam, Bihar, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, West Bengal. It is a relatively abundant large riverine species found in rivers and reservoirs. The species is primarily nocturnal and omnivorous.

The species is heavily exploited for its meat and calipee (the outer cartilaginous rim of the shell) throughout the northern and eastern India and Bangladesh. The calipee is in high demand in Southeast Asian markets as it is used in Traditional Chinese Medicine (Das et al. 2010). Based on market surveys in early 1980s, Moll (1983) found the species to be the third most commonly exploited turtle in eastern India, after *Lissemys punctata* and *N. gangetica*.

Threats in the River Ganges to the species are those generic for all large river turtles including reduction in fish stock, as a result of overfishing, pollution, increase in river traffic, and sand-mining, among others (Rao 2001). The species is most heavily exploited in Bangladesh to export to China (Das 1990); and in Pakistan for export to China both as meat and calipee (Noureen et al. 2008).

The species is included as “Vulnerable” in the IUCN Red List 2010; in Appendix I of CITES; Schedule I of the Indian Wildlife (Protection) Act, 1972; and in Schedule III of the Bangladesh Wildlife (Preservation) Act 1974.

6. Spotted Northern Indian Flapshell Turtle (*Lissemys punctata andersoni*): This subspecies is the most common species (Das 1991) in Bangladesh, northern India (Assam, Bihar, Haryana, Jammu, Madhya Pradesh, Meghalaya, Rajasthan, Sikkim, Uttar Pradesh, West Bengal), Myanmar, Nepal, and Pakistan (Bhupathy et al. 2014).

Lissemys punctata occurs in a variety of aquatic habitats, ranging from rivers and streams to reservoirs, marshes, ponds, lakes, and even salt marshes, rice fields, gutters, and canals in metropolitan areas (Hossain et al. 2008). The species is an opportunistic omnivore. Food items include adult frogs, tadpoles, fish, crustaceans, molluscs, earthworms, insects, carrion, and water plants (Schleich and Kästle 2002).

Lissemys punctata and its eggs are rather heavily exploited for food. Some 50–70 thousand are sold each year (early 1980s) in the Howrah Market near Kolkata (Das 1991; Whitaker 1997). Choudhury et al. (2000) noted that habitat loss was not a major concern. The species is protected under the Indian Wildlife (Protection) Act, Schedule I of 1972, and the Bangladesh Wildlife Preservation (Amendment) Act (BWPA), Schedule II of 2012.

Education programmes should be implemented to inform local populations and fishermen of the usefulness of these turtles in consuming carrion and their negligible effect as predators on active healthy fish (most fish-eating seems to involve dead or dying fish and carrion) (Bhupathy et al. 2014).

7. Red-crowned Roofed Turtle (*Batagur kachuga*): This species is restricted to the fast flowing rivers of northern India and Bangladesh in Ganges Basin. The diet of Red-crowned Roofed Turtles consists entirely of water plants. Basking takes place on sandbanks, rocks and logs. It is a comparatively rare turtle, little is known of its natural history. It is occasionally exploited for its flesh. These turtles are probably the most threatened freshwater turtles in India. This species is protected under Schedule I of Indian Wildlife (Protection) Act, 1972.

8. Spotted Black Terrapin (*Geoclemys hamiltonii*): It is a medium-sized (straight carapace length to 40.5 cm) freshwater turtle from lentic and lotic water bodies of the northern and Northeastern Indian subcontinent. The species is primarily carnivorous, feeding on snails and insect larvae, but vegetative material has been found in some digestive tracts. Two clutches of 18–30 eggs are produced annually, eggs measuring ca. 51 x 21 millimetres. Drainage of standing water bodies for agriculture and urbanisation and capture for food and pet markets are factors suspected to threaten wild populations. The species has been reported to be rapidly declining in Bangladesh, but populations in a few protected areas in India are apparently relatively abundant. It is included under Appendix I of CITES (Das and Bhupathy 2010).

9. Indian Narrow-headed Soft-shell Turtle (*Chitra indica*): It is widely spread in South Asia in the Ganges-Padma, Jamuna, Meghna, Brahmaputra, Indus, Godavari, Coleroon and Mahanadi in India, Bangladesh, Nepal and Pakistan (Das and Singh 2009). Choudhury (1990) reported one caught from River Lohit in Upper Brahmaputra and Datta (1997) from Dhubri District in Lower Assam. In the early part of twentieth century it was reported from Jalpaiguri District of North Bengal (Inglish et al. 1920). It is not available in abundance. Its optimal habitat is moderate to large rivers with low turbidity and sandy bottom.

Slow-flowing small rivers in the Terai (foothill plains of the Himalayas) serve as marginal habitats for this species. We encountered a group of turtle poachers poaching this species in the River Sarda (River Mahakali in Nepal) near Palya in Terai region in the north-west part of Uttar Pradesh in India in March 1994. The river had a very slow-flow, about 1.5-2 metre deep with sandy bottom, and highly transparent water during the season.



Chitra indica (Photo by Gopal Sharma)

Although the meat of this species has low preference but it is exported to China where its calipee, the fibro-cartilaginous leathery outer margin of the shell, is in high demand for traditional medicine. Poachers after boiling and drying export to China via Nepal or Bangladesh. In Bangladesh there is much demand for meat in local markets (Das and Singh 2009).

The trade in this species needs to be more carefully monitored and controlled. The species is listed as Endangered on the IUCN Red List and Schedule II of the Indian Wildlife (Protection) Act, 1972.

RECOMMENDATIONS

Following measures are suggested for conservation of non-avian higher vertebrates in the Ganges-Brahmaputra-Meghna River Basin in the Indian subcontinent:

1. The Indian Wildlife (Protection) Act, 1972 and the Bangladesh Wildlife (Preservation) Act, 1974 must be enforced strictly to combat illegal exploitation and trade of the protected species. .
2. Poaching of dolphin, otter, gharial and turtles must be banned effectively.
3. Adequate water flow and water quality should be maintained in the entire distribution range for suitable habitats. This will facilitate assimilation of pollutants also by the rivers.
4. There should be ecosystem approach for the conservation and management of rivers and associated wetlands in the GBM basin.



Turtle poachers in the River Sarda in March 1994. (Photo by Gopal Sharma)

5. Toxic chemicals including heavy metals, organochlorine, butyltin have been reported from the tissues of the dolphin and other animals. There is a serious need to prevent such toxic chemicals getting discharged into the river systems.
6. Scientific information must be collected and

updated to address the ecological or otherwise threats to all the higher vertebrate groups and initiate conservation and management actions accordingly.

7. Actions are required to ensure alternative livelihoods for the river-dependent community, especially fishers.
8. Intensive and extensive education and awareness campaign to spread the knowledge about importance and role of these species in functioning of the river ecosystem should be undertaken for various strata of the society in the basin area.

ACKNOWLEDGEMENT

Financial assistance provided by the Ministry of Environment and Forests, Government of India for Dolphin Surveys in the Ganges Basin is duly acknowledged.

The authors are thankful to the IUCN India Country Office, New Delhi for giving opportunity to present this paper in the River Symposium at Patna.

Thanks are also due to the reviewers for their valuable comments which helped in improving the manuscript.

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Monitoring the Mortality of Freshwater Cetaceans in the Sundarbans, Bangladesh: Progress, Challenges, and Potential

Rubaiyat Mowgli Mansur, Zahangir Alom, Brian D. Smith and Farhana Akhtar

Wildlife Conservation Society, Bangladesh Cetacean Diversity Project,
House No. 89 (2nd Floor), Road No. 02, Sonadanga R/A (1st phase),
Khulna - 9000, Bangladesh
E-mail: rmansur@wcs.org

ABSTRACT

The Wildlife Conservation Society's Bangladesh Cetacean Diversity Project established a mortality monitoring network among university students, Forest Department staff, NGO partners, fishing communities and local tourism boat operators in the Sundarbans. From February 2007 to December 2013, 40 Ganges River dolphins (*Platanista gangetica gangetica*) and 12 Irrawaddy dolphins (*Orcaella brevirostris*) mortalities were documented from Sundarbans.

Twenty six Ganges River dolphin carcasses were examined and biological samples collected and the causes of death were identified as entanglement in fishing gears for 13 of them, and vessel collision for two, direct killing by villagers for two, with the cause of death unknown for the remaining individuals. Of the dolphins documented as entangled in fishing gear, 10 were in gill nets, two in long lines, and one in a set bag net.

Five Ganges River dolphins were also released alive after entanglement by fishermen. A key challenge is to expand the mortality monitoring network to remote areas of the western Sundarbans and to quantify bycatch rates so that these can be incorporated into population viability analyses for both Ganges River and Irrawaddy dolphins.

Key words: Mortality monitoring, freshwater cetaceans, sundarbans, Ganges river dolphin

INTRODUCTION

Mortality in fishing gear, especially gill nets, is considered among the most severe threats to the “endangered” Ganges River dolphin (*Platanista gangetica gangetica*). This dolphin ranges almost throughout the Ganges-Brahmaputra-Meghna river system of Nepal, India, and Bangladesh, and in the comparatively much smaller Karnaphuli-Sangu river system of southern Bangladesh (Smith et al. 2004). However, information on actual interactions with fisheries is almost entirely lacking in the literature, and information on the perceived threat is based

almost exclusively on anecdotal accounts and the observed preference of the species for inhabiting counter-current pools below confluences and meanders where gillnets are most densely deployed (Smith 1993; Smith et al. 1998).

“Vulnerable” Irrawaddy dolphins (*Orcaella brevirostris*) are caught accidentally in fishing nets in almost all areas where they have been studied (Smith et al. 2007; Reeves et al. 2008), including in drift gill nets targeting elasmobranchs in the coastal waters of Bangladesh (Smith et al. 2008) and

bottom-set gill nets targeting crabs in Malampaya Sound, Philippines (Smith et al. 2004). Similar to Ganges River dolphins, when in freshwater or estuarine systems Irrawaddy dolphins also primarily inhabit counter-current pools below confluences and meanders which is also where gill nets are most densely deployed (Smith et al. 2009).

MATERIALS AND METHODS

A dolphin mortality reporting network was established among fishing communities, boatmen, tourism operators, and forest department (FD) guard posts. Posters and stickers with a dedicated phone number for reporting dead or by caught dolphins (Dolphin Hotline) were distributed during activities and community outreach conducted by partner NGOs. When an entanglement was reported we fielded a mortality response team of trained boat operators, university students and FD staff.

A protocol was developed with instructions on examining cetacean carcasses and collecting biological samples. For all cetacean carcasses or body parts, information was collected on the:

1. Location, date and time
2. Species description and identification
3. Photographs of the carcass
4. Condition of the carcass
5. Evidence of the cause of death according to net, hook or propeller marks, contusions, lacerations, or internal haemorrhaging
6. Standard external measurements and tooth counts
7. Determination of sex, and
8. Lactating status of females

The response team collected biological samples from each carcass (Figure 1). A high priority was to obtain a small piece of skin and store it in a numbered vial of preservation fluid (80 per cent ethanol) for genetic analysis.



Figure 1: Members of WCS Bangladesh Mortality Monitoring Team collecting biological sample from an Irrawaddy dolphin carcass

Additional biological samples were also collected. These include: blubber for contaminant analysis (stored frozen), muscle tissue for isotope analysis (stored frozen or dried salted), skull for taxonomic analysis and education (stored dry), and teeth for age determination and isotope analysis (stored dry). All samples were collected with sterilised instruments provided in a cetacean carcass sampling kit.

RESULTS

From February 2007 to December 2013, 90 cetacean mortalities were documented throughout Bangladesh: 33 from newspaper reports, 50 from our dolphin hotline, and seven from direct observations during dedicated fieldwork on cetaceans in the Sundarbans and coastal waters including surveys and ecological investigations.

These included 63 Ganges River dolphins, 16 Irrawaddy dolphins, five finless porpoises (*Neophocaena phocaenoides*), and two Indo-Pacific humpbacked dolphins (*Sousa chinensis*), one Sperm whale (*Physeter macrocephalus*), one False-killer whale (*Pseudorca crassidens*) and two unidentified cetaceans.

Fifty five of these (40 Ganges River dolphins, 12 Irrawaddy dolphins and three finless porpoises) were from Sundarbans and of these, 44 were reported via our dolphin mortality hotline, six from newspaper reports and five from direct observation during field visits (Table 1).

Table 1: Number of Ganges River and Irrawaddy dolphin and Finless Porpoise carcasses documented in the Sundarbans during February 2007 to December 2013 according to direct observations, reports received over our cetacean mortality hotline number and through newspaper reports

How the information was collected	Ganges River dolphin	Irrawaddy dolphin	finless porpoise
Observation	0	3	2
Hotline	35	8	1
Newspaper	5	1	0

Of the Irrawaddy dolphins, three were male sub adults/ adults, two were female including one calf, and the sex was unknown for seven sub adults/ adults. For Ganges River dolphins, seven were male including two calves, 10 were female including one calf, and the sex was unknown for the remaining 23 including two calves. For Finless Porpoises, two were adult male, and the sex was unknown for the remaining one adult individual.

Twenty six Ganges River dolphin carcasses were examined and biological samples collected (e.g. skin, blubber, muscle, liver, teeth, skull and stomach). Based on visible marks on the body and direct reports from fishermen and respondents, the cause of death was identified as entanglement in fishing gear for 13 individuals, vessel collision for two, direct killing for unknown reasons by villagers for two, and the cause of death was unknown for the remaining nine individuals.

Of the dolphins documented as entangled in fishing gear, 10 were in gill nets, one was in a set bag net (an anchored net with a wide mouth which narrows to a cod end) and two were in a long line. Besides these, eight Irrawaddy dolphin carcasses were also examined and biological samples collected.

Similar to Ganges River dolphins, the cause of death was identified as entanglement in fishing gear for five individuals and unknown for the remaining individuals. Of the dolphins documented as entangled in fishing gear, two were in gill nets, one was in a set bag net and two were in unknown gears (Figure 2).

The 10 Ganges River and two Irrawaddy dolphin entanglements in gill nets demonstrate a critical need to reduce or eliminate these nets from priority dolphin habitat. The mortalities from vessel collision are the first recorded in the Sundarbans and demonstrate the value of information we have been collecting on vessel traffic in the wildlife sanctuaries.

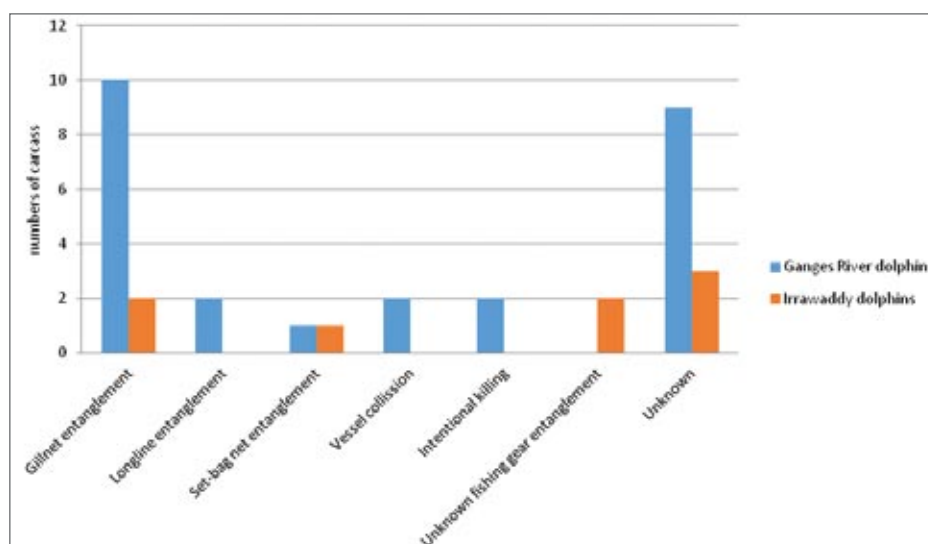


Figure 2: Number of Ganges River and Irrawaddy dolphin mortalities in the Sundarbans and the cause of death based on examination of carcasses and interview with local people

DISCUSSION

Gill nets and, to a lesser extent, set bag nets and long lines are entangling and killing dolphins at rates that are probably unsustainable. The need to reduce or eliminate these fishing gears from priority dolphin habitat (areas where dolphins congregate due to river morphology and abundance of prey) was demonstrated by the entanglements documented by our mortality monitoring network.

The eastern Sundarbans of Bangladesh where our mortality monitoring network is focused and the three wildlife sanctuaries that were recently established for the protection of freshwater dolphins, support a significant portion of the population of Ganges River dolphins.

At this location, their numbers are sufficiently large that early conservation interventions can be effective in preventing their extinction. The eastern Sundarbans supports much lower numbers of Irrawaddy dolphins. This means that in order to conserve this species, protective efforts and mortality monitoring should be extended to the western side of the mangrove forest where Irrawaddy dolphins occur in higher numbers due to more favourable salinity conditions (Smith et al. 2006). Since the beginning of 2011, there has been a dramatic increase in the number of commercial cargo vessels (5.5 vessels day⁻¹ in

2010 and 22.3 vessels day⁻¹ during 2011) transiting through priority habitat for freshwater dolphins in the eastern Sundarbans of Bangladesh including through the three new wildlife sanctuaries, covering 32 linear kilometres (10.7 square kilometres), established for their protection.

Although in 2011, the Prime Minister of Bangladesh ordered a ban on oil tankers and other cargo vessels transiting through sensitive areas of the Sundarbans, our study on vessel traffic shows that the ban has not been effective and there is a risk of vessel collision with resident cetaceans. This was cited as one of the major factors contributing to the recent extinction of the Yangtze River dolphin or Baiji (*Lipotes vexillifer*) (Chen and Hua 1989; Zhang et al. 2003). Vessel collision was also documented for the first time for Ganges River dolphins in the Sundarbans by our mortality monitoring network.

The best approach for protecting the dolphins and the ecological integrity of the waterways in the wildlife sanctuaries for freshwater dolphins would be to enforce the existing ban on these vessels transiting through them. However, if this is not possible, a “no wake” speed limit (e.g., less than 8 km hr⁻¹) and no dumping regulation should be strictly monitored and enforced.

CONCLUSION

Next steps for the mortality monitoring network are to expand it to remote areas of the western Sundarbans of Bangladesh, where Irrawaddy dolphins occur more frequently (Smith et al. 2006) and to quantify bycatch rates for incorporating into population viability analyses along with rigorous estimates of abundance estimates for both Ganges River and Irrawaddy dolphins.

A high priority is also to analyse tissue samples to investigate population structure and genetic diversity, stomach samples to further investigate prey, blubber and liver samples to investigate contaminants, muscle samples to investigate stable isotopes/prey, and skulls to compare morphometrics across populations/ subspecies.

ACKNOWLEDGEMENT

This research would not have been possible without the dedicated effort of our student volunteers, field assistants, and local villagers.

We appreciate the help of Rajib Chandra Bhowmick, Alom Sheikh and Md. Sohag for their work on data collection.

Alex Aguilar provided valuable input in preparing the protocol.

Finally, we thank the Forest Department of the Government of the People's Republic of Bangladesh for their great support.

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Trans-boundary Sanctuary between Bangladesh and India for Gharial (*Gavialis gangeticus*) Conservation

S. M. A. Rashid, Anisuzzaman Khan and A. B. M. Sarowar Alam

Centre for Advanced Research in Natural Resources & Management (CARINAM),
House: 545, Level: 6, Road: 11, Baitul Aman Housing Society,
Adabor, Dhaka -1207, Bangladesh
E-mail: carinam.bangladesh@gmail.com

ABSTRACT

Surveys conducted to assess the status and to identify suitable habitats for gharials (*Gavialis gangeticus*) in Bangladesh revealed that suitable habitats still exist in some secluded areas of the River Padma (Ganges). One such area is Guhomabuna (N24°22'.365", E88°27'.677") in Rajshahi district adjoining the Indian border where adult gharials and hatchlings have frequently been sighted.

This area shares the no-man's-land between Bangladesh and India and is relatively peaceful with low level threats. High sandy banks, deep pools serve as the nesting habitat and refuge for the gharials. The population of gharials in Bangladesh has reduced significantly; gharials once used to nest at Char Khidirpur, downstream of Guhomabuna. Upstream the Farakka Barrage hinders movement of the gharials so alternately the gharials might have chosen the tributaries/ distributaries of the Padma for their movement. Joint surveys by Bangladeshi and Indian biologists can shed more light and the area can be proposed for the creation of a trans-boundary gharial sanctuary setting an example of transboundary cooperation.

INTRODUCTION

Bangladesh and India share geo-morphological and physical characteristics as well as many of the diverse ecosystems and species that we commonly term as "biodiversity". Apart from these, both the countries also share a common anthropological ancestry and socio-political heritage. These two countries are also linked with the natural phenomenon (such as flood, cyclone, earthquake, etc.) and the natural water flow.

As a result anthropological activities in the upstream do have a consequence on the livelihoods and biodiversity of the lower riparian country that is Bangladesh. There are many trans-boundary rivers and ecological issues between the neighbouring countries that need to be resolved to conserve the biodiversity on a regional basis.

It is, therefore, in the interest of all countries sharing the international rivers to work together in directions that will enable lower riparian countries to withstand the environmental management, biodiversity conservation and economic challenges.

Bangladesh's topography is formed by three of the largest river systems (the Ganges-Brahmaputra-Meghna) in the world. It occupies the greater part of the Bengal Basin which was slowly built up by alluvial deposits carried from the adjoining mountains of the Himalayas by the Ganges-Brahmaputra river system. It is a riverine country with about 700 rivers including tributaries (Khan 1990).

The Ganges-Brahmaputra-Meghna (GBM) river systems drain a total area of about 1.72 million square kilometres in India, China, Nepal, Bhutan

and Bangladesh and henceforth, the name Ganges-Brahmaputra-Meghna River Basin (Figure 1). A lower riparian located at the lower most reaches of the three large rivers, Bangladesh itself makes up only seven to eight per cent of the watershed (Ahmad et al. 2001).



Figure 1: The Ganges-Brahmaputra-Meghna (GBM) River Basin. Location of Farakka barrage is also shown. (Source: Mirza 2004)

A total of 57 major rivers of Bangladesh have entered the country, of which 54 rivers are from India and three rivers from Myanmar (Afroz and Rahman 2013). These 57 rivers have many tributaries and distributaries which contribute in forming almost 230 rivers in Bangladesh. These rivers receive water from the Himalayan glaciers and upstream rainfalls falling on both the hills and plain lands.

Water sharing among the riparian countries is one of the major ecological and socio-political issue on which the livelihoods of hundreds of thousands of people living in the lower riparian Bangladesh and natural resources including biodiversity depend. Bangladesh is always looking forward to amicable solutions based on mutual discussions with the neighbouring countries on the sharing of water of the international rivers.

Rivers are the lifeline of the people of Bangladesh as well as river biodiversity on which livelihoods of millions of Bangladeshis and survival of river biodiversity depend. However, while so much more could have been done, achievements in terms of sharing, development, and management of water resources of these rivers as well as sharing and exchange of information and data through mutual

cooperation have not been encouraging thus far (Biswas 2008).

The recent plans of linking and construction of Tipaimukh dam, without consensus among riparian countries, have generated considerable concerns in Bangladesh and also widely in India. It is important to recognise that water resources must be developed and managed in a rational, efficient and equitable way, so that it can act as the engine to promote socio-economic development, shaping the future of millions of people living in this region (Biswas and Uitto 2001) as well as support the biodiversity and the ecosystem services.

Gharial (*Gavialis gangeticus*) was found in the rivers Padma (= Ganges) and the Jamuna (= Brahmaputra) and some of the tributaries and distributaries in Bangladesh (Figure 2). It nested regularly in Bangladesh till the late 1980s. Three such sites are known - Char Khidirpur in the Padma River; Pechakhola in Bera, Pabna district and Baladuba Char, Kurigram district in the Jamuna River.

With the shifting of the river and increased and erratic water flow in the River Jamuna, the Pechakhola nesting site existed no more after the late 1970s. Nesting occurred in Char Khidirpur along the River Padma till the late 1980s (Khan 1987, Rashid & Khan 1986, Rashid et al. 1986) and mid-1990s in Baladuba Char, Kurigram in the River Jamuna (Nurjahan et al. 2003) (Figure 2).

STUDY AREA

The study area comprised the entry point of the River Brahmaputra (= Jamuna) at Narayanpur in Kurigram district, Bangladesh. The River Ganges (=Padma) first entered in Bangladesh at Thutpara under Monakasha Union of Shibganj upazilla where it merges with the River Mohananda and re-enters again at Hakimpur in Chapai Nawabganj District in Bangladesh. Section of the River Padma from Hakimpur to the confluence of the Padma and Jamuna rivers at Aricha and downwards up to Mawa was part of the study area (Figure 3).



Figure 2: Figure showing past (in red) and potential present sites (in blue) of Gharial distribution in Bangladesh. Nesting sites



Figure 3: The area bordered within red line comprised the study area and was surveyed for gharials

The two rivers, Padma and Jamuna, differ from each other in terms of their morphology and hydrology. Uncertainty prevails on the availability of water in the River Padma. Abstraction of water upstream and Farakka Barrage in India affects the water depth in the river thus affecting the habitat and abundance of aquatic fauna.

On the other hand, marked changes are seen in the morphological behavior of the River Jamuna due to its braided nature, channel shifting, char (sand bar) formation, etc. The braided nature of the River Jamuna offered some sanctuary to the aquatic fauna and the chars normally remained dry and went under water only in high flood.

The River Padma had fewer chars. At one time, the distributaries were sufficiently deep to function efficiently, but are now badly silted up (for example, the Gorai off-take of the Ganges and the Old Brahmaputra and the Dhaleswari off-take of the Brahmaputra) due to marked reduced water flow, which has favoured sediment accumulation reducing the depth of the river bed and restricting deep water pools in some sections restricting the larger aquatic animals such as gharial and dolphins in their movement.

The water in the rivers is the lifeline of all activities for both the humans and the aquatic life. With reduced water levels, the whole landscape changes and huge sand bars (locally known as *chars*) emerge mostly due to the deposition of sand washed down from upstream as well as from river bank erosion during the monsoon.

It is these chars and the sandy river banks that provide the nesting and basking habitat for the gharials. Moreover, the exposed river banks and chars are also cultivated during the dry season of the year thus conflicting with the gharial habitat.

Further with less water flow and fragmentation of the river habitat fishing activities increase in magnitude in the deeper sections causing disturbances to the

aquatic megafauna such as gharials, freshwater turtles, otters and dolphins.

METHODOLOGY

No detailed surveys have ever been conducted to ascertain the population of the surviving gharials in Bangladesh. Prior to conducting the present survey information from some sporadic reconnaissance surveys at some specific locations in the 1980s and detailed review of the existing and available literature was done to get the knowledge of the past distribution and nesting sites of the gharial (Faizuddin 1985; Khan 1982; Rashid and Khan 1986; Whitaker and Daniel 1978; Whitaker and Basu 1983; and Sarker et al. 2003) was carried out.

Further, reports of sighting of gharials and entangling in fishing nets have also appeared in the national dailies from areas not previously recorded. These and old newspaper clippings were reviewed. Information through personal communication with the old fishermen, senior citizens and Forest Department staff were gathered on the past and present distribution. The survey was conducted from November 2009 to December 2011. A pre-designed questionnaire was developed, tested and used in the field to gather information from the local people on the occurrence and other aspects of gharial biology.

An awareness pamphlet in local Bangla language was designed and printed for distribution in the field and to disseminate the gharial conservation message. Pictures of gharials and other aquatic animals likely to be found in the project area were printed for field-use to enable the local people identify/ distinguish gharials and other animals found in the area.

A field activity plan was developed to systematically cover the project area and to keep track of the areas surveyed. Networking with various local educational institutions, non-governmental organisations and representatives from the print and electronic media was also an important activity for information gathering and awareness about the gharial.

Many of the areas were close to the Indian border; so, for safety and security reasons the Border Guards Bangladesh (BGB) and the Bangladesh Police were also informed about our survey and field plan.

The fishermen, local community members, government officials were interviewed for any sightings or other information regarding gharials. This gave us an idea of the time frame within which the gharials were sighted and localities where the probability of sighting gharials was greater.

Information on the habitats of the potential areas, on-going activities (such as sand mining, fishing, water extraction for irrigation, etc.), and threats were also noted. In addition, information on other aquatic and water-dependent animals such as Gangetic Dolphins, Smooth-Coated Otters, Freshwater Turtles, Migratory and Resident Waterfowl were also recorded.

Land transportation was used to reach the riverine ports (locally known as *ferry* or *kheya ghats*). Local mechanised boats were hired to survey the rivers for observation and interview the fishermen (of different ages) fishing in those areas.

The survey started early morning (usually 0700 hours) in mechanised country boats cruising at an average speed 10 kilometres per hour, usually 20-30 metres from the bank looking for any direct sighting or spoors of gharial on the sandy river bank.

Additionally, local public representatives, community members, villagers living close to the rivers or were dependent on the rivers for their livelihood were also interviewed for any information on the gharials.

Inquiries were also made at the village markets where there were assemblages of people from different walks of life. Overnight halts were made for easy access to remote areas. The areas where the habitat was potentially good for the likeliness to support gharials or where there were recent sightings reported were intensively surveyed for any

trails/ spoors. Night surveys were also conducted in some likely areas.

Data collected were coded and analysed to identify important areas for gharials. Some criteria used in the selection of habitats considered to be worth intensive surveys for the gharials included: 1) Mixed-high sandy banks and chars 2) Areas (enclaves) with less water flow, more or less calm and clean waters 3) Less disturbance from human activities such as fishing, transportation 4) Availability of water round the year and 5) Availability of prey, mainly fish.

RESULTS

Based on the above criteria and using a matrix (Table 1) the following areas were found to be potential habitats for gharial occurrence (Figure 3) (CARINAM 2010):

1. Godagari-Baligram-Hakimpur (Chapai Nawabganj) (Padma river) (fish sanctuary exist in this section) (N24°27'.636", E88°13'.422" to N24°25'.149", E88°20'.745"),
2. Asharia-Doho (Rajshahi) (Padma river) (N24°22'.789", E88°22'.988") ,
3. Gohomabona (Rajshahi) (Padma river) (N24°22'.365", E88°27'.677"),
4. Char Yusufpur-Khidirpur (Rajshahi) (Padma river) (N24°20'.274", E88°35'.140"),
5. Charchat (Rajshahi)(Padma river) (N24°15'.379", E88°45'.364"),
6. Faishar Char (Kurigram) (Jamuna river) (N25°56'.125", E89°47'.644"),
7. CharKoroiboishal/CharLalsamad(Gaibandha) (Jamuna river) (N25°28'.137", E89°41'.056"), and
8. Onnayapur (Manikganj) (Jamuna river)

Among the list of potential sites, Gohomabona came out as the priority area that fulfilled many of the ecological requirements for the gharials to breed, take refuge and survive and that the area needed some protection of any kind for the future of the gharials.

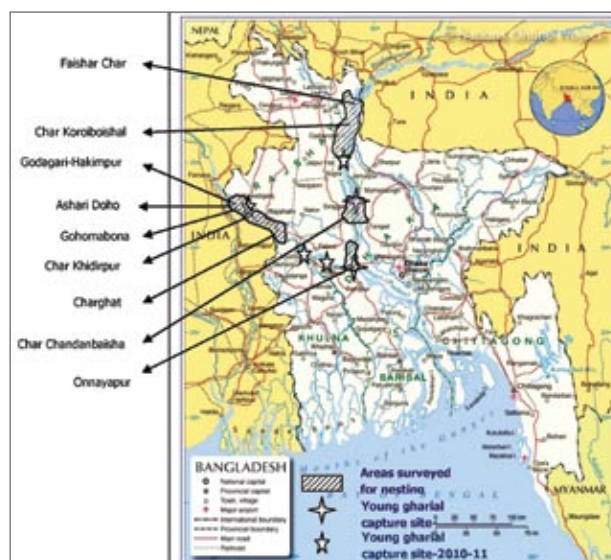


Figure 3: Important habitats for gharial identified during the survey

During the interviews with the local community members and fishermen it was evident that many of the cases of gharial sighting and captures go unrecorded and in some cases the local media publish the news in the local newspapers, which do not get covered by the national newspapers and the incident gets lost. Table 2 provides some information on the numbers of gharials captured during the study period.

DISCUSSION

During the survey it was evident from the interviews that gharials have been using the tributaries and distributaries of the River Padma for movement between India and Bangladesh. One adult female was observed at Godagari area which later moved upstream into the Indian Territory (Saurav 2010, *pers. comm.*). Having noticed it, the idea of proposing a trans-boundary sanctuary between Bangladesh and India cropped up since wildlife know no borders.

Further no information exist on the movement of gharials between the two neighboring countries sharing an international river which further inspired and motivated to propose a trans-boundary sanctuary that satisfied most of the ecological requirements needed by the gharials to survive.

Table 1: Matrix for selection of suitable habitat/ area for gharial sanctuary. (Ranking is done between -5 and +5. A minus sign indicates unfavorable while positive sign denotes a favourable condition. Only the +ve scores were added)

Location	Steep Sand Banks	Deep Water Pools	Transport	Sand Mining	Threats	Other Human Disturbance	Water Availability (Dry Season)	TOTAL
					Fishing Intensity			
Godagari-Hakimpur (Padma River)	+2	+2	-3	-1	-3	-3	+5	+9
Asharia Doho (Padma River)	0	+2	-1	-1	-3	-1	+2	+4
Gohomabona (Padma River)	+5	+5	0	0	-1	+3	+5	+17
Char Yousufpur-Khidirpur (Padma River)	+3	0	-2	-3	-2	-2	+2	+5
Charghat (Padma River)	+1	0	-4	-3	-3	-2	+3	+4
Faishar Char (Jamuna River)	0	0	-4	-2	-2	-1	+1	+1
Char Koroiboishal/Lalsamad (Jamuna River)	0	+2	-4	-2	-2	-3	+2	+4
Onnayapur (Padma River)	+2	+3	-5	-4	-4	-3	+3	+8

Table 2: Gharials accidentally caught by fishermen in the fishing nets during the survey period

Year	Gharials Captured	Remarks
2009 -10	9	1 brought to Dhaka Zoo, later died; 8 released on site, 3 in the Jamuna River and 6 in the Padma River.
2010 - 11	7	1 brought to Rajshahi Zoo, later died; 6 released on site. 2 in the Jamuna River and 5 in the Padma River.
2011 - 12	5	2 brought to Bhawal National Park (managed by CARINAM and Forest Department), 3 released on site. 2 in the Jamuna River and 3 in the Padma River.

Based on the information from the local people possible routes were chalked out during this survey (Figure 4). The importance and the need for establishing a sanctuary was never felt so seriously than now as the gharial is losing its natural distribution areas and is in dire straits mostly due to impacts caused by anthropological activities particularly reduced water flow due to the Farakka Barrage in Bangladesh. Considering this, among these habitats studied, Gohomabona seemed to be the potential site that may be proposed as a protected area for gharials in Bangladesh as well as for trans-boundary sanctuary

between Bangladesh and India. Gharials had been nesting regularly at Char Khidirpur, Rajshahi District (Khan 1982, 1987, Rashid and Khan 1986) close to the Indian border till the late 1980s. Nesting records were also narrated from Pechakhola, Bera, Pabna District in the River Jamuna during the 1970s (Mirza Shahpar Jalil 2010, pers. comm.).

The other strong consideration was that gharials were no longer nesting at Char Khidirpur due to habitat destruction by abstraction and diversion of water upstream in India, erosion of the sand banks

due to excessive flow of water during monsoon when the Farakka Barrage gates are opened and other reasons.

The recent rediscovery of gharial in the Hoogly and Bhagirathi rivers in India (Ghosh and Merrill 2010) may be of some evidence worth verifying since the gharials that were not able to migrate to Bangladesh may have moved downstream in search of new habitats — Hoogly and Bhagirathi rivers, in this case.

One of the other major advantages for Gohomabona is that it is located close to the international border between the two countries and most of the ecologically potential areas lie within the no-man's land. This area already enjoys protection from many anthropogenic activities including transportation, fishing, sand mining and others. Moreover, gharial hatchlings are observed almost regularly by the villagers in this area suggesting that gharials may be nesting somewhere nearby.

Gharials may have been moving between the two countries — Bangladesh and India — using the routes identified during this survey (Figure 4) but the importance and the need for establishing a sanctuary was never seriously felt than now as the gharial is losing its natural distribution areas and is in dire straits mostly due to impacts caused by anthropological activities particularly reduced water flow due to the Farakka Barrage in Bangladesh.

Interviews with the local people revealed that gharials were rarely sighted and the numbers have declined significantly. Based on the gharial sighting reports from the elderly citizens within the study area it was estimated that one to two pairs may still inhabit the Bangladeshi rivers.

Many researchers doubt the occurrence of gharials in Bangladesh and the presence of gharials in Bangladesh is questioned (Stevenson and Whitaker 2010). However, based on the evidences gathered during the present survey it may be said that gharials



Figure 4: Proposed potential site - Guhomabona (dashed red) for transboundary gharial sanctuary. Red arrows show possible movement routes of the gharials between Bangladesh and India

may not be nesting but movement between the two countries do occur.

By having a trans-boundary sanctuary and with proper management and monitoring it may be possible to reestablish breeding population of gharials in Bangladesh as there are still some potential habitats for gharials.

CONCLUSION

River biodiversity and the natural value of river ecosystems is an increasing area of interest for management and research. There is an unprecedented need to preserve and restore aquatic and riparian biological diversity before extinction eliminates the opportunity (Kauffman et al. 1997).

This is more urgent need in the context of international rivers like the Ganges on which millions of people as well as river biodiversity depend. The relationship between conservation and initiatives to re-establish diminishing populations of river biodiversity may be complementing each other.

Establishing a trans-boundary sanctuary may help revive the gharial population in Bangladesh and may set a unique example of regional cooperation for biodiversity conservation.

ACKNOWLEDGEMENT

The survey was made possible through a Mohammed bin Zayed Species Conservation Fund (MBZ) grant awarded to CARINAM. We are grateful to MBZ.

The Forest Department issued the necessary research permit which gave us legality to conduct the survey.

We thank Mr. Ishtiak Uddin Ahmed, ex-Chief Conservator of Forest and Dr. Tapan Kumar Dey, Conservator of Forest (Wildlife & Nature Conservation Circle), Mr. Tausiful Bari, Divisional Forest Officer, Bogra, Mr. Abul Bashar, Divisional Forest Officer, Rajshahi for their whole hearted support.

We are also indebted to the officials of the Dhaka and Rajshahi Zoos for allowing us to collect information/ data on the gharials that were brought to the zoos after capture.

The local community members, fishermen willingly and spontaneously provided us with information, participated in discussions, and contacted us whenever a gharial was captured. We thank them all.

Last but not the least we thank the anonymous reviewers for their valuable comments.

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Current Status of Ganges River Dolphin (*Platanista gangetica gangetica*) in the Rivers of Uttar Pradesh, India

Sandeep Kumar Behera¹, Hari Singh², Viveksheel Sagar³ and Rupak De⁴

¹Ministry of Water Resources, River Development and Ganga Rejuvenation (NMCG),
New Delhi - 110003, India

² ARNI University Katgarh Indora, Kangra - 176401, Himachal Pradesh, India

³Society for Conservation of Nature, Etawah, Uttar Pradesh, India

⁴17- Rana Pratap Marg, Lucknow - 226001, Uttar Pradesh, India

²E-mail: hsingh7wild@gmail.com

ABSTRACT

River dolphins are unique fresh water mammals, but the species is among the highly endangered species of the world. In recent years, human activities appear to present the greatest threat to the Ganges River dolphin.

Due to the declining status of the species, a comprehensive understanding about the population status is important to design conservation measures for this species. To know the population status and threats faced by the species in the River Ganges and its tributaries, a boat survey was conducted from October 5-7, 2012 in nine rivers of Uttar Pradesh (the Ganges, Yamuna, Chambal, Girwa, Ghaghara, Ken, Betwa, Surya and Rapti) covering an approximate distance of about 2400 kilometres.

The survey was carried out by 18 different teams with 150 participants consisting of NGO's, state forest departments, environmentalists, scientists, students, local villagers and media persons. A total of 671 dolphins (best estimate) were recorded during the survey. The aim of the survey was to understand the population status and distribution of the species and to develop capacity and awareness among the local people/ NGO's and government staff in the state.

Key words: Ganges, river, dolphin, conservation, survey, tributaries, threats, conservation

INTRODUCTION

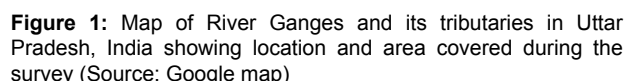
The Ganges River dolphin (*Platanista gangetica gangetica*), commonly known as "Soons" is one of the four freshwater dolphins of the world which inhabit rivers and estuaries in Asia and South America (Behera et al. 2014). The species is distributed in the Ganges, Brahmaputra, Karnaphuli-Sangu, and Meghna river systems and their tributaries, from the foothills of the Himalaya to the limits of the tidal zone in India, Bangladesh, Nepal, and probably Bhutan

(Anderson 1879; Jones 1982; Sinha et al. 2000; Smith et al. 2000b).

The Ganges River dolphin prefers to stay in deep water in and around the confluence of rivers, shares its habitat with crocodiles, freshwater turtles and wetland birds many of which are fish eaters and potential competitors with dolphins (Behera and Rao 1999). Being the main large mammal species of the river, its conservation is a high-priority issue (Smith

Abundance monitoring of dolphin populations in the River Ganges has been conducted since the early 1990s, using direct visual counts from vessels or point counts from the riverbank. WWF-India has conducted the first ever status survey of the species in the country in collaboration with network partners during 2005 (WWF-2006, unpublished).

The aim of the survey was to formulate a strategy and Action Plan for the conservation of Ganges River Dolphin and to collect baseline information of the species distribution and population status in the states of Uttar Pradesh.



River Ganges

The survey in the River Ganges was carried out between Bijnor to Varanasi (Aprox. 1200 kilometres) in Uttar Pradesh, India. Within this, a stretch of 165 kilometres from Bijnor to Narora has been declared as a protected area and reported to be rich in biodiversity such as, Ganges River Dolphin *Platanista gangetica gangetica*, Smooth-coated Otter *Lutrogale*

perspicillata, eleven species of fresh water turtles and Mugger Crocodile *Crocodylus palustris* (Behera 1995; Rao 1995; Behera and Rao 1999; Bashir et al. 2010a, 2012; Behera et al. 2013).

The river has the richest freshwater fish fauna (378 species) includes *Tor tor*, *Tor pituitora*. Beside these, more than 150 species of birds are also reported from this river stretch (Rao 1995). The banks of the entire river stretch up to Narora are sandy and muddy. During the major part of the year the climate of the area is influenced largely by the prevalence of dry air, the summer being intensely hot and the winter cold (Behera 1995; Behera et al. 2013).

A stretch of Upper Ganges between Rishikesh and Kanpur functions as an ecologically important section because of its hydrological characteristics (Behera 1995). But, due to high regulation of dams, barrages and associated irrigation canals, infrastructure development, water abstraction and pollution, present-day flow of the upper Ganges Basin has decreased by about two-eight per cent and such a reduced flow regime also impacts downstream water availability, water quality and riverine ecosystems (Salemme 2007; Bharati et al. 2011).

People are involved in different occupations such as fishing, agriculture, construction activities, nurseries, dairy farming, tanneries, chemicals, fertilisers and cotton industries, religious activities, all of which are dependent on the river and hence also have an impact on the aquatic system (Rao 1995; Behera et al. 2013).

River Yamuna

The River Yamuna, which is the largest tributary of the river Ganges, originates from the Yamunotri glacier near the Bander punch peaks (38°15'90"N, 78°12'70"E) of the lower Himalayas at an elevation of 6320m above mean sea level, in the state of Uttaranchal of northern India (CPCB 2006). In addition to Delhi, it traverses parts of the states of Himachal Pradesh, Haryana, Uttar Pradesh, Uttaranchal, Rajasthan and Madhya Pradesh. Of these, Delhi is the foremost

pollution load contributor with 26 identified industrial areas adding their load to the river. Except for the monsoon months (July-September) when the catchment area of the river receives 80 per cent of the annual rainfall, the flow conditions remain almost the same (CPCB 2006).

River Chambal

The National Chambal Sanctuary lies between 24°55' to 26°50' N and 75°34' to 79°18'E in Dholpur. It consists of the large 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 sector, extending from Jawahar Sagar Dam to Kota Barrage, and the lower sector, extending from Keshoraipatan in Rajasthan to the Chambal-Yamuna confluence in Uttar Pradesh (Sale 1982).

The present survey was conducted between Rajghat (N-26° 39'.446; E-77° 54'.241) to Pachhnada (N-26° 26'.369; E- 79°12'.778) in the lower sector covering an area of about 235 kilometres. The area lies within the semi-arid zone of north-western India at the border of Madhya Pradesh, Rajasthan and Uttar Pradesh States. The area is semi-arid and the temperature in the region varies from 20°C to 49°C during winter and summer respectively (Singh 2010). The southwest monsoon is the major source of rainfall. The mean annual rainfall over the Chambal basin was 797 millimetres (Hussain 1993). Unlike many rivers of the greater Ganges river system, the River Chambal is relatively unpolluted (Saksena et al. 2008).

River Girwa and Ghaghara

The River Ghaghara arises in Nepal, as a vast network of mountain streams in the Central Himalayas in Nepal that form the river basin of the Karnali, with a total drainage of 43,000 square kilometres. The Karnali emerges in the plains at the scenic Shivalik gorge of Chisapani, following which it bifurcates into two rivers, the Girwa and the Kauriala.

The River Mohan flowing west to east along the Indo-Nepal border joins the Kauriala, which reunites with the Girwa, about 18 km downstream of the Indo-Nepal border at Kotiyaghat to form the Ghaghara River. Several large tributaries join the Ghaghara along its course, viz. the Suheli and Sarda on the right bank and the Saryu, Kuano and Rapti on the left bank (WWF 2006 unpublished).

River Rapti

The Rapti rises south of a prominent E-W ridgeline midway between the western Dhaulagiri Himalaya and the Mahabharat Range (N 26°29.2778; E-83°67.1111) with an altitude of 3,500 metres (11,500 feet). Originating in the foot hills of Nepal, the Rapti flows to the north of Behraich District. After traversing about 130 kilometres, it enters to the northern portion of the Gonda before entering the Sant Kabir Nagar District in the north-west. The Rapti then meets the River Ghaghara.

River Sarayu

The River Sarayu situated in 27°21'0 N, 81 23' 0 E flows through the Indian state of Uttar Pradesh. The Sarayu forms at the confluence of the Karnali (Ghaghara) and Mahakali (Sharda) in Bahraich District in Uttar Pradesh. The Mahakali or Sharda forms the Indian-Nepalese border.

River Ken

The River Ken located at an altitude of 25° 55'N 80°12'E is an interstate river between Madhya Pradesh and Uttar Pradesh with a catchment area of 28,058 square kilometres, out of which 24,472 square kilometres (87.22 per cent) lies in Madhya Pradesh and the remaining 3586 square kilometres (12.78 per cent) in Uttar Pradesh. The river is the last tributary of Yamuna before it joins the Ganges. Out of its total length of 427 kilometres, 292 kilometres lies in Madhya Pradesh and 84 kilometres in Uttar Pradesh and the remaining 51 kilometres forms a common boundary between Madhya Pradesh and Uttar Pradesh.

River Betwa

The Betwa is a river in Northern India, and a tributary of the Yamuna. Also known as the Vetravati, the Betwa rises in the Vindhya Range just north of Hoshangabad in Madhya Pradesh and flows north-east through Madhya Pradesh and through Orchha to Uttar Pradesh. The confluence of the Betwa and the Yamuna rivers takes place in the Hamirpur town in Uttar Pradesh, in the vicinity of Orchha. Betwa is an interstate river between Madhya Pradesh and Uttar Pradesh that rises in the Raisen district of Madhya Pradesh and flows in a northeasterly direction across the Jhansi district of Uttar Pradesh. The total length of the river from its origin to its confluence with Yamuna is 590 kilometres, out of which 232 kilometre lies in Madhya Pradesh and the balance 358 kilometres in Uttar Pradesh.

MATERIAL AND METHODS

The boat survey in nine rivers of Uttar Pradesh was conducted from October 5-7, 2012 by 150 participants in 18 teams comprising frontline staff of the Uttar Pradesh state Forest Department, Madhya Pradesh State Forest Department, local NGOs, researchers, WWF staff and the local community members.

Each team consisted of three dolphin observers including an expert in dolphin counting. Before, conducted the survey, participating teams were given training for adopting effective data collection skills, leading to a successful completion of the survey. The participants were trained through four training sessions on scientific ways of dolphin counting, and to build an understanding of the geographical area. The 2400 kilometre river length was divided into smaller stretches, enabling each team to cover 60 to 70 kilometres of the river stretch each day.

The boat speed was maintained at an average of seven to 10 kilometres per hour to reduce the duplication of the sightings. A direct count method (Perrin and Brownell 1989; Mohan et al. 1993; Sinha and Sharma 2003) was adopted in which density was estimated from dolphin counted during a survey, assuming complete detection of all individuals

and following simple calculations of numbers per sampled area.

Sighting of dolphins were conducted by three independent observers stationed in different directions (right, left, and front). Estimates of the total number of individuals and of group size were calculated from the “best” estimates of group size, while the high and low estimates were used to evaluate the uncertainty of the observers about the accuracy of their best estimates (Smith et al. 2006).

RESULTS

River Ganges: A total of 261 dolphins were enumerated with an encounter rate of 0.21 dolphin/km in the main River Ganges (Bijnor to Varansai) approx. 1200 kilometres. The highest encounter rate (0.42/ km) of dolphin was observed from Allahabad to Varansai followed by Garh to Narora (0.36/ km). The lowest encounter rate (0.027/ km) was observed from Farrukhabad to Kanpur (Figure 2).

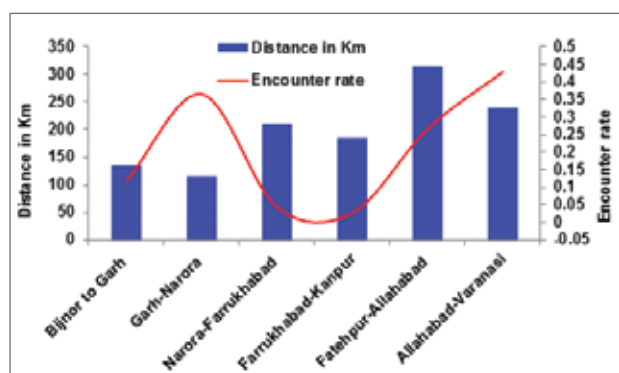


Figure 2: Encounter rate of dolphin in main Ganges (Bijnor to Varanasi). No dolphin was sighted from Kanpur to Fatehpur.

River Yamuna: The results of three days survey in the Yamuna River (Pachhnada-Allahabad), approximately 400 kilometres, a total of 31 dolphins were enumerated with an encounter rate of 0.075 dolphin/ km (Figure 3).

River Chambal: The survey results show the total number of dolphins counted in the River Chambal were 85 individuals in the survey stretch of 235 kilometres from Rajghat to

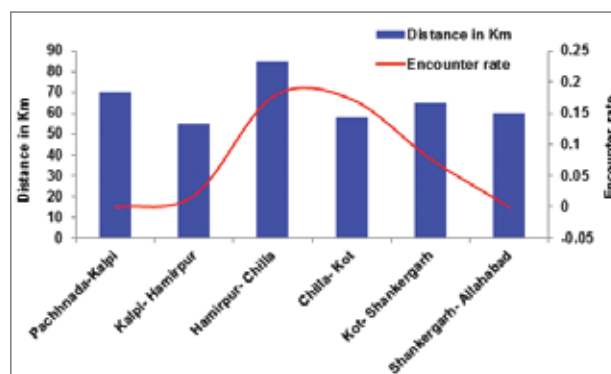


Figure 3: Encounter rate of dolphin in River Yamuna (Pachhnada-Allahabad)

Pachhnada. The encounter rate of dolphins in the River Chambal is based on “best” estimate of 85 dolphins with an encounter rate of 0.34 dolphins/ km river length (Figure 4). The maximum encounter rate (0.48/ km) of dolphin was recorded from Pinhat to Pachhnada and the minimum encounter rate (0.10/ km) dolphin was recorded from Rajghat to Pinhat.

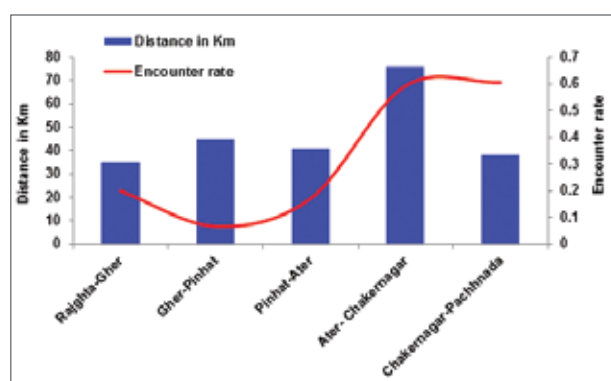


Figure 4: Encounter rate of dolphin in River Chambal (Rajghat-Pachhnada)

River Girwa and Ghaghara: In the River Girwa (18 kilometres) 39 dolphins were counted with an encounter rate of 1.56 dolphins/ km. In the River Ghaghara the encounter rate of dolphins was 0.45 dolphin/ km, based on the best estimate of 231 dolphins recorded in the 445 kilometre length of the river surveyed (Figure 5).

Tributaries of River Ganges

The highest (16 individuals) population of dolphin was recorded in Saryu River (approximately 31 kilometres) with an encounter rate of 0.51/

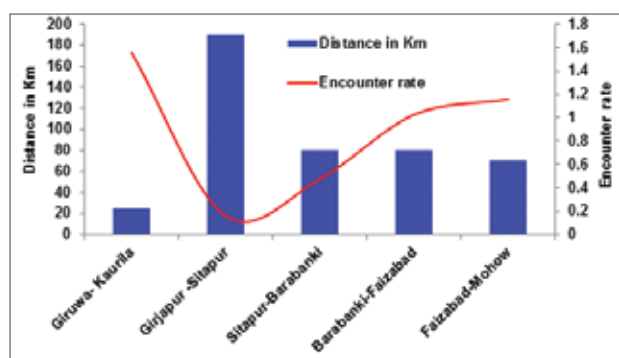


Figure 5: Encounter rate of River Ganges Dolphin in River Girwa and Ghaghara

km followed by River Rapti (approximately 30 kilometres) eight dolphins with an encounter rate of 0.26/ km. No dolphin was recorded both in Ken (approximately 30 kilometres) and River Betwa (approximately 29 kilometres) during the survey (Figure 6).

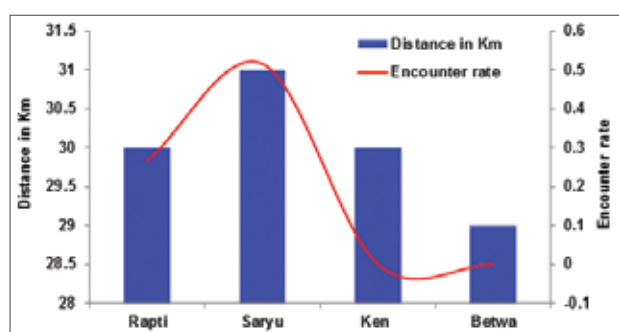


Figure 6: Encounter rate of River Ganges Dolphin in main tributaries of Ganges River

CURRENT AND POTENTIAL FUTURE THREATS

Barrages on the River Ganges at Rishikesh, Haridwar, Bijnor and Narora have an adverse impact on dolphin habitat. The dolphins seem to have disappeared from the River Ganges upstream Bijnor barrage. A few dolphins remain in between Bijnor barrage and Narora barrage. These barrages have created a permanent barrier across the river blocking the movements of the dolphins.

Absence of dolphins below Kachla ghat up to Kanpur, a polluted stretch, indicates that dolphins are intolerant of pollutants. Non-selective and destructive fishing methods through gill net fishing, fishing with

explosives, electricity, and poisons often accidentally kills or injure dolphin. Heavy fishing was recorded at River Yamuna, River Ganges downstream of Kanpur barrage and River Ghaghara.

Many fishermen regard the dolphin as a nuisance due to damage caused to nets by it and some of them kill dolphins out of revenge. From downstream of Kanpur heavy fishing and sand mining activities with fishing boat were recorded between Nauvasta village, Sihori near Kokhraj Bridge, Allahabad Sangam and Handia.

In River Yamuna between Chill to Khakhareru Ghat, heavy fishing were recorded in between Khakhareru ghat, Pratappur Ghat and Sarswati Ghat. Intense sand mining was recorded near section of Mahua Ghat, Mahila Ghat, Bamosa Mountain, Pandu village and Lakhanpur.

DISCUSSION

River Ganges

Anderson (1879) reported that the Susu's 19th century range in the Ganges extended from the delta region of the Sundarbans upstream to Haridwar. The uppermost distribution of dolphin was recorded between Bijnor and Narora barrages (approximately 165 kilometres) 22 dolphins were recorded during the years 1993-1995, 35 dolphins in February, 1998 and 56 in the year 2010 (Rao 1995; Behera and Rao 1999; Bashir et al. 2010b, Behera et al. 2013). From Narora barrage to Kanpur (approximately 505 kilometres) 3 dolphins were observed during 2010 (Behera et al. 2013). During the present survey no dolphin was recorded from Kanpur to Fatehpur due to pollution and low water depth. Kannan et al. (1997) concluded that river dolphins in India may be at greater risk from environmental contamination than marine cetaceans because pollution discharge sites in the Ganges are often located in preferred habitat.

The significant DDT concentrations found in the fish from the gut of dolphins analysed by (Kumar et al.1999) shows their exposure to DDT through the

food they consumed. Absence of dolphins below Kachlaghat upto Kanpur, a polluted stretch, indicates that dolphins are intolerant of pollutants (WWF-India 2009 unpublished).

Between Kanpur and Allahabad (about 272 kilometres) 108 dolphins were observed in January-February 2010 (Behera et al. 2013). During the present survey a total of 261 dolphins were recorded with an encounter rate of 0.21/ kilometres.

The highest encounter rate 0.42/ km was observed from Garh to Narora. In the same stretch 0.52 individuals/ km was recorded during 2010 (Bashir et al. 2010b). This was found to be similar to the encounter rate for this species in the River Brahmaputra, Assam 0.44 individuals/ km (Mohan et al. 1997).

However, estimates in Vikramshila Gangetic Dolphin Sanctuary (1.8 individuals/ km) were found to be higher (Choudhary et al. 2006) while the encounter rate in the River Lohit, Eastern Assam was 0.23 individuals/ km (Wakid 2005).

River Yamuna

Anderson (1879) reported Susu throughout the year in the River Yamuna as far upstream as Delhi. During the present survey from Pachhnada-Allahabad (approximately 390 kilometres), a total of 31 dolphins were enumerated with an encounter rate of 0.075 dolphin/ km. The population status of dolphin in River Yamuna was reported by different workers. 25–40 dolphins in 1997 from the confluence of the River Chambal to Hamirpur (approximately 250 kilometres), 48 dolphins in June 1998 (Sinha et al. 2000) 16-21 dolphins in the year 1995 from Kausambi to Allahabad (approximately 90 kilometres) (Behera et al. 2013) 60 in between Yamuna-Chambal confluence at Hamirpur to Allahabad (approximately 350 kilometres) (Sinha et al. 2000) 48 from Pachhnada (Chambal confluence) to Hamirpur (approximately 250 kilometres) in the year 2001 and 48 from Chilla to Allahabad (approximately 183 kilometres) in the year 2010

(Behera et al. 2013). When we compare the result of the previous survey it seems that the population of dolphin in river Yamuna has decreased due to heavy fishing and mining in the river.

River Chambal

In the River Chambal, 85 dolphins were recorded at 235 kilometres from Rajghat to Pachhnada with an encounter rate of 0.34 dolphins/ km. The encounter rate estimated during the present study was higher than the previous studies conducted by different workers. The increased numerical status of dolphin in Chambal in spite of increasing anthropogenic activities in the river reflects the level of success with the law through National Chambal Sanctuary (NCS) (Sharma and Singh 2014).

From Batesura to the confluence of the River Yamuna at Barhee (approximately 305 kilometres) 45 dolphins were reported with an encounter rate of 0.15 individuals/ km (Singh and Sharma 1985). From Batesura to Pachhnada 43 dolphins were counted in February 1985-86 with an encounter rate of 0.8 individuals/ km (Rao et al. 1989). From Pali to Barhee (approximately 370 kilometres) about 72 dolphins with an encounter rate of 0.16 dolphins/ km were recorded (Sharma 1993). From Pali to Pachhnada (approximately 425 kilometres) about 81 dolphins were recorded in the year 2005 (WWF-India 2006 unpublished), 69 in the year 2006 with an encounter rate of 0.16 dolphin/ km (Tagore and Rao 2010) 91 in the year 2007, 86 in the year 2008 with an encounter rate of 0.21/ km (Singh 2008; Singh and Rao 2012) and 69 dolphin in the year 2010 (Singh 2010; Behera et al. 2013).

In the years 2013 and 2014 a total of 59 and 66 adults were counted respectively with an encounter rate of 0.27 in 2013 and 0.30 in 2014 (Sharma and Singh 2014).

Rivers Girwa and Ghaghara

The encounter rate of dolphins in the Girwa River was 1.56 dolphins/ km. The present encounter rate was higher than the earlier population

record. Smith et al. (1994) recorded 20-24-29 and 13-15-16 dolphin, Basu and Sharma (2000) recorded 25 dolphins in the same stretch, WWF-India recorded 39 dolphin in 2006, 30 dolphins in 2008 (WWF-India 2009 unpublished; Behera et al. 2013). In the Ghaghara River the encounter rate of dolphins was 0.45 dolphin/ km. In March, 1992 from Kailashpuri Irrigation Barrage to its confluence with the Ganges near Chapra in Bihar (Approx.532 km), 127-200 individuals in 76 dolphin groups were recorded (WWF-2009 unpublished). In June 1999 from Ayodhya to Tanda, in Ghaghara River (approximately 60 kilometres) 17 dolphins in four-five groups were sighted (Basu and Sharma 2000).

Tributaries of River Ganges

During the survey of different tributaries of the River Ganges, it was observed that the maximum (16 dolphins) population of dolphin was recorded in Saryu River (approximately 31 kilometres) with an encounter rate of 0.51/km followed by River Rapti (eight dolphins) in 30 kilometres with an encounter rate of 0.26 /km.

In rivers Ken and Betwa no dolphin was recorded during the present survey. However, the earlier record shows the presence of dolphin in these river stretches. In June 1998, eight dolphins were recorded in 30 kilometres segment of the River Ken from the confluence of the Yamuna at Chilla to Sindhan Kala village (Behera et al. 2013). In the same year six dolphins were recorded in River Betwa in 84 kilometres segment from the confluence of the Yamuna at Hamirpur to Orai (Behera et al. 2013). This shows that the population in these two river segment has been extirpated.

THREATS

The River Ganges Dolphin has been commonly hunted since time immemorial. Hunting and deliberate killing for dolphin oil was reported in River Ganges and River Brahmaputra in Bihar and Assam by many workers (Mohan and Kunhi 1996; Sinha 2002; Mohan et al. 1997; Bairagi 1999; Wakin 2009). In the upper

Ganges River, no such killing was reported in recent times. However, some other potential threats such as heavy fishing, industrial pollution and sand mining was recorded at Bithoraghat to Nauvasta village, Sihori near Kokhraj Bridge, Allahabad Sangam and Handia.

Similar threats were recorded in 2010 (WWF India 2010. Unpublished). The dolphins have disappeared from the River Ganges river upstream Bijnor barrage. A few dolphins remain in between Bijnor barrage and Narora barrage. These barrages when closed during the lean water season have created a permanent barrier across the river blocking the movements of the dolphins (WWF-India 2010. Unpublished).

In River Yamuna, heavy fishing and sand mining was recorded. In between Chilla to Saraswati Ghat dolphins were observed in the sections where fishing activity was recorded. Intense sand mining was recorded near section of Mahua Ghat, Mahila Ghat, Bamosa Mountain, Pandu village and Lakhanpur.

Similar observation was recorded in 2010 (WWF-India 2010. Unpublished). In River Chambal threats to the survival of dolphin and/ or gharial have been identified in Jones (1982) and subsequent researchers (Singh and Sharma 1985, Sharma and Basu 2004; Hussain 2009; Singh 2008; Nair 2009; Singh 2010; Taigor and Rao 2010; Katdare et al. 2011; Singh and Rao 2012).

One of the serious threats is shrinkage of the stretch of river that is inhabitable by dolphins. Illegal fishing on commercial scale was observed in most of the stretches. The sustained and heavy exploitation of small fishes of rivers by the wide spread use of the mosquito nets in the river may affect the prey base of the River Ganges Dolphin and crocodile (Singh and Rao 2014 in press). Sand mining along the river for construction purposes and agricultural activities on the sandy banks has increased considerably, which is affecting the gharial, mugger, turtles and island birds (Hussain 2009). In River Ghaghara, some information and evidences regarding incidental

mortality of dolphins in fish-net accidents were obtained during 2009.

It is evident that dolphin carcasses had been processed to extract dolphin oil (WWF-India 2009 unpublished). Two other evidences of incidental mortality of dolphins were found; a carcass of an adult that was floating in water between the villages Mangalsi and Tulsipur and the old remains of a juvenile skeleton opposite Ayodhya Ghat (WWF-India 2009 unpublished).

ACKNOWLEDGEMENT

We would like to extend our gratitude to Uttar Pradesh Forest Department, Madhya Pradesh Forest Department, Rajasthan Forest Department, NGO partners; Local communities, media and volunteers. We would not have reached this stage without their valuable inputs and kind support.

We would also like to thank the two anonymous reviewers for their suggestions and comments that helped us greatly in improving the manuscript.

Financial support from the HSBC Water Programme is highly acknowledged.

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Identification and Ecological Characteristics of Freshwater Dolphin “Hotspots” in the Sundarbans, Bangladesh

Zahangir Alom¹, Rubaiyat Mowgli Mansur and Brian D. Smith

Wildlife Conservation Society, Bangladesh Cetacean Diversity Project,
House no 89 (2nd Floor), Road # 02, Sonadanga R/A (Phase 1),
Khulna - 9000, Bangladesh

¹E-mail: cetacean.bangladesh@gmail.com

ABSTRACT

Between 2002 and 2005, a dolphin sighting network established among nature tourism vessels covered 26,208 linear kilometres in the Eastern Sundarbans Reserved Forest, Bangladesh. Based on a scoring system that used group, individual and calf encounter rates of Ganges River and Irrawaddy dolphins, rates of co-occurrence for both species, and encounter rates in neighboring channels, six five-kilometre channel segments were identified as “hotspots” for priority conservation attention, from 38 that were surveyed on at least three occasions during each season. According to this information, the Government of Bangladesh declared three wildlife sanctuaries in January 2012 that encompass all six of these “hotspot” segments.

Dedicated surveys on the relative abundance of freshwater dolphins were conducted in the six identified hotspots and six segments chosen randomly from the 32 remaining non-hotspot segments. During dry, pre-monsoon, monsoon and post-monsoon seasons, encounter rates of Ganges River dolphins were greater ($p < 0.05$) in hotspots (mean = 3.0 - 4.0 individuals/ survey) versus non-hotspots (mean = 0.3 - 1.0 individuals/ survey). Although there were no significant differences between hotspots and non-hotspots for Irrawaddy dolphin sightings, stratified according to season, composite encounter rates were greater ($p < 0.05$) in hotspots (mean = 0.4 individuals/ survey) versus non-hotspots (mean = 0.2 individuals/ survey).

There was no support for our hypothesis of larger fish and crustacean catches in hotspot versus non-hotspot segments. These results can probably be explained by the greater fishing activity recorded in hotspots ($p < 0.05$), with five out of six located adjacent to villages, and all six non-hotspots located faraway from human settlements where fishing is more strictly regulated. The relatively rare and clumped availability of priority habitat for freshwater dolphins in areas subject to high fishing pressure implies the vital importance of effective conservation management in the three new wildlife sanctuaries established in the Sundarbans.

Key words: Ganges River dolphin, hotspot, irrawaddy dolphins, non-hotspot, Sundarbans, Eastern Sundarbans reserved forest

INTRODUCTION

The status of freshwater biodiversity is in crisis, particularly in Asia, due to the overexploitation, water pollution, flow modification, destruction or degradation of habitat and invasion by exotic species (Dudgeon et al. 2006). Among the declines in biodiversity, the fate of freshwater dolphins is particularly troubling (Reeves et al. 2000) due to incidental catches in fishing nets, hunting in some areas, and water development causing changes in freshwater and sediment regimes and interrupting dolphin movements (Smith et al. 2000; Reeves et al. 2003).

The tenuous existence of these animals was clearly demonstrated with the recent extinction of the Yangtze River dolphin or *Baiji* (*Lipotes vexillifer*). *Unlike many other species that have been decimated through systematic hunting, the extinction of the Baiji resulted primarily from incidental catches in local fisheries and habitat loss* (Turvey et al. 2007). *Without action to ensure that habitat is protected and human-caused mortalities are dramatically reduced, populations of the last two remaining species of freshwater dolphins in Asia: the Ganges River Dolphin (*Platanista gangetica gangetica*) and Irrawaddy Dolphin (*Orcaella brevirostris*) could also rapidly decline to extinction.*

The Ganges River dolphin is considered “endangered” in the IUCN Red List and ranges far upstream in the Padma-Jamuna-Meghna river system of Nepal, India and Bangladesh and in the comparatively much smaller Karnaphuli–Sangu river system of southern Bangladesh. The Irrawaddy Dolphin is considered “vulnerable” in the IUCN Red List (Smith et al. 2008) and occurs in some of Asia’s largest rivers (Mekong, Ayeyarwady and Mahakam) and in coastal waters of the Indo-Pacific with freshwater inputs (Smith and Jefferson 2002; Smith, Shore, and Lopez 2007).

Both the Ganges River dolphin and Irrawaddy dolphin are protected by the Bangladesh Wildlife (Conservation and Security) Act 2012, and occur

together in waterways of the Sundarbans mangrove forest in large enough numbers (Smith et al. 2006, 2008) for early conservation interventions to be effective. In this manner the Sundarbans can serve as global safety nets for preventing the extinction of both species if threats can be minimised.

In 2002, a comprehensive survey of waterways of the Sundarbans mangrove forest in Bangladesh indicated the presence of about 225 Ganges River dolphins (CV = 12.6 per cent) (Smith et al. 2006). This represents a significant portion of the species population which is precisely unknown but believed to number in the low to mid thousands (Smith, Braulik, and Sinha 2012). The density of Ganges River Dolphins is particularly high in the low-salinity eastern portion of the Sundarbans mangrove forest with even greater concentrations found at channel confluences.

This same survey indicated that the Sundarbans provide habitat for about 451 Irrawaddy dolphins (CV = 9.6 per cent) (Smith et al. 2006). Together with another 5,383 Irrawaddy Dolphins estimated in the coastal waters in 2004, this makes the Bangladesh population of this threatened species the largest in the world (Smith et al. 2008). The density of Irrawaddy Dolphins is particularly high in the high-salinity western portion of the mangrove forest but important habitat also occurs where the range of both species overlaps in the eastern side.

Between April 2002 and March 2005, a dolphin sighting network established among captains of nature tourism vessels cruising in the Eastern Sundarbans Reserved Forest of Bangladesh (ESRF) covered a total of 26,208 linear kilometres during monsoon, post-monsoon and dry seasons. The network recorded data on 1,005 sightings of Ganges River dolphin groups (1,993 individuals; 11.8 per cent calves) and 281 sightings of Irrawaddy dolphin groups (566 individuals; 5.7 per cent calves). The cruising route was then divided into 5-kilometre long segments with a unique identity number assigned to each. All dolphin sightings were then plotted in each

METHODS

General Procedures

In 2010/ 2011, a total of 96 days of dedicated survey efforts were conducted in six five-kilometre dolphin “hotspot” (total area 1,437 hectares) channel segments identified by Smith et al. (2010) where occurrence of freshwater dolphins was much higher than in other areas, and six five-kilometre “non-hotspot” (total area 1,395 hectares) channel segments chosen randomly from the remaining 32 channel segments where fresh water dolphins occur in much lower numbers (Figure 1). Two visits (2 days each) were made to each segment for investigating their ecology and human use (e.g., fishing activities and vessel traffic), one each during spring and neap tides (2) during each season (4) of the year for a total of eight visits per segment.

Dolphin Surveys

During each visit, two dolphin surveys were conducted, one in incoming and one in outgoing tides, during daylight hours in each hotspot and randomly selected non-hotspot segments (i.e., 16 surveys per segment per year for a total 192 surveys) in good sighting conditions. Dolphin sightings and search efforts were systematically recorded according to standard survey procedures. A three-person observer team, two with binoculars and one with naked eye, searched for dolphins from the roof of the vessel. Channels narrower than 1,000 metres, as measured from a satellite map, were surveyed only once in the rough middle of the channel, while channels greater than 1,000 metres wide were surveyed twice, once near each bank with efforts made to avoid double counting groups in the middle.

When dolphins were sighted, the recorder immediately recorded a waypoint on the global positioning system (GPS) and the waypoint number, time, and distance estimate and binocular bearing to the dolphin group. The team proceeded to the location of dolphin occurrence where they recorded a new waypoint and time along with information on the species identification, best estimate of group size, number of calves and the initials of the observer who

made the distance estimate, and then depth, water surface temperature, salinity and turbidity was also measured at location of the sighting.

Environmental Sampling

Data were collected on salinity, temperature, depth and turbidity from 18 points in each five-kilometre river segment. These points were predetermined along cross sections spaced at one fourth ($\frac{1}{4}$) the channel width of cross-sections spaced every one kilometre according to a digitised map (Figure 3) and downloaded into a GPS.

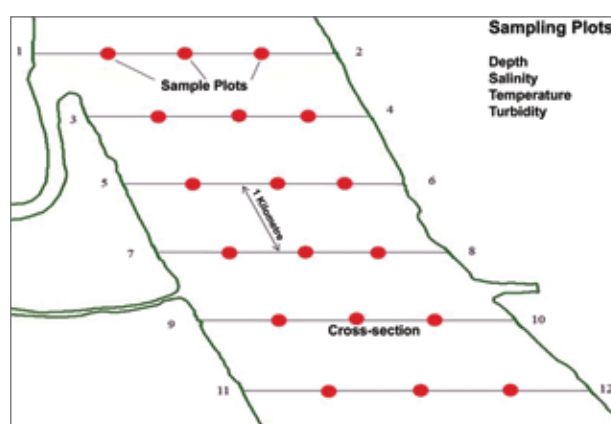


Figure 3: Locations of 18 sampling points in each five-kilometre long channel segments for collecting data on depth, salinity, temperature and turbidity

Fishing Gear Survey

During the dolphin surveys (see above), all deployed fishing gears within the segment were counted according to type using Das (2000a, b), and Bernacsek and Haque (2001), as well as local expertise, to quantify and evaluate the difference in fishing activities in hotspot versus non-hotspot segments. A scoring system, based on a qualitative assessment of the relative impact of each fishing gear on freshwater dolphin habitat was developed according to information on entanglements, gear specifications, and bycatch of fish and crustaceans (Table 1).

Applying these criteria to different fishing gear types, the calculated impact scores for each gear were 494 for drifting gill and fixed floating gill nets, 363 for set-

Table 1: Parameters considered for the scoring of different fishing gears recorded during dolphin surveys

Parameters	Sub parameters	Score
Dolphin entanglement record from mortality monitoring network and interview surveys (Mansur, Alom, and Smith in press)	Per entanglement	10
Soaking/ fishing area (considering disturbance to the movement of dolphins and their prey and the potential for entanglement)	Full channel cross section	6
	Half (side to middle) channel cross section	3
	Middle of the channel	2
	Any part of the channel	1
	Side of the channel	0
Fishing gear's materials (considering strength)	Nylon	4
	Mixed types	3.5
	Plastic	2
	Cotton	1
Mesh size (considering dolphin prey size)	<1 cm	3
	1-3 cm	1
	>3 cm	0
Funnel length (considering fish and crustacean bycatch and potential for dolphin entanglement)	>5 metre	2
	<5 metre	1
Catch type (considering dolphin prey)	Fish or crustacean fry	2
	Fish and crustacean	1
	100 gram catch	1
Average catch gm/hour (considering dolphin prey)	100 larvae bycatch	1
Number of post-larvae bycatch/ hour (considering dolphin prey)	10 individuals	1
Number of individuals of target fish and crustacean species caught/hour for each gear (considering dolphin prey)		
Main rope length (considering the potential for dolphin entanglement)	100 metre	1
Mouth opening/ mouth circumference (considering dolphin prey and entanglement)	4 metre	1
Twine number (considering dolphin entanglement)	<12 number	1
	>12	0
Hooks (considering dolphin entanglement – score applied for each hook on gear).	Each hook	0.1

bag nets, 222 for long lines, 59 for post-larvae (PL) set-bag nets, 52 for PL box nets, 92 for long shore nets, 47 for PL hand push nets, 46 for PL hand drag nets, 31 for PL seine nets, 31 for PL drag nets, 27 for cast nets and otter fishing lift nets, 17 for crab traps, 15 for crab lines and creek nets, 11 for hooks and rods, and 10 for hand push nets and drag nets. The scores were applied to the number of fishing gears recorded according to type, then summed for each segment, and divided by the total number of surveys in the segment to generate a composite index of vulnerability from fishing activities.

Fishes and Crustacean Catch Composition

During each visit to each segment (see above), fish and crustacean catches were recorded, as available, for three gill net soaks, three set-bag net soaks, one shore net soak, ten cast net throws, three drag net soaks, three crab line soaks, three crab trap soaks, two hours of long line soak, and two hours of rod and hook fishing. Data were recorded on:

- 1) The start and end time of the sampling period
- 2) Fish and crustacean species identification according to Paul (2001), Rahman (2005, 2009), and Siddiqui (2007)

- 3) And, the number of each identified species, their weight and median size.

To avoid the non-normality issues in the data set, a Mann-Whitney *U* test was used to compare the abundance and catch-per-unit effort (CPU) in weight, and species diversity after exponent of Shannon entropy (Shannon 1948), from “hotspot” versus “non-hotspot” segments. The exponent of Shannon entropy was used because it converts a common diversity index value for true diversity (or “effective number of species”) by weighing species according to their frequency in the community and it is the most appropriate general-purpose measure of diversity (Hill 1973, Jost 2006).

Investigation on Fishes and Crustacean Abundance and Diversity

To compare relative abundance and species diversity of fishes and crustacean in “hotspot” versus “non-hotspot” segments, dedicated fish sampling was conducted in the winter of 2007-2008, with the assistance of local fishermen using fixed floating gill and set-bag nets for two-day sampling in each segments. A set-bag net was set for five hours on each visit in three different locations (starting at low or high tide) chosen by the fisherman to maximise catch.

Similarly, a fixed-floating gill net was used three times in different locations of the segment for five hours each. Date, time and soak duration of each catch from each of the two gears were recorded and fish and crustacean catches were sorted and identified according to species. The total number of individuals, total weight and median length were measured for each species. The differences between catches from hotspot versus non-hotspots were then analysed using Mann-Whitney *U* test. We also used an ordination or multi-dimensional scaling (MDS) approach to examine dissimilarities in the fish and crustacean species composition of set bag net catches in hotspot and non-hotspot segments.

RESULTS

Dolphin Encounters in Hotspot Versus Non-hotspot Segments

During dedicated surveys in the six five-km long channel segments selected as “hotspot” and six five-km long channel segments chosen randomly from the 32 remaining “non-hotspot” segments, a total of 181 sightings of 334 Ganges River Dolphins, including 67 calves, and 22 sightings of 41 Irrawaddy Dolphins and no calves were recorded in hotspot segments whereas a total of 40 sightings of 62 Ganges River Dolphins including 18 calves and eight sightings of 17 Irrawaddy Dolphins including two calves were recorded in non-hotspot segments.

During dry, pre-monsoon, monsoon and post-monsoon seasons encounter rates of Ganges River Dolphins were greater (Mann-Whitney *U* test $p < 0.05$) in hotspot segments (mean = 3.0 - 4.0 individuals/survey) versus non-hotspot segments (mean = 0.3 - 1.0 individuals/survey) with a similar pattern for calves (Mann-Whitney *U* test $p < 0.01$; mean = 0.7 versus 0.2 individuals/survey, respectively).

Although there were no significant differences between hotspot and non-hotspot segments for Irrawaddy Dolphins stratified according to season, composite encounter rates were greater (Mann-Whitney *U* test $p < 0.05$) in hotspot segments (mean = 0.4 individuals/survey) compared to non-hotspot segments (mean = 0.2 individuals/survey) (Figure). Environmental conditions at the location of dolphin sightings showed that Ganges River Dolphins prefer significantly (Mann-Whitney *U* test $p < 0.01$) lower salinity (mean = 3.0 versus 4.5 parts per thousand) and probably (Mann-Whitney *U* test $p = 0.06$) higher turbidity (mean = 223 versus 153 nephelometric turbidity units) compared to Irrawaddy Dolphins, respectively. No significant differences (Mann-Whitney *U* test $p > 0.05$) were found in the depth and temperature preferences of each species.

Environmental Characteristics in Hotspot Versus Non-hotspot Segments

In the hotspot versus non-hotspot segments, salinity was significantly lower in the dry, monsoon and post-monsoon seasons but higher in pre-monsoon season; temperature was significantly higher in pre-monsoon, monsoon and post-monsoon seasons but significantly lower in the dry season; turbidity was significantly higher in the dry, pre-monsoon and post-monsoon seasons, but not in monsoon season; depth was significantly higher in the pre-monsoon and monsoon seasons but not in dry and post monsoon seasons, all at Mann-Whitney U test $p < 0.05$. The composite environmental data from all seasons shows significantly lower salinity (mean = 0 - 9.6 versus 0.2 - 8.4 parts per thousand) and depth (8.5 - 9.2 versus 10.2 - 11.0 metre), and greater turbidity (mean = 166 - 220 versus 85 - 189 nephelometric turbidity units) and temperature (mean = 21.1 - 30.1 versus 24.7 - 30.4 degree celsius) in hotspot versus non-hotspot segments, respectively, all at Mann-Whitney U test $p < 0.05$ (Figure 5). The relatively low Wilks' lambda measurements with high

canonical coefficient and structure matrix confirmed that turbidity and depth are the best at differentiating between the dolphin hotspot and non-hotspot segments (Table 2).

Intensity of Fishing Activities in Hotspot Versus Non-hotspot Segments

A total of 481 fishing gears from 12 types and 137 fishing gears from nine types targeting edible fish and crustaceans were recorded in the dolphin hotspot versus non-hotspot segments, respectively. A total of 2,998 salt-water shrimp and freshwater prawn post-larvae (PL) collection nets from six gear types and 143 PL nets from four gear types were recorded in hotspot versus non-hotspot segments, respectively. Encounter rates of both edible fish and crustacean fishing gears (36 versus 3 gears/survey; Figure 6) and PL nets (41 versus 2 gears/ survey, Figure 7) were much higher in hotspot versus non-hotspot segments (Mann-Whitney U test $p < 0.01$). The overall fishing impact score was more than double in dolphin hotspot compared to non-hotspot segments during all seasons (Figure 8).

Table 2: Wilks' Lambda, Standardised Canonical Coefficients and Structure Matrix values from a discriminant analysis of environmental parameters recorded in 18 points in hotspot and non-hotspot segments

Parameters	Wilks' Lambda	F	df1	df2	Mann-Whitney U test (P value)	Standardised canonical coefficients	Structure matrix
Salinity (ppt)	0.997	3.817	1	1291	0.034	0.114	0.168
Temperature (oC)	0.996	4.540	1	1291	0.011	-0.270	-0.184
Turbidity (ntu)	0.936	88.133	1	1291	0.000	0.837	0.809
Depth (m)	0.973	35.468	1	1291	0.000	-0.495	-0.513

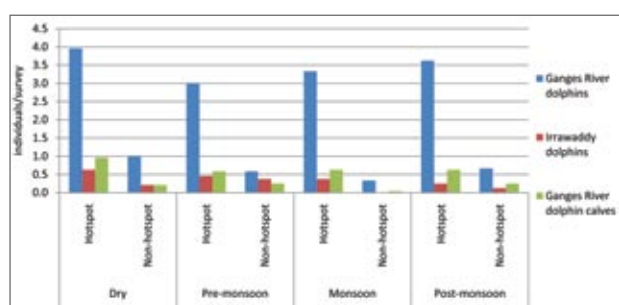


Figure 4: Encounter rates of Ganges River and Irrawaddy Dolphins in hotspot versus non-hotspot segments during four seasons of the study

Fish and Crustacean Catch Composition

A total of 113 fishes and 30 crustacean species were recorded during 407 hours of fishing effort from 10 types of fishing gears in hotspots, and 99 fishes and 26 crustacean species were recorded during 295 hours fishing effort from eight types of fishing gears in non-hotspots. Of these, 67 fishes and 23 crustaceans were commonly found in both segments types. No differences were found in fish

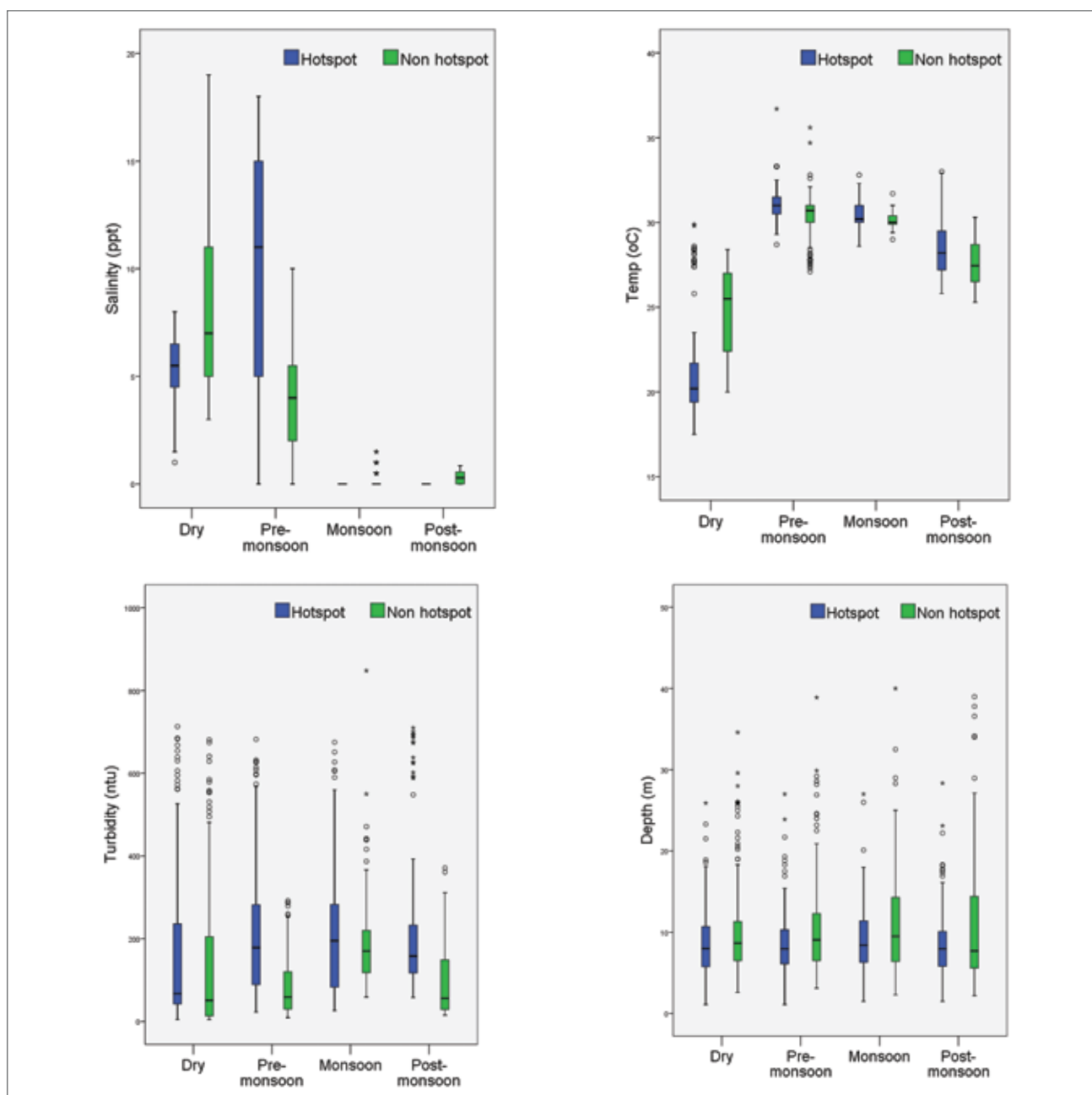


Figure 5: Environmental conditions recorded at 18 points in dolphin hotspot versus non-hotspot segments during dolphin surveys in four seasons: Salinity (parts per thousand) (top left), temperature (degree Celsius) (top right), turbidity (nephelometric turbidity units) (bottom left) and depth (metre) (bottom right)

and crustacean diversity in hotspot versus non-hotspot segments from set-bag and long-shore net catches (Mann-Whitney U test $p > 0.05$).

Due to insufficient sample size, it was not possible to compare fish and crustacean diversity from other gears. The catch-per-unit effort (CPU) in hotspot versus non-hotspot segments was significantly

(Mann-Whitney U test $p < 0.05$) lower for set bag nets (720 versus 2,693 gram/hour, respectively) and long-shore nets (337 versus 777 gram/hour, respectively). No differences were found for the CPU of gill nets and crab line (Mann-Whitney U test $p > 0.05$), and sample sizes were insufficient to test for other gears.

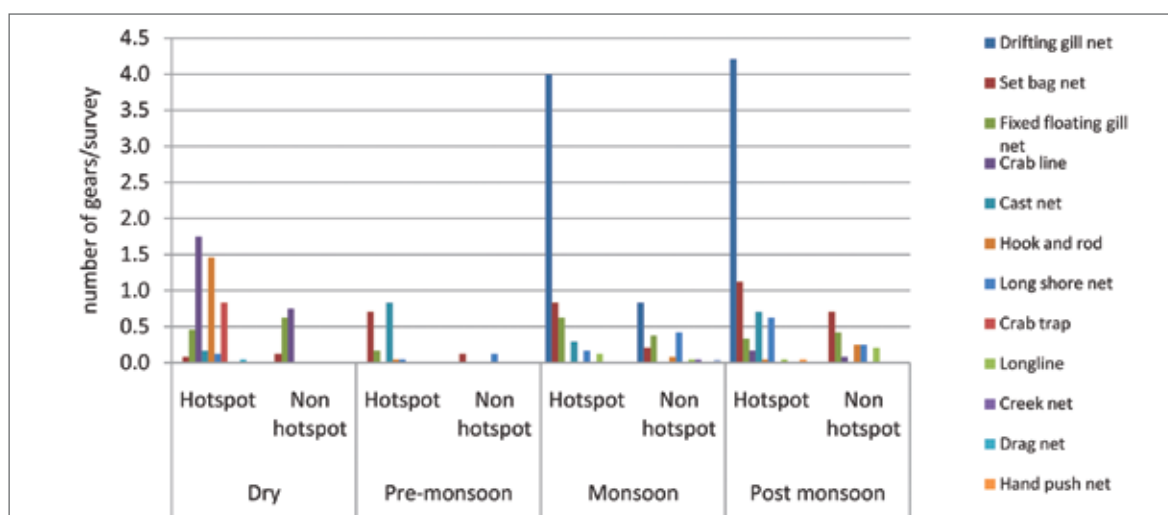


Figure 6: Mean number of fishing gears targeting fishes and crustaceans according to type per survey from six hotspot and six non-hotspot segments for freshwater dolphins in the Sundarbans

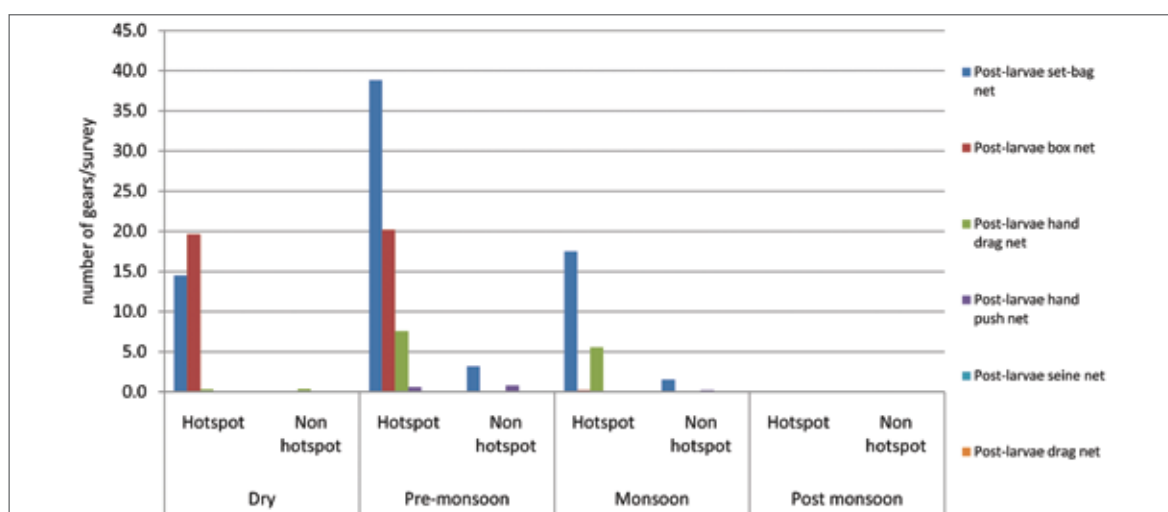


Figure 7: Mean number of fine-mesh shrimp and prawn post-larvae collection nets according to type per survey from six hotspot and six non-hotspot segments for freshwater dolphins in the Eastern Sundarbans Reserved Forest

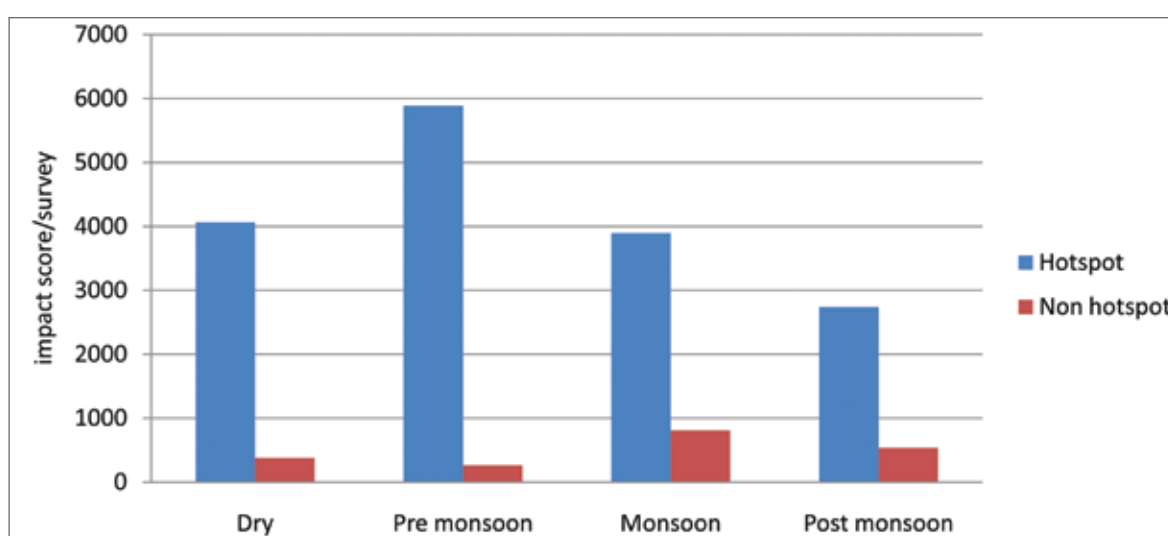


Figure 8: Impact scores/ survey from different fishing gears in hotspot and non-hotspot segments during four seasons of the study

Fish Abundance and Diversity in Hotspots Versus Non-hotspots

Our working hypothesis was that the dolphin hotspot segments would support a greater abundance and diversity of fish and crustaceans compared to non-hotspot segments. However, the data indicated either no relationship, or the opposite of what we had expected, with significantly greater catches for crustaceans according to weight in gill nets (Mann-Whitney U test $p < 0.05$) and close to significantly greater catches for fish and crustaceans according to weight in set-bag nets (Mann-Whitney U test $p = 0.078$ for both) in non-hotspot segments.

Extremely low stress values (0.00074 and 0.00196 according to the weight and number of individuals, respectively) in the ordination analysis indicate that high fishing effort in hotspot segments plays a major role in determining the species composition of catches. However, the relatively low stress values compared to a random distribution in non-hotspot segments, where fishing pressure is much lower, indicate that additional environmental factors as yet to be determined also play a strong role in structuring fish and crustacean communities.

DISCUSSION

This study confirmed that the six hotspot segments (designated as three wildlife sanctuaries by the Government of Bangladesh in 2012) are particularly effective at covering high priority habitat for Ganges River Dolphins, but only marginally effective in covering high priority habitat for Irrawaddy dolphins. This, in turn, reinforces the value of efforts to protect priority freshwater dolphin habitat in the Western Sundarbans Reserved Forest where Irrawaddy Dolphins are more abundant due to more favourable salinity conditions.

The relatively low salinity and high turbidity of freshwater dolphin habitat in the ESRF implies the importance of adequate freshwater flow. The relatively low depth implies that sedimentation may be a problem due to upstream water development and sea level rise. These same factors may also be

responsible for decreasing of fish production and ecological niches available for supporting diverse river biota (Smith and Mansur 2012).

An alarming numbers of Ganges River (10) and Irrawaddy Dolphins (two) entanglement from gill nets in the Sundarbans were recorded during 2007 - 2013 (Mansur et al. in press). The use of gill nets in the priority habitat for freshwater dolphins or “hotspots” should be reduced or eliminated to secure successful long term conservation management.

The significantly lower fish and crustacean catches found during the study in hotspots versus non-hotspots can probably be explained by the greater fishing activity recorded in hotspots ($p < 0.05$), with five out of six located adjacent to villages, and all six non-hotspots located within the ESRF, where fishing is strictly regulated, or inside the Sundarbans East Sanctuary where fishing is prohibited.

The results also indicated the destructive ecological impacts of the use of fine-mesh mosquito nets to catch saltwater shrimp and fresh water prawn PL. These nets result in an extraordinarily high bycatch of non-target crustacean PL and fish fingerlings, and are believed to be partly responsible for the depletion of fish and crustacean stocks in the Sundarbans and adjacent waters. The relatively rare and clumped availability of priority habitat for freshwater dolphins in areas subject to high fishing pressure implies the vital importance of effective conservation management in the three new wildlife sanctuaries established in the Sundarbans.

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Captive Breeding of the River Terrapin - *Batagur baska* (Gray 1830) in Bangladesh

A. G. J. Morshed¹ and Istiak Sobhan²

¹Wildlife Biologist, Vienna Zoo, Austria

²IUCN - Bangladesh, Dhaka, Bangladesh

E-mail: morshed01552@gmail.com

ABSTRACT

River Terrapin (*Batagur baska*), a riverine turtle species from Ganges delta, is now facing the threat of extinction in the wild. The species has been categorised “Critically Endangered” in Bangladesh as well as for its global population (Critically Endangered A1cd). The species has been known to occur in the large rivers and estuaries of coastal districts of Noakhali, Barisal and Khulna of Bangladesh. However, for more than a decade, the species has not been being sighted or trapped in fishing nets even in its main habitats in the Sundarbans of both Bangladesh and India.

In the absence of a viable breeding population in the wild and continuation of underlying cause of population decline it was felt to take necessary action to conserve the species through captive breeding program. In that context, in 2010, one captive breeding center for the species was set up in Bhawal National Park of Ghazipur district, Bangladesh.

They started to mate between October to December and laid eggs in March and April, each year. In 2011, 28 eggs were obtained from one female; however, no egg was hatched. In 2012, 92 eggs were laid by five females and placed in natural nests, of which 26 were hatched. In 2013, in total 99 eggs were collected from the same females and placed in artificially constructed sand bed nests, of which 61 hatched.

This success rate in captive breeding was a first in the world. The paper deals with various aspects of captive breeding along with the success and failure trials. The future plans of the initiative will also be discussed.

Keywords: River terrapin, captive breeding, translocation, Bangladesh

INTRODUCTION

Batagur baska (Family Geoemydidae), commonly known as River Terrapin is the world's fourth most critically endangered freshwater turtle (TCC 2011). Historically, the species occupied most coastal rivers and estuaries of South Asia (India, Bangladesh, and Myanmar). Populations of River Terrapins occurring in Southeast Asia (Thailand, Cambodia,

Malaysia, and Indonesia) were formally referred as same species but now considered a separate closely-related species, the Southern River Terrapin (*Batagur affinis*).

The life history, taxonomy, and distribution of this species were provided by Ernst and Barbour (1989), while overview of their natural history was provided

by Moll (1980) and Holloway (2003); dietary requirement on the growth was documented by Norkarmila et al. (2002).

B. Baska reaches a maximum shell length of approximately 60 centimetres (Moll 1980; Ernst et al. 2000). The Terrapin's decline has primarily resulted from its widespread exploitation for its meat and eggs. Associated indirect factors, including habitat alteration and destruction through various water management projects and pollution also played vital roles to degrade their nesting and feeding habitat and restrict their historic migration routes.

Intensive and destructive fishing practices are also major causes of their demise, with the introduction of efficient mechanised fishing boats and use of very wide-area nets throughout the estuaries. Use of often illegal fixed set-bag nets without turtle excluding devices in its habitat is also causing major kills (Das 1997; Moll 1997; Kalyar et al. 2007; Platt et al. 2008).

The species has been listed as Endangered by IUCN Red Data Book since 1982 (IUCN 1982) and subsequently listed as Critically Endangered (CR A1cd) throughout its range on 2000 IUCN Red List (IUCN 2012). It has also been considered Endangered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and positioned in Appendix 1 of the CITES, in which the species and its products cannot be traded in the international markets.

India formally endorsed this species on Schedule I of its Wildlife (Protection) Act of 1972, prohibiting all kinds of trade nationally and internationally while in Myanmar, the species is protected by the Law with trade opportunity through government permission. The species was not listed under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974 but it has been included as protected animal in Schedule 1 of Wildlife (Conservation and Security) Act, 2012, which makes it illegal to hunt or capture the species from the wild and indulge in any kind of trade of the

species. The species is recorded as Endangered under the United States Endangered Species Act and also endorsed in Annex A of European Union regulation 338/97 (Moll et al. 2009).

To know the present population status, extensive surveys have taken place in a few of its range countries. Countries such as Malaysia, India, and Cambodia have recorded very small population of the species. However, both Malaysian and Cambodian populations are now regarded as *B. affinis*. In Bangladesh, Rashid (1990) and Reza (2005) conducted surveys on the species in the Sundarbans areas. The results showed that no viable population persisted in the wild.

However, we have found that rearing the species in the ponds of coastal districts (mainly Greater Noakhali, Barisal and Khulna) in Bangladesh is an age-old tradition and almost all of our specimens were collected from this captive population. We received local anecdotal reports of rearing the species in domestic ponds for 70-80 years or even more. Moreover, *B. baska* is extremely rare in the market, though other turtles or tortoises are found in the markets.

Nesting sites have also become extremely rare throughout the northern River Terrapin's former range; we found only three wild hatchlings after many years. Conservation action for the Terrapin has been simply inadequate throughout the range, although they are protected by laws. Both in India and in Bangladesh, the Terrapin population now appears to be so low that the only alternative to save this species from extinction may be to collect all possible remaining wild individuals to keep in captive breeding facilities until they attain a viable population size and wait for such time as it is feasible to re-establish a wild population in a safe protected sanctuaries. In situ conservation measures were taken in Cambodia (Holloway 2003; Platt et al. 2003), while hatchling and management of *B. baska* in the captivity was also successful in Malaysia and in the Bronx Zoo (Shariff et al. 1986; Blanco 1991).

To establish a captive breeding facility, “Project Batagur” was launched in Bangladesh through a national and international collaboration in 2009-10. *Schönbrunn Zoo* (Zoo Vienna) and *Turtle Survival Alliance* of USA are the main international partners in this initiative and provide technical supports; SOS - *Save Our Species* provides the financial support with national partners which include Bangladesh Forest Department, IUCN, International Conservation Union, Bangladesh country office and CARINAM.

The main objective of this initiative was to collect all available specimens from private captivity and traders and establish an assured colony of this critically endangered species in Bangladesh. A captive husbandry centre was set up in Bhawal National Park of Ghazipur district, 45 kilometres north of the Dhaka. The captive breeding success for *B. baska* reported here gives the impression that this practice could play a vital role for the recovery of this species.

MATERIALS AND METHODS

In Search of the *B. baska*

Based on the literature and anecdotal evidence, our journey led us towards the coastal areas of Bangladesh, especially in the south-central and south-western parts in quest of the target species, the *B. baska*. We visited coastal areas in Feni, Khulna and Satkhira districts.

We applied the snowball approach to explore the information of the species. We also applied rapid rural appraisal in 11 settings which included local shops, fishermen, traders, and pond owners where we showed the pictures of the target species. This species is locally termed as *Kalamukhikaitta* (Black-headed turtle), *Sadamukhikaitta* (White-headed turtle) or even *Nonakaitta* (Saline turtle). Based on the collected information we finally identified key persons, who were engaged in illegal trade of turtles and whom we further interviewed to get more information about the occurrence of this species in the wild. But no trace of this species in the wild was found.

We finally recovered our first specimen in a fish breeding pond in a captive environment in Gopalganj district. After lots of persuasion and discussions we managed to come to a mutual understanding with the pond owners in three locations who voluntarily handed over the specimens to us for conservation and breeding purpose. This was in addition to our collection from the turtle traders.

Until now, we have collected 19 live *B. Baska* specimens from these locations and trans-located them in Bhawal National Park, Dhaka for captive breeding. Out of these 19 specimens, only five were females and 14 were males. Most of these individuals grew in captivity almost for their entire life. However, things were not so straightforward in all the cases and in a few instances, we failed to convince them to hand them over to us. In other cases the owners hid their possessions and translocated them to a different pond.



Figure 1: Sample of collected adult *Batagur baska*

Measures of Ex-situ Conservation

The Bangladesh Forest Department handed over two derelict ponds located inside Bhawal National Park in Ghazipur district to establish *B. baska* conservation and breeding facility. In fact, these ponds were purposively constructed during mid-1990s for freshwater turtle breeding under a different conservation initiative.

One pond was considered for keeping and nurturing the specimens, while the other one was used for breeding purpose. These ponds were surrounded by Shal (*Shorea robusta*) trees. The dikes of the ponds were covered with bushes.

A complete refurbishment of these ponds was carried out to make them suitable for the purpose of breeding (Figure 2). The size of the breeding pond was 48.77m x 17m x 2.2m; its water depth increases over 3m during the monsoon season.

A sand filled artificial beach was prepared at one end of the pond to facilitate basking and egg laying for the turtles. The depth of the sand was approximately one metre. This sandy beach had a gentle slope starting from the water edge to the top of the dike to create a favourable environment for the breeding females.

The ponds were fenced all around by bamboo poles with thick and strong bamboo chips to deter predators. Visitors were restricted to provide female broods an undisturbed environment for laying eggs. Some units of a tumble-down hatchery within the facility were renovated, especially in the rearing tank to relocate the eggs.

Translocation of the Collected Individuals

The collected *B. baska* individuals were translocated from its origin to the newly renovated holding pond in Bhawal National Park in Ghazipur. The distance between the collection points and the translocated captive husbandry site is about 300 kilometres (Figure 3).

From the collection site, each of the specimens was transported using surface transport; specimens were packed in individual jute hessian. The travel time varied from four to eight hours depending on



Figure 2: Redeveloped breeding facility



Figure 3: Locations of collected species and captive husbandry site in Bangladesh

the distance. Length and weight were measured and sex was determined upon arrival at the new breeding facility. The species was identified after Khan (1982) along with expert consultation on site.

Each of the individuals was treated with potassium permanganate solution before being released into the holding pond. A full time caretaker from the community was hired to look after the project facility and the total activities.

Feeding Protocol

There was the limitation of availability of natural food for turtles in the breeding pond and thereby, a feeding protocol was maintained. Water hyacinth was floated on the pond with watercress (*Allocasia* sp.) – 2.5 kilograms; small shrimp - 1.5 kilograms; fruits (ripe banana, jackfruit, mango, apple, etc.); shell animals (molluscs) were fed six times a week.

Selection of Brood Batagur Individuals

Among the 19 collected *B. baska* individuals, eight broods (five females and three males) were released in the breeding pond. Two males and four females were released in December 2011, while one male and one female were released in March 2012. Each of the individuals was tagged with PIT (Passive Integrated Transponder)¹ number, external features were measured before released into the breeding pond (Table 1). The behaviour of the brood was monitored almost throughout the day for their mating, nesting, egg-laying movements and associated behaviour.

Physico-chemical Parameters

Data loggers were placed for recording the temperature of the water and the nests for one year at two hours interval. A total of six data loggers were placed — two in the water and four under the sand. Diurnal weather conditions including temperature and humidity were measured throughout the breeding period.

Table 1: External feature of selected Batagur broods

S. N.	PIT number	Sex	December 2011			
			Carapace Length (cm)	Carapace Width (cm)	Plastron Length (cm)	Gross Weight (kg)
1	40098100332515	Female	50.0	47.0	49.0	19.2
2	40098100333151	Male	44.0	40.0	37.5	12.7
3	40098100331788	Female	46.5	39.1	44.5	18.1
4	40098100330389	Female	49.6	38.9	46.2	20.1
5	40098100331425	Male	40.4	32.9	35.4	10.3
6	40098100337077	Female	46.6	36.7	44.8	18.6
7	40098100328475	Male	42.6	33.4	37.0	11.0
8	40098100332692	Female	48.9	42.0	46.5	19.9

*PIT is a small durable microchip used for recognition

Identification and Relocation of Nest

In 2012, each of the nests was labelled with a serial number and date for identification and each nest was fenced with a bamboo stick and a small meshed net to prevent predators (Figure 4). Nest number three was shifted to two new locations due to its close proximity to pond water.

The clutch with 15 eggs was split into two clutches. One clutch with seven eggs was placed in a single layer at a depth of 30 centimetres in the renovated rearing tank, while the other with eight eggs was relocated in the sandy beach and retained in a single layer at 30 centimetres depth. Both the clutches were fenced with marking as 3a and 3b. Relevant information such as the date of hatching and relocating of eggs and number of unhatched eggs was recorded. The shape of the egg was spherical and its colour was white.



Figure 4: Identification of the nests in 2012

In 2013, four nests were identified at the first instance and each of them was relocated and placed in separate sand filled plastic baskets. The eggs were placed in single layers at 30 centimetres depth of sand. Four such buckets were then enclosed with 6'x 6' wire-made fence to prevent predators. At the end of this measurement, the fifth nest was identified and left in nature.

RESULTS

In 2012, the captive breeding project in Bhawal National Park delivered and brought off 26 hatchlings from 92 eggs, representing a hatching success of 28 per cent. The clutch size of individual nests and their hatchling rates differed greatly as shown in Table 2.

The first clutch of eggs was laid on March 22, 2012 and the last clutch was laid on April 15, 2012. The clutches were left *in-situ* and not opened for counting the number of eggs except clutch number three (see Materials and Methods). Individual clutch size varied from 11 to 26 eggs. However, it could not be confirmed whether the same female had laid the eggs on different dates or had two clutches. The average diameter of a natural nest was 34 centimetres. The eggs in the nests were found at a depth of 20-30 centimetres in two-three layers.

After 64 days of incubation, on June 7, 2012, the first *B. baska* hatchling piped its shell and came out from nest 3b with a weight of 37.5 grams and carapace length of 61.8 millimetres (Figure 5).

One more hatchling was collected by digging the nest 1 on the same day. There were 24 more hatchlings collected by digging the nests from June 8-14, 2012 (Figure 6). Of these hatchlings, seven were carrying extra-embryonic membrane or yolk sac which was absorbed later. Five unhatched eggs were found with developing embryos. The fifth nest



Figure 5: First hatchling of *Batagur baska* in 2012

was found infertile with none of the 11 eggs showing any development at all after opening on the 60th day of the incubation period.

The highest hatchling success was recorded in transferred clutch number 3a, where seven hatchlings out of seven eggs hatched; in clutch 3b, five of eight eggs hatched out with incubation period ranging between 64 and 74 days. The lowest hatchling success was received from clutch number 1 with one hatchling from 26 eggs.

Overall, the incubation period of those four clutches ranged between 59 and 74 days. The temperature inside the nests ranged between 27

and 30° centigrade, while temperature outside the nests varied between 21.5 and 40.8° Centigrade. Atmospheric humidity during breeding period varied between 43 and 83 per cent.

In 2013, five females laid 99 eggs with an average clutch size of 20 eggs (range 15-24 eggs). The average incubation period was 64 days (range 62-65 days) with an overall hatching success rate of 62 per cent (61 hatchlings). The highest hatching success was at recorded 91 per cent in fourth nest and the lowest was 0.12 per cent in the fifth nest (hatchlings number 2) (Table 2).

DISCUSSION

Providing a favourable environment and with constant nursing, a breeding strategy with three males and five females brought success in captive location at Bhawal National Park in Bangladesh. Despite the usual requirement of 25 males and 50 females to make an effective viable breeding population, less than ten females are also recommended (Yamada and Kimura 1983). The sex ratio of adult male to female for breeding was 1: 1.66, which is close when compared to Moll's (1980) sex ratio (1: 1.29).

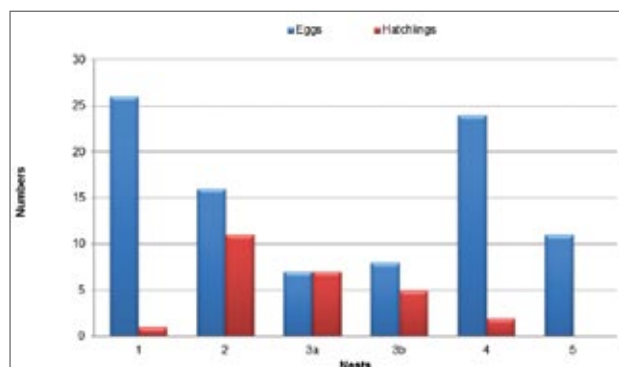


Figure 6: Nest-wise hatching success at BNP in 2012

Table 2: Details of eggs and hatchlings for year 2012 and 2013

Year	Nest	Egg			Hatchlings					
		No.	Length cm	Weight gm	No.	Average Weight gm	Average Carapace Length mm	Average Carapace Width mm	Average Height mm	Average Plastron Length mm
2012	Nest 1	26	4	35	1	30	57.5	52	24	54.2
	Nest 2	16	4.1	37	11	38.18	60.2	59.82	25.64	58
	Nest 3	15	4.5	40	12	38.75	61.35	54.6	26.97	57.5
	Nest 4	24	4.3	38	2	40	54.21	54.29	27.3	53.2
	Nest 5	11	4.6	40	0	Nil	Nil	Nil	Nil	Nil
	Avg.	18.4	4.3	38	5.2	38.26	60.17	56.68	26.32	57.25
2013	Nest 1	18	8	60	16	42.63	63.81	55.31	27.44	59.06
	Nest 2	15	6.5	45	2	37.5	59	23	25.5	55
	Nest 3	22	6.5	45	21	35.62	58.76	51.1	26.67	54
	Nest 4	24	7.8	60	22	36.95	61.27	46.45	26.55	57.77
	Nest 5	20	6.5	45	0	Nil	Nil	Nil	Nil	Nil
	Average	19.8	7.06	51	12.2	38.00	61.00	49.61	26.79	56.72

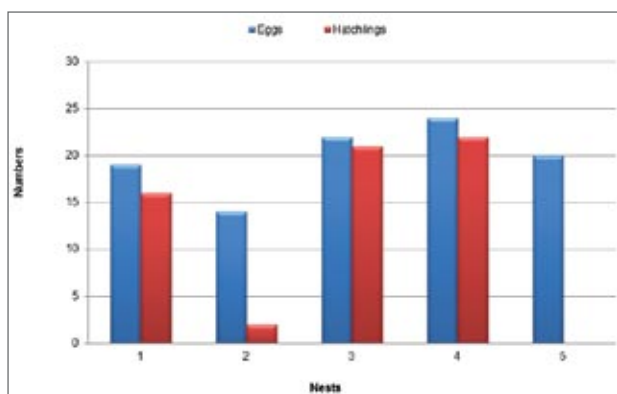


Figure 7: Nest-wise hatching success at BNP in 2013

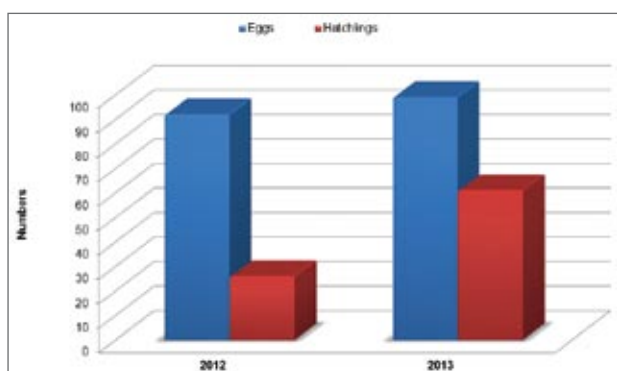


Figure 8: Comparison of hatching status between 2012 and 2013

The species is known to lay eggs in nature during January and March, while in captivity they laid eggs from end of March to end of April. In this captive breeding programme, hatching occurred between May and July.

The clutch sizes of individual nests and their hatchling rate differed greatly. The mean clutch size was 18.4 (range 11 to 26, $n = 5$ nests) and 19.8 (range 15 to 24, $n = 5$ nests) in year 2012 and 2013 respectively. Moll (1980) reported a mean clutch size of 26.4 (range 5 to 38) in Malaysia, while Holloway (2003) reported mean clutch size was 10.25 (range 3 to 17, $n = 8$ nests) in Cambodia. The hatching success rate varied with the lowest 3.84 per cent and the highest being 100 per cent with a mean value of 28 per cent in 2012, which is lower than the findings of Shariff (1986) in captive breeding through three different techniques.

It was observed in nest one, two and four that eggs in the top layer were hatched and the bottom layers

did not hatch at all. This could be due to the fact that the required temperature and moisture content did not prevail all around the eggs in lower layers. Conversely, the relocated nests 3a and 3b together achieved 80 per cent hatching success as the eggs in those nests were placed in one layer where physical factors including temperature and moisture contributed appropriately. In 2013, as we placed the eggs to reconstructed nests with single layer, the hatching rate went up to 62 per cent, indicating that artificial nesting provides better environment during the hatching period.

The mean incubation period was 70 days (range 59 to 77 days) at 21°–34° centigrade, which is much shorter period than those reported from other areas (Holloway, 2003; Moll, 1980). Three of the 26 hatchlings of 2012 died due to infection and accidents leaving the mortality rate below 12 per cent. In 2013, there was no mortality among the hatchlings.

FUTURE PLANS

The Batagur project achieved 84 juveniles from two hatching seasons. The hatchlings obtained from this captive breeding facility are now conserved in captivity to reach a considerable size and sex determination before they are ready to be released into the wild.

For long term survivability of this species, emphasis is given to more sophisticated breeding and conservation measures. To reduce the genetic depression due to the small number of captive females, we are now increasing the number of breeding ponds in which a single male and female Terrapin will be paired in a separate pond to ensure parental identity of all the incoming offspring.

New methods will be adopted to yield maximum number of individuals from each season. Temperature will be controlled during incubation period to produce equal number of both sex individuals. Search will continue in and around Sundarbans areas and other potential areas for new individuals and those will be brought under the conservatory management plan.

CONCLUSION

It has now been established and demonstrated that *B. baska* captive breeding can be successful; we now harbor more than 100 individuals (both adult and juvenile). This facility now probably holds the single largest population of this critically endangered species.

With a very small and unknown population size in the wild, *B. baska* still have long way to go before we can consider them safe; as threats still prevail throughout its natural range, it is still difficult to initiate its release in the wild.

A strong determination from all the parties involved made this impossible journey to possible and successful. Similarly, for any new species, we are basically learning by positive action; with every outgoing year, the team is becoming more enabled and informed. Every new hatchling provides us the courage and spirit to continue.

ACKNOWLEDGEMENTS

We would, first and foremost, like to thank Forest Department, Government of the People's Republic of Bangladesh for their ongoing support by providing space and permission to continue this work.

We are also thankful to the people of coastal Bangladesh who helped us to collect these endangered turtles from their ponds.

We express our heartfelt gratitude to Mr Peter Praschag and Ms Rupali Ghosh of Zoo Vienna for their never-ending guidance and encouragement.

We are also obliged to Save Our Species (SOS) for financing this initiative. We are grateful to Schönbrunn Zoo (Zoo Vienna) and Turtle Survival Alliance of USA for their continuous support.

We are also thankful to Dr S M A Rashid of CARINAM, Bangladesh for playing the pioneering role of this breeding initiative.

Special thanks are due to Bhawal National Park authority for providing required facilities within and the animal keeper, Md Noorul Haque, for his assistance throughout the project.

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THEME

Fish and Fisheries

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Impact of Anthropogenic and Natural Drivers on Ganges-Brahmaputra-Meghna River Fish Diversity in Bangladesh

Gouri Mondal

Upazila Fisheries Office, Singair, Manikganj, Bangladesh
E-mail: ufosingair@gmail.com

ABSTRACT

The Ganges-Brahmaputra-Meghna River systems (GBM) drain about 1.72 million square kilometres and finally flow to the Bay of Bengal. Being trans-boundary in nature these river systems carry huge quantity of water and sediment from its entire catchment area. These river systems have enormous biological resources and very rich fish diversity which is one of the main nutritional and economical sources of the people of Bangladesh.

It is a matter of great concern, though, that over the years the fish catch from GBM has declined significantly and species composition has changed to some extent due to various natural and anthropogenic factors. These factors have broadly altered many of the physical, chemical and biological characteristics of our river ecosystems and also led to decline fish diversity.

In this connection, it is necessary to identify the causes of biodiversity loss of GBM. This study analyses the present management regimes of the GBM fishery resources and finds out a number of relevant gaps present largely in national management system and proposes several suggestions for further improvement.

Key Words: Ganges-Brahmaputra-Meghna River system (GBM), biodiversity, driver, climate change, overfishing, water pollution

INTRODUCTION

Bangladesh has been formed as the greatest deltaic plain at the confluence of the Ganges-Brahmaputra-Meghna River and their tributaries. It is a low lying, disaster-prone and over populated country. Blessed with abundant water resources, it is criss-crossed by a network of 230 rivers.

The Ganges-Brahmaputra-Meghna River basin is a trans-boundary river basin with a total area of just over 1.72 million square kilometres, distributed between India (64 per cent), China (18 per cent),

Nepal (nine per cent) and Bangladesh (seven per cent). These three main rivers flow from Himalayas and join only just a few hundred kilometers upstream of the mouth in the Bay of Bengal and then finally flow into the Bay of Bengal. This system is the third largest freshwater outlet to the world's oceans.

Not only is each of these three individual rivers big, each of them also has tributaries that are important by themselves in social, economic and political terms (Ahmad et al. 2001; Biswas and Uitto 2001). About 80 per cent of the country is made up

of fertile alluvial lowland that becomes part of the greater Bengal plain. About seven per cent of the total area of Bangladesh is covered with rivers and inland water bodies and the surrounding areas are routinely flooded during monsoon when intensive rainfall occurs simultaneously over several tributary basins for a long duration.

Bangladesh receives a normal annual average rainfall is about 2300 millimetres. This system carries huge quantity of sediment. During the period 1956-1988, annual average sediment load entering Bangladesh and transported to the Bay of Bengal through main rivers was about 0.77 billion tons (Sustainable Development of Deltas 1998).

Sufficient rainfall and sedimentation process in river systems make Bangladesh suitable for fisheries industries. The GBM works as the source of many plant and animal species which have important social, dietary and medicinal uses. These wetlands are considered to be of international importance in terms of their biodiversity. In Bangladesh almost 260 species of open water fish are found (Rahman 2005).

In inland fisheries, Bangladesh ranks third with 0.53 million metric ton (FAO 2000) representing 6.7 per cent of world inland fish production among the top 10 fish producing countries of the world. Besides, Hilsa is the largest single fishery in this sub-sector with an annual production of about 0.34 million tons.

About two per cent i.e. 2.5 million people of the country are directly or indirectly involved in the Hilsa fishery for their livelihood (DoF 2013). The fisheries sector plays an important role in the economy in terms of nutrition, income, employment and earning foreign exchange. In 2011-12, Bangladesh produced 0.145 metric tons of freshwater riverine fish. The fisheries sector contributed to 4.39 per cent of gross domestic product (GDP) and 2.46 per cent of export earnings.

Fish provide 60 per cent of animal protein intake of the country's population. However, the average consumption 18.94 kg/ cap/ yr. compared to the required quantity 20.88 kg/ cap/ yr. (DoF 2013). Production cannot keep pace with the growth of Bangladesh's population. About 11 per cent i.e. 16 million people of the country are directly or indirectly



Figure 1: Catchment area of Ganges-Brahmaputra-Meghna River System

involved in the fishery for their livelihood. Other direct and indirect economic benefits of GBM remain unquantified; they continue to have an important place in the environmental and social landscape of Bangladesh. But unfortunately, now-a-days, fish biodiversity has been changing negatively. IUCN (2000) identified 54 species of fish in its red list as endangered, critically endangered and extinct category. In this context, the present study aims to identify the major drivers of the loss of fish biodiversity of GBM system of the country.

OBJECTIVES

The main objective of the study is to identify the major drivers of the changes in fish biodiversity of the country. The study also aims to analyse the present management scenario of GBM fishery resources and to find out the relevant gaps in the overall national management policies.

METHODOLOGY

This work is based on the review of secondary literature. No primary level data has been collected for this study. Books, government reports and scientific papers were used as secondary literature for preparing this paper.

ANTHROPOGENIC AND NATURAL DRIVERS OF GBM FISH DIVERSITY LOSS

The drivers responsible for the loss of GBM fish diversity of Bangladesh can be categorised into two types. These two drivers often work together as one driver influences the other one.

These two are:

- Anthropogenic/ man-made drivers, and
- Natural drivers

Anthropogenic Drivers

Due to increasing population pressure and demand, excessive fishing is a common practice throughout the year in all types of open water bodies of Bangladesh. Fishing by using banned fish trap, net etc. is common practice in Bangladesh. As a result of it, fish habitats usually face destruction

and undersized fish are frequently caught by these fishing gears. Thus, fish spawn, fingerling, fry and brood are depleting day-by-day.

In addition to it, common resources such as aquatic habitats of the country are degrading day-by-day. Open water and its fishery are converted into private property due to many socio-economic and political pressures. Powerful parties are putting restrictions on entry of the poor fishermen. Often they grab open water bodies illegally, seize fish and gradually develop culture fishery. These restrict open water fish to migrate to floodplain and hamper its natural production cycle.

Due to conflicting demands for various purposes such as industrial development and food production, the use of land and water appears to be unplanned in most of the cases (Hussain 2010). The construction of embankments as flood control measures have crucial influence on the fishery sector.

Studies of Flood Action Plan-2 identified fisheries as one of the worst affected sectors by flood control measures in Bangladesh (Hughes et al. 1994). To protect against floods and cyclones the government has so far constructed a total of 8613 kilometres of embankments. These structures have obstructed the migration pathways between floodplains, rivers and other water bodies and have, therefore, reduced accessibility to feeding, breeding and the provision of nursery areas which hamper fish to reproduce and finally, result in the loss of biodiversity (Figure 2).

Moreover, to develop roads and highways, bridges, culverts etc. are constructed without assessing environmental impact in most of the cases. The siltation and sedimentation process results in the rise of the river beds which leads to shallowing and gradual disappearance of rivers. Sometimes, due to siltation, many regional rivers have lost their connection with their perennial water sources in the dry season and all these factors together result in loss of fish habitats.

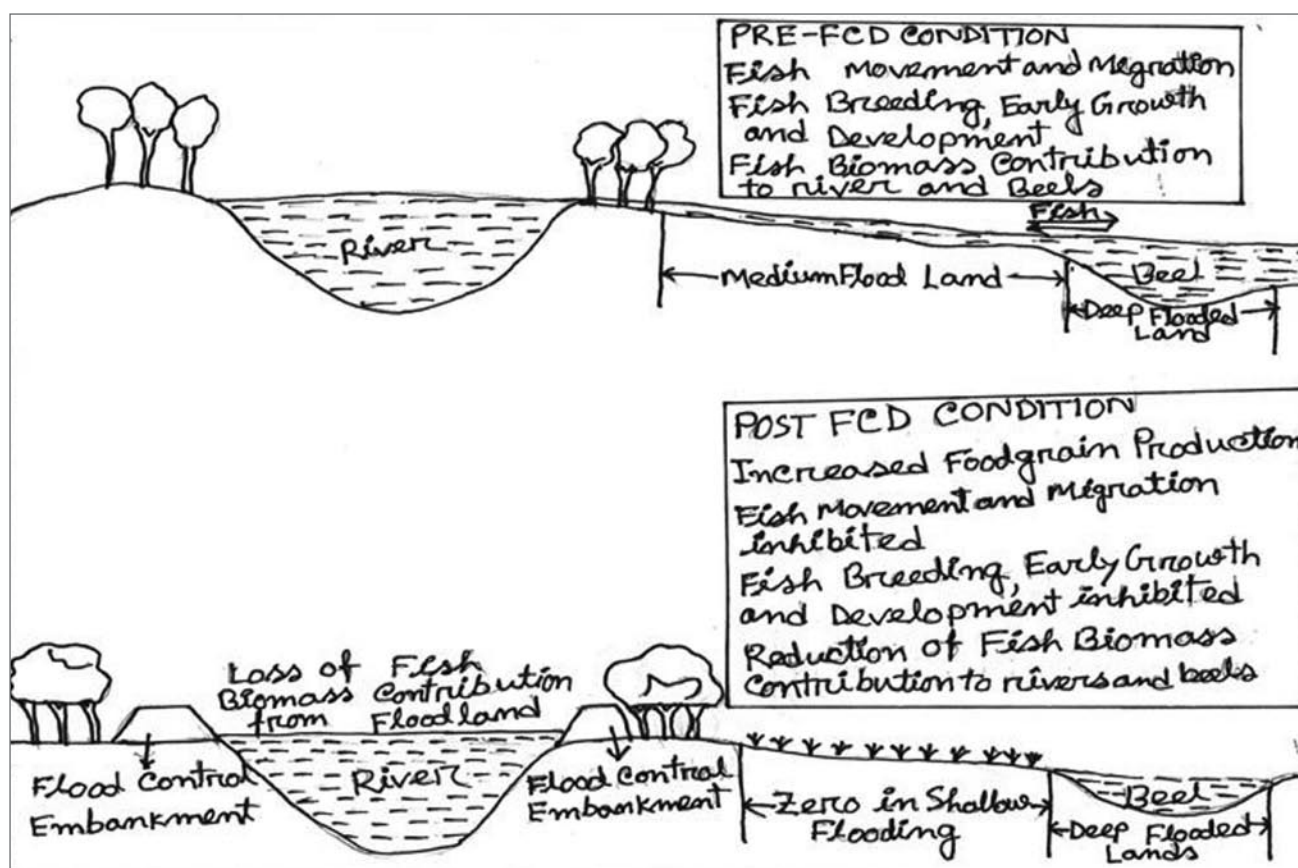


Figure 2: Effects of FCD/ I projects on river and floodplain (Redrawn from Ali 1989)

For irrigation, farmers use a large amount of groundwater which leads to movement of water from the wetlands to aquifers to maintain groundwater balance thereby reducing fish habitat area.

The use of banned fertilisers, pesticides and sometimes, overdose of these chemicals in agricultural fields often causes polluted surface run-off to the adjacent rivers. Those chemicals are reported for their neurotoxic or gonadotoxic nature for fishes and thereby, natural reproductive cycle of fishes gets disturbed which ultimately causes loss of biodiversity (Ali 1997).

Loading of heavy metals such as chromium, manganese etc. from urban and industrial residuals (particularly leather tanneries) and sewage pollute water and degrade water quality of rivers. Aquatic fauna are the worst sufferer in the polluted water condition (Khan et al. 1994).

Rivers provide the cheapest means of transport and it increases the demand of waterways for transportation. But the used oil, leftover food and other wastes thrown from the water vessels also pollute the river water. The polluted water is not suitable for the sustenance of fish community (Sustainable Development of Deltas 1998).

Outbreak of diseases by the introduction of exotic species causes disruption of the existing fish communities (Hughes et al. 1994).

Natural Drivers

Climate change in recent years is likely to exacerbate the existing anthropogenic causes of biodiversity losses in Bangladesh (NAPA 2005). Based on the climatic models, Bangladesh National Adaptation Programme of Action (NAPA), 2005 suggests that Bangladesh would be affected from many adverse impacts of climate change including sea-level rise,

higher temperature, enhanced monsoon precipitation and run-off, reduced dry season precipitation, increase of salinity intrusion etc.

Although it is not easy to determine the impact of climate change on fishery sector in a straight forward way, but researchers showed that increased temperature, changes in hydrological regimes, quantity of dissolved oxygen content, toxicity level of the pollutants could have diversified impact on riverine fishery (AQUASTAT survey 2011).

It is predicted that under the changing climate, the expansion of flooded areas could result in the increase of capture fisheries especially the floodplain fisheries (Second National Communication of Bangladesh to the United Nations Framework Convention on Climate Change 2012). At the same time, rising sea water level could cause to reduce the habitat of riverine fisheries.

Higher level of salinity could reduce the production of some specific kinds of fresh water fisheries which are particularly sensitive to increased level of salinity. Similarly, changes in temperature could have various impacts on riverine fisheries. All the fresh water fish are poikilothermic and their body temperature is similar as the water temperature.

Body temperature of a fish is directly related to biochemical reaction rates of fish which controls all the bio-physical aspects of fish body. So, different aspects of an individual fish such as physiological characteristics, growth rate, reproductive properties and other activities of an individual fish are influenced by changes in temperature. Depending on the temperature tolerance properties of different species, climate change will have varied impact on fish population. It could impact on increasing or decreasing of fish quantity or some species could face extinction.

Water temperature is negatively related to the oxygen solubility of water. Thus, fish exposed to higher temperature could face shortage of dissolved

oxygen content; generally, the toxicity of common pollutants to fish increases with higher temperature. Thus fish, exposed to some kinds of toxic elements such as cadmium, lead and other kind of heavy metals, are unable to metabolise the metals and these accumulate in the fish tissue and other organs (Shafi 2003). Their toxic concentrations in fish tissues can have many negative impacts including the reduction of reproductive capacities, aging of fish and gradual decrease in the number of fish population (Ali 1997).

Sedimentation and siltation is also a common phenomenon for GBM delta region. A part of sediment load of river is deposited on the riverbed and floodplains during the flood season, gradually changing its topography and drainage conditions which results in loss of fish habitats (Khan et al. 1994).

Causes of biodiversity loss

Cause	Effect
Climate change	Sea level rise Salinity intrusion Temperature rise Drought Species composition change to some extent
Development structure (Embankment, bridge)	River bank erosion River bed rise Increase rate of siltation and sedimentation Reduce fish production Destruction of fish habitat
Urbanisation	Change physico-chemical parameter Water pollution Outbreak of diseases Destruction of fish habitat
Increase in population	Overexploitation Disobey fishery act Reduce fish stock
Unplanned land and water use	Reduce water depth Reduce fish stock

INITIATIVES TAKEN BY DIFFERENT STAKEHOLDERS

To prevent crucial loss of fish biodiversity, government agencies of Bangladesh have taken various initiatives in collaboration with a number of NGOs, international NGOs. The fishery department of the country has introduced stocking programme of Small Indigenous Species (SIS) fish fry in open water body with a view to protect and conserve the endangered fish species.

The concerned government agencies have amended different acts on fisheries and tried to update it. Amendment of Fish Preservation and Conservation Act 1950, prohibits utilisation of banned trawl net (mesh size up to 1 centimetres), fixed net of any mesh size, gill net (mesh size up to 4.5 centimetres) for certain period of the year. There is also a provision of punishment for the sellers of undersized fish¹.

Government department has established fish sanctuaries and banned fishing during definite breeding period of different fish species, especially Hilsa fish which help to regain endangered species. For this banned period of fishing, government

agencies provide food which is known as vulnerable group feeding (VGF) and alternative income generating (AIG) elements to fishermen families.

Government facilitated improvement of fish habitat by excavating feeder channels, *Beels* under the wetland biodiversity rehabilitation project and these acts as open fish migration route from river to floodplain for feeding and breeding.

Different NGOs had involved local participatory groups to conserve wetland and biodiversity jointly which are known as co-management. They support vulnerable groups by providing alternative income generating options.

A number of NGOs organise awareness raising programmes such as knowledge sharing meetings, training programmes, seminars, study tours for user groups of water bodies. They make local people convinced to protect water body by taking appropriate initiatives. IUCN, Bangladesh prepared a Red List of vulnerable, endangered and critically endangered fish species in 2000.

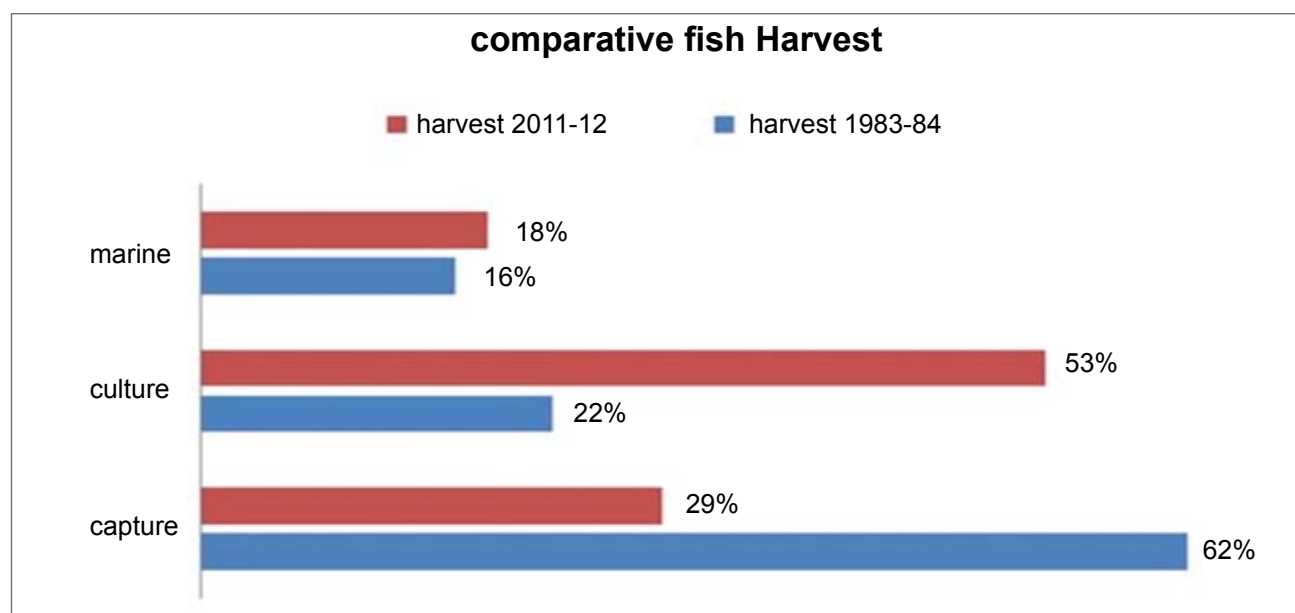


Figure 3: Fish harvest during 1983-84 and 2011-12

¹ Up to the length of different fish species forfeited in the Fish Preservation and Conservation Act, 1950 (Bangladesh Gazette 2013).

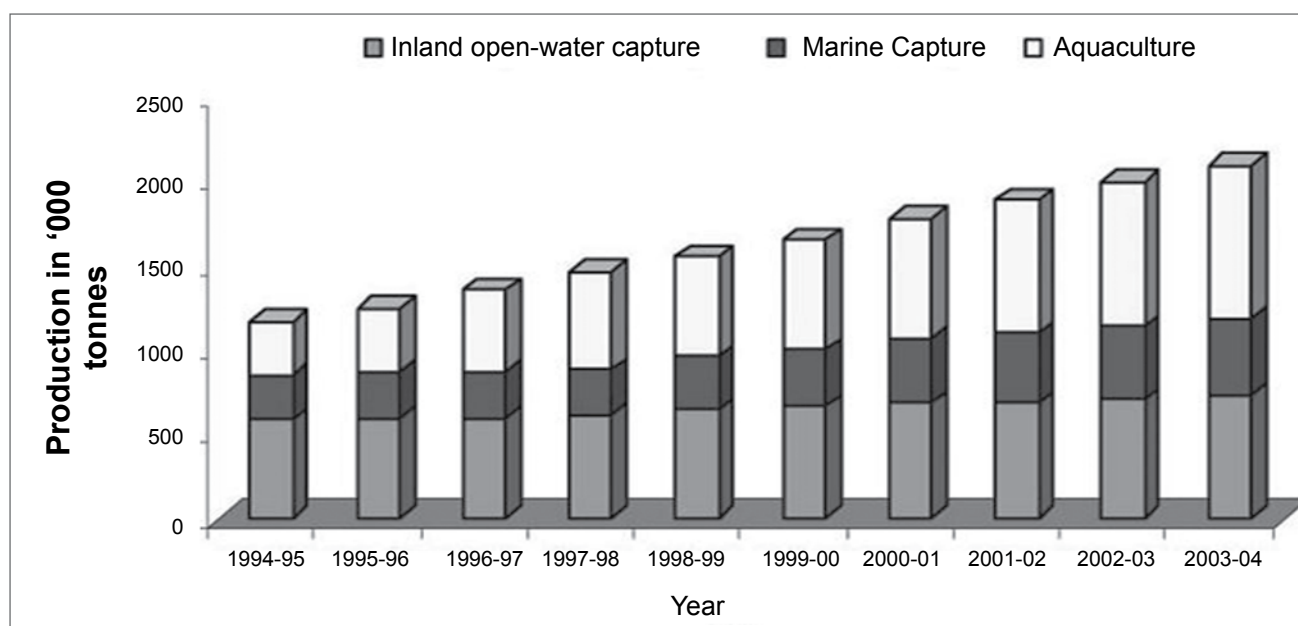


Figure 4: Aquaculture production trend compared to inland and marine capture fishery during 1995–2004

Identified Gaps in the Present Management Policies

As a result of the different initiatives taken by government departments and various NGOs, total fish production was 3.26 million metric ton in 2011-12 where as it was 0.75 million metric ton in 1983-84. In spite of these initiatives, the total catch of inland open water was only 29 per cent of the total catch in 2011-12, whereas it was 62 per cent of it in 1983-84.

Thus, it can be concluded that the percentage of total catch of inland open water capture fish has decreased in the recent years from 62 per cent to 29 per cent (DoF 2013).

Moreover, there is a pressing need for conducting a new survey all over the country to update the Red List and it should be further complemented with advanced research on biodiversity loss.

The country needs a centrally-defined land and water use plan to carefully manage her water and land resources and design the necessary infrastructure for their development in terms of long term sustainability by ensuring a maximisation of benefits, equity and social justice.

Embankments and rural roads are not, in most of the cases, designed with environment-friendly measures. But, it is impossible to break embankments and make the river free. In that case, it is possible to disperse flood water through water control structure sequentially; as a result of it, the river bed will be deepened and the floodplain will be fertile with new silt. For this, we need a combined plan (Rudra 2008).

The user group communities have no control over the decision-making processes related to water management. So there is a need for an integrated water resources management plan to ensure participation of user groups. Creating awareness is also necessary among the users to make them understand the importance of biodiversity of wetlands and to encourage the community not to use detrimental instrument for fishing.

CONCLUSION

Bangladesh is rich in fisheries resources. In the past, inland open water supplied the maximum production of fish. The natural fisheries of inland open waters have increased slightly due to a variety of reasons, whereas production of culture fisheries has increased notably.

The overall management of inland open waters is complex. They are the primary source of fishes to be used as food for the common people of Bangladesh. Therefore, even a small increase in growth in this sector is bound to have a major impact.

In order to ensure proper management of GBM and to reduce fish biodiversity loss, the country needs a unique integrated management system involving different government departments such as Department of Fisheries, Bangladesh Water Development Board, Department of Environment, Local Government and Engineering Department etc and other concerned national and international NGOs.

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Fish Species Diversity in the River Madhumati, Bangladesh

Md. Khalilur Rahman, Jubaida Nasreen Akhter and
Mohammad Ashaf-Ud-Doulah

Bangladesh Fisheries Research Institute,
Mymensingh - 2201, Bangladesh
E-mail: krahman2863@yahoo.com

ABSTRACT

Fish species diversity in the River Madhumati, Bangladesh has been presented in this paper. A total of 92 fish species from 68 genera under 29 families of freshwater and estuarine origin inhabit the River Madhumati; among them carps, barbs and catfishes are dominant.

Out of the total, 56 species are commercially important, and 19 rare in the river. Number of riverine, floodplain, brackish water and migratory species was found as 24, 33, 15 and 20, respectively.

A total of 41 fish species use river as spawning habitat while 36 species use surrounding floodplains and 15 species use estuary as spawning habitat. Fishes from seven trophic guilds and six reproductive guilds were found in this river. Water quality parameters were found suitable for surviving, grazing and spawning of fishes.

Low water flow, siltation, sand bars, over-exploitation and obstructed migration routes are the main causes of fish disappearance and low fish production in the river.

Keywords: River Madhumati, Bangladesh, fish diversity, trophic guild, reproductive guild

INTRODUCTION

Bangladesh is criss-crossed by 761 rivers. The main river systems are the Borak-Meghna, Brahmaputra-Jamuna, Ganges-Padma and other 57 transboundary rivers of the Himalayan origin, flowing through Bangladesh, and emptying into the Bay of Bengal. The total length of all rivers and tributaries is about 24,140 kilometres (Rashid 1991) that covers a catchment area of about 1.61 million square kilometres.

A total of 190 rivers have already become dead (Akhter and Rahman 2008) due to low flow and siltation. River Madhumati (Latitude 22.88°,

Longitude 89.86°), is a principal tributary of River Padma, flowing through southwestern Bangladesh. The course of the Madhumati is wide, long and meandering. The same river is named as the *Gorai* in the upper course and *Madhumati* in the lower course.

The Gorai-Madhumati is one of the longest rivers (306 km) in Bangladesh that flows through Kushtia, Jessore, Faridpur, Khulna, Pirojpur and Barguna districts. The main river bifurcates and rejoins several times as it flows southeast to Mohammadpur upazila in Magura district. From Mohammadpur, it changes its name to *Madhumati*. Tributaries of the River

Madhumati include River Ghagar, River Dari and River Kaliganga.

The Gorai-Madhumati has a flood discharge of nearly 7000 cumec, but in winter its flow goes down up to five cumec. The River Madhumati suffers from low flow conditions and siltation. Due to Farakka Barrage, the river does not get sufficient water during winter months.

Currently, the river flows seasonally in rainy season with surface run-off and flash flood (BWDB 2007). The river has dried up due to siltation at different points. Consequently, fish production, density and diversity have declined severely and many fish species have disappeared from the river (DoF 1997).

Published information on the present status of fish and fisheries of the River Madhumati is scanty. The aim of this study is to generate data on fish and fisheries of the River Madhumati, which might help researchers, policy makers, planners, donors and administrators to formulate guidelines to manage and conserve riverine ecosystem, fish and fisheries of the River Madhumati.

MATERIALS AND METHODS

This study was conducted during March 2006 to December 2011. Four sites such as Magura, Kalna, Mohammadpur and Lohagara on the River Madhumati were selected to collect data on fish species diversity (Figure 1 and Table 1). Fish species diversity data were collected by experimental fishing with *seine net*, *lift net* and *cast net*. Data were also collected from the commercial catch of the local fishermen. In addition, local markets were surveyed to collect riverine fish species.

Data were collected both in the winter and summer months. Fishermen were interviewed to obtain information on rare and disappeared fish species. Moreover, information on fish species diversity in the River Madhumati was collected from different reports (IUCN 2000), journals (Ghosh 2001; Rahman et al. 2003a and b, 2005; Rahman and Akhter 2006, 2007) and books (Hamilton 1822; Jayaram 1981; Shafi and Quddus 1982; Talwar and Jhingran 1991; Rahman 2005). Collected fish species were identified up to species level following the text written by Rahman (2005).



Figure 1: Sampling sites on the River Madhumati, Bangladesh

Table 1: Description of sampling sites on River Madhumati, Bangladesh

Site	Depth (m)	Width (m)	Tidal influence	Erosion	Vegetation
Magura	1.0-1.5	160	X	X	√
Kalna	5.0-60	500	√	√	X
Mohammadpur	4.0-5.0	350	√	√	X
Lohagara	3.5-4.5	300	√	X	X

RESULTS

Water Quality Parameters of the River Madhumati at Different Sites

Water quality parameters of the River Madhumati were found suitable for surviving, grazing and spawning of fishes (Table 2). Dissolved Oxygen (DO) ranged between 4.1 and 6.6 mg l⁻¹, while pH ranged between 6.4 and 7.6. Concentration of total NH₃ (unionised) was nil indicating quality water with a healthy habitat for aquatic organisms including fishes and prawns.

FISH SPECIES DIVERSITY IN THE RIVER MADHUMATI

A total of 92 fish species from 68 genera and 29 families had been recorded from the River Madhumati (Table 3). Among the recorded fish species, 56 were commercially important, out of them 19 were *rare* in the fish catch as per the senior fishers.

An aquatic mammal, the Gangetic dolphin, (*Platinista gangetica gangetica*) was also observed in the River Madhumati. Distribution, density and

Table 2: Water quality parameters of the River Madhumati at different sites

Sites	DO (mg l ⁻¹)	Free CO ₂ (mg l ⁻¹)	NH ₃ (unionized) (mg l ⁻¹)	Alkalinity (mg l ⁻¹)	Total Hardness (mg l ⁻¹)	Conductivity (µS cm ⁻¹)	pH	Water temp. (°C)
Magura	6.1	0.20	0.00	6.1	4.4	120	7.4	26
Kalna	6.6	0.20	0.00	7.1	4.6	110	7.6	28
Mohammadpur	4.1	0.40	0.00	6.0	4.3	150	6.4	25
Lohagara	5.2	0.30	0.00	5.6	4.2	110	7.1	26

Table 3 : Fish species diversity (n=92) in the River Madhumati of Narail District, Khulna Division, Bangladesh

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
Cyprinidae 1*								
1	<i>Amblypharyngodon mola</i> (Hamilton) 1**	Mola	Minor carp	FS	Ci	FB	Ph	P
2	<i>Aspidoparia jaya</i> (Hamilton) 2	Piali / Jaya	Minor carp	RS	NC	RB	Ph	P
3	<i>Aspidoparia morar</i> (Hamilton)	Piali / Morar	Minor carp	RS	NC	RB	Ph	P
4	<i>Barilius barna</i> (Hamilton) 3	Bani koksa	Barilius	RS	NC	RB	Ph	I
5	<i>Barilius vagra</i> (Hamilton)	Koksa	Barilius	RS	NC	RB	Ph	I
6	<i>Brachydanio rerio</i> (Hamilton) 4	Anju	Zebra danio	FS	NC	FB	PI	O
7	<i>Catla catla</i> (Hamilton) 5	Catla	Major carp	MS	C	RB	Br	P
8	<i>Chela laubuca</i> (Hamilton) 6	Kash khaira	Indian glass barb	MS	NC	RB	Br	O
9	<i>Chela cachius</i> (Hamilton) 7	Chep chela	Glass barb	FS	NC	FB	Br	O
10	<i>Cirrhinus mrigala</i> (Hamilton) 8	Mrigel	Major carp	MS	C	RB	Br	B

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
11	<i>Cirrhinus reba</i> (Hamilton)	Raik / Laasu	Minor carp	MS	C/R	FB	Br	B
12	<i>Danio dangila</i> (Hamilton) 9	Napati	Danio	RS	NC	RB	Ph	O
13	<i>Danio devario</i> (Hamilton)	Chebli	Minor carp	FS	NC	FB	Ph	O
14	<i>Esomus danricus</i> (Hamilton) 10	Darkina	Flying barb	FS	NC	FB	Ph	O
15	<i>Labeo rohita</i> (Hamilton) 11	Rui / Rohu	Major carp	MS	C	RB	Br	P
16	<i>Labeo bata</i> (Hamilton)	Bata	Minor carp	MS	C/R	RB	Br	P
17	<i>Osteochilus neilli</i> (Hamilton) 12	Nali	Minor carp	RS	NC	RB	Br	P
18	<i>Puntius chola</i> (Hamilton) 13	Chala punti	Swamp barb	FS	C/R	FB	Ph	H
19	<i>Puntius conchonius</i> (Hamilton)	Canchan punti	Rosy barb	FS	C/R	FB	Ph	H
20	<i>Puntius sarana</i> (Hamilton)	Jait punti	Barb	FS	C/R	FB	Ph	O
21	<i>Puntius sophore</i> (Hamilton)	Jait punti	Barb	FS	C/R	FB	Ph	O
22	<i>Puntius ticto</i> (Hamilton)	Tit punti	Tic-Tac-Toe barb	FS	C	FB	Ph	O
23	<i>Rasbora daniconius</i> (Hamilton) 14	Darkina	Slender rasbora	FS	NC	FB	Ph	P
24	<i>Salmostoma bacaila</i> (Hamilton) 15	Katari	Minor carp	MS	C	RB	Br	O
25	<i>Salmostoma phulo</i> (Hamilton)	Phul chela	Minor carp	MS	C	RB	Br	O
Bagridae 2								
26	<i>Aorichthys aor</i> (Hamilton) 16	Aire	Bagrid catfish	MS	C	RB	Nb	C
27	<i>Aorichthys seenghala</i> (Sykes)	Guizza aire	Bagrid catfish	MS	C	RB	Nb	C
28	<i>Batasio batasio</i> (Hamilton) 17	Tengra	Bagrid catfish	MS	C	FB	PI	C
29	<i>Mystus bleekeri</i> (Hamilton) 18	Gulsha tengra	Bagrid catfish	MS	C	FB	PI	C
30	<i>Mystua cavasius</i> (Hamilton)	Kabashi	Bagrid catfish	MS	C/R	FB	PI	C
31	<i>Mystus tengara</i> (Hamilton)	Bujuri tengra	Bagrid catfish	FS	C	FB	PI	C
32	<i>Mystus gulio</i> (Hamilton)	Guilla/Nuna tengra	Long-whiskered catfish	RS	Ci	FB	PI	C

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
33	<i>Rita rita</i> (Hamilton) 19	Rita	Bagrid catfish	RS	Ci	RB	PI	C
Schilbeidae 3								
34	<i>Ailia coila</i> (Hamilton) 20	Kajuli/Baspata	Schielbid catfish	RS	C/R	RB	PI	C
35	<i>Ailia punctata</i> (Day)	Kajuli	Schielbid catfish	RS	C/R	RB	PI	C
36	<i>Clupisoma garua</i> (Hamilton) 21	Ghaura	Schielbid catfish	RS	C	RB	PI	C
37	<i>Eutropiichthys vacha</i> (Hamilton) 22	Bacha	Schlbeid catfish	MS	C/R	RB	PI	C
38	<i>Silonia silondia</i> (Hamilton) 23	Shilong	Schielbid catfish	RS	Ci / R	RB	PI	C
Pangasiidae 4								
39	<i>Pangasius pangasius</i> (Hamilton) 24	Pangas	Pangas catfish	RS	Ci	RB	PI	O
Siluridae 5								
40	<i>Ompok bimaculatus</i> (Bloch) 25	Kani/Boali pabda	Butter catfish	FS	C/R	RB	PI	C
41	<i>Wallago attu</i> (Bloch & Schneider) 26	Boal	Freshwater shark	MS	C	FB	PI	C
Ariidae 6								
42	<i>Arius gagora</i> (Hamilton) 27	Gagla/Mad/Kata	Gagor catfish	RS	Ci / R	RB	PI	C
Chacidae 7								
43	<i>Chaca chaca</i> (Hamilton) 28	Cheka	Chaca	FS	NC	RB	Nb	C
Anabantidae 8								
44	<i>Anabas testudineus</i> (Bloch) 29	Koi	Climbing perch	FS	C	FB	Ph	I
45	<i>Colisa fasciata</i> (Bloch & Schneider) 30	Kholisha	Giant gourami	FS	C/R	FB	Nb	I
46	<i>Ctenops nobilis</i> (McClelland) 31	Naftani	Gourami	FS	NC	FB	Nb	I
Channidae 9								
47	<i>Channa marulius</i> (Hamilton) 32	Gajar	Snakehead	FS	C	FB	Gr	C
48	<i>Channa gachua</i> (Hamilton)	Cheng	Brown snakehead	FS	NC	FB	Gr	C
49	<i>Channa punctatus</i> (Bloch)	Taki	Snakehead	FS	C	FB	Gr	C
50	<i>Channa striatus</i> (Bloch)	Shol	Snakehead	FS	C	FB	Gr	C
Mastacembelidae 10								
51	<i>Macrognathus aculeatus</i> (Bloch) 33	Tara baim	Spiny eel	FS	C/R	FB	Ps	B

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
52	<i>Mastacembelus pancalus</i> (Hamilton) 34	Guchi	Spiny eel	FS	C/R	FB	Ps	B
53	<i>Mastacembelus armatus</i> (Lacépède)	Shal/Baral baim	Spiny eel	FS	C	FB	Ps	B
Clupeidae 11								
54	<i>Gonialosa manminna</i> (Hamilton) 35	Goni Chapila	Herring	RS	C	RB	Br	P
55	<i>Gudusia chapra</i> (Hamilton) 36	Chapila	Herring	MS	Ci	RB	Br	P
56	<i>Tenuulosa ilisha</i> (Hamilton) 37	Ilish	Indian river shad	RS	Ci	RB	Br	P
Notopteridae 12								
57	<i>Notopterus chitala</i> (Hamilton) 38	Chitol	Featherback	MS	C/R	RB	Nb/Gr	C
58	<i>Notopterus notopterus</i> (Pallas)	Foli	Featherback	FS	C	RB	Nb/Gr	C
Gobiidae 13								
59	<i>Apocryptes bato</i> (Hamilton) 39	Chiring	Goby	BS	NC	EB	Ps	C
60	<i>Glossogobius giurus</i> (Hamilton) 40	Baila / Bele	Tank goby	FS	Ci	RB	Ps	C
61	<i>Parapocryptes batoides</i> (Day) 41	Chewa / Chiring	Goby	BS	NC	EB	Ps	C
62	<i>Pseudapocryptes lanceolatus</i> (Bloch & Schneider) 42	Chewa / Chiring	Goby	BS	NC	EB	Ps	C
63	<i>Boleophthalmus boddarti</i> (Pallas) 43	Dahuk	Mudskipper	BS	NC	EB	Ps	C
64	<i>Brachygobius nusus</i> (Hamilton) 44	Nuna bailla	Golden-banded Goby	RS	NC/R	RB	Ps	C
Engraulidae 14								
65	<i>Setipinna phasa</i> (Hamilton) 45	Phasa	Gangetic hairfin anchovy	BS	Ci	EB	PI	P
66	<i>Setipinna taty</i> (Hamilton)	Teilla phasa	Scaly hairfin anchovy	BS	Ci	EB	PI	P
Mugilidae 15								
67	<i>Liza parsia</i> (Hamilton) 46	Parshay / Parshia	Goldspot mullet	BS	Ci	EB	PI	P
68	<i>Liza subviridis</i> (Hamilton)	Bhangna bata	Greenback grey mullet	BS	Ci	EB	PI	P
69	<i>Mugil cephalus</i> (Hamilton) 47	Khorul bata	Flathead grey mullet	RS	Ci	RB	PI	P
70	<i>Rhinomugil corsula</i> (Hamilton) 48	Khorsul / Kholla	Yellow-tail mullet	RS	Ci / R	RB	PI	P

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
Nandidae 16								
71	<i>Badis badis</i> (Hamilton) 49	Napit koi	Badis / Leaf fish	FS	NC/R	FB	Nb/Gr	C
72	<i>Nandus nandus</i> (Hamilton) 50	Bheda / Mani	Mud perch	FS	C/R	FB	PI	C
Belonidae 17								
73	<i>Xenentodon cancila</i> (Hamilton) 51	Kaikka / Kakila	Niddle fish	FS	C	RB	Br	C
Hemiramphidae 18								
<i>Hemiramphus georgii</i>								
74	Cuvier & Valenciennes 52	Ek thuitta	George's halfbeak	BS	NC	EB	PI	I
Synbranchidae 19								
75	<i>Monopterusuchia</i> (Hamilton) 53	Kuchia	Gangetic mud eel	FS	NC	RB	Ps	C
Cobitidae 20								
76	<i>Nemacheilus savona</i> van (Hasselt) 54	Savon khorka	Loach	MS	Ci	FB	PI	B
77	<i>Nemacheilus corica</i> (Hamilton)	Koirka	Loach	MS	NC	FB	PI	O
Gobioididae / Taenioididae 21								
78	<i>Odontamblyopus rubicundus</i> (Hamilton) 55	Lal chewa	Rubicundus eelgoby	BS	NC	EB	Ps	C
79	<i>Taenioides buechanani</i> (Hamilton) 56	Raja chewa	Goby	BS	NC	EB	Ps	C
Trypauchanidae 22								
80	<i>Trypauchen vagina</i> (Bloch & Schneider) 57	Sada chewa	Burrowing goby	BS	NC	EB	Ps	C
Eleotridae 23								
81	<i>Eleotris fuscus</i> (Bloch & Schneider) 58	Budh bailla / Kuli	Sleeper goby	BS	NC	EB	Ph	O
82	<i>Butis melanostigma</i> (Bleeker) 59	Kalo baila / Kuli	Blackspot sleeper	BS	NC	EB	Ph	O
Sciaenidae 24								
83	<i>Johnius coitor</i> (Bloch) 60	Koitor	Drams / Croakers	RS	NC	RB	Br	C
84	<i>Pama pama</i> (Hamilton) 61	Poa	Drams / Croakers	RS	C	RB	Br	C
85	<i>Otolithes cuvieri</i> (Trewavas) 62	Poa	Lesser tiger-toothed croaker	MS	Ci	MB	Br	C
Tetraodontidae 25								
86	<i>Chelonodon patoka</i> (Hamilton) 63	Sada potka	Gangetic puffer fish	RS	NC	RB	Ph	M

S. N.	Family/ Scientific name	Bangla name	Fish base name	NH	Status	BG	RG	TG
87	<i>Tetraodon cutcutia</i> (Hamilton) 64	Potka	Common puffer fish	FS	NC	FB	PI / Gr	M
Cynoglossidae 26								
88	<i>Cynoglossus cynoglossus</i> (Hamilton) 65	Khongi/ Kukur Jib	Gangetic tonguesole	RS	NC	RB	Ps	B
89	<i>Cynoglossus lingua</i> (Hamilton)	Khongi/ Kukur Jib	Long tonguesole	BS	Ci	EB	Ps	B
Dasyatidae 27								
90	<i>Himantura fluviatilis</i> (Hamilton) 66	Shangus	Gangetic stingray	RS	NC/R	RB	PI	C
Oryziidae 28								
91	<i>Oryzias melanostigma</i> (McClelland) 67	Kanpona	Killifish / Medaka	FS	NC	FB	Ph	I
Cyprinodontidae 29								
92	<i>Aplocheilichthys panchax</i> (Hamilton) 68	Kanpona	Blue panchax	FS	NC	FB	Ph	I

B= Benthivore, BG= Breeding Group, Br= Broadcaster, BS= Brackishwater species, C= Carnivore, Ci= Commercial, EB= Estuarine breeders, FB= Floodplain Breeders, FS= Floodplain species, Gr=Guarders, H= Herbivore, I= Invertivore, M= Molluscivore, MS= Migratory species, NC= Non-commercial, Nb= Nest builders, NH= Natural Habitat, O= Omnivore, P= Planktivore, Ph= Phytophils, PI= Phytolithophils, Ps= Psammophils, R= Rare / Threatened species, RB= Riverine Breeders, RG= Reproductive guild, RS= Riverine species, TG= Trophic guild, * = Serial number of Family, ** = Serial number of Genus.

production of all the collected fish species were low as compared to 30 to 35 years back. It was due to natural and anthropogenic activities. Illegal fishing by destructive gears (*Current jal* or Monofilament gill net) was observed in the River Madhumati.

Current jal, lift net and cast net were found to be used in all the sampling sites of River Madhumati. Current jal (monofilament gill net) is destructive as all sorts of fish are entangled during its operation.

DISCUSSION AND CONCLUSION

The River Madhumati does not get sufficient water flow i.e. eco-flow to maintain its biodiversity including its fishery resources. The Ganges/ Padma, the main contributor of the River Madhumati has been dammed at Farakka, West Bengal, India, to conserve water for maintaining navigability of the Rivers Hooghly and Bhagirathi.

Consequently, water flow decreases to a critical level during winter season causing siltation while it flows with very high water level during rainy season, causing flood and erosion. Low water flow, siltation, sand bars, over-exploitation and obstructed migration routes are the main causes of fish disappearance from the River Madhumati.

Fish fauna of the River Madhumati was poorly explored, as only four sampling sites in the river were surveyed. Intensive survey by different gears should be done round the year throughout the river to update the checklist of piscine fauna of the river.

Fish diversity is decreasing in the rivers of Bangladesh due to habitat degradation (Rahman and Akhter 2007). Therefore, it is recommended to restore degraded habitats for enhancing fish diversity following the International rules for native

and transboundary rivers/ common rivers as per Helsinki Rules 1966.

It is further recommended to undertake detailed studies on geo-morphological, ecological and hydrological features and faunal diversity in order to formulate guidelines for the management, protection and conservation of aquatic resources of the River Madhumati. Eco-flow has to be estimated for different types of fish species.

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Freshwater Fish Distribution Pattern in the Tributaries of Ganges Basin: Application of Multiple Indices and Identifying Priority Sites for Conservation

Uttam Kumar Sarkar, Ajey Kumar Pathak and Prakash Singh

National Bureau of Fish Genetic Resources,
Canal Ring Road, PO. Dilkusha, Lucknow - 226002, Uttar Pradesh, India
E-mail: usarkar1@rediffmail.com, uksarkar@nbfgres.in

ABSTRACT

Rivers and tributaries of the Ganges basin are facing several threats due to indiscriminate and illegal fishing, pollution, water abstraction, flow regulation, siltation and invasion of exotic species and causing reduction in fish diversity and changing distribution pattern.

In this connection, important tributaries of the river basin in the Gangetic plains were studied, and the distribution pattern of fish were determined using multiple indicators. The geographical information system (GIS) was used for mapping and analysing the data. The assessment also indicated that the tributaries of the Ganges basin are particularly relevant because they comprise several attributes associated with ecosystems susceptible to conservation: high species richness with most diverse fish fauna which represents rich diversity of native belonging to 74 genera under 26 families.

The analysis highlights the fact that fish species living in these tributaries are significantly varied and sensitive to anthropogenic disturbance. Based on this study, potential sites could be identified for sustainable management.

Keywords: Fish biodiversity, Ganges basin, distribution, multiple indices, GIS

INTRODUCTION

Throughout the world, freshwater environments are experiencing serious threats to both biodiversity and ecosystem stability (Suski and Cooke 2006) and biodiversity is the main issue of the 21st century, which is under threat worldwide (Wilson 2000; Bowker 2005). The freshwater biodiversity is declining at an alarming rate, far greater than that which has been noted for even the most affected terrestrial systems (Dudgeon et al. 2006).

The Ganges basin in India has suffered a lot due to indiscriminate and illegal fishing, pollution, water abstraction and invasion of exotic species which have not only affected the health of the ecosystem but also its constituent biodiversity (De Silva and Abery 2007, Sarkar et al. 2012). Assessing the ecosystem of Ganges basin is much important and it is a subject of great challenge.

Recent studies in some major tributaries of the basin in north of India such as Gomti, Ghaghara, Betwa and Gerua revealed the presence of rich spectrum

of threatened, migratory and commercially important fishes with wide distribution in terms of species, families and genera (Joshi et al. 2009; Lakra et al. 2010; Atkore et al. 2011; Sarkar et al. 2009, 2012, 2013).

But, recent studies exhibited that the fish fauna in these rivers are experiencing considerable threats due to several anthropogenic factors (Lakra et al. 2010). Thus, in order to develop and test hypotheses about processes responsible for decline in fish biodiversity and set conservation priorities, it is essential to introspect into the spatial variation of the fish diversity and distribution in the tributaries of Ganges basin, Uttar Pradesh.

MATERIALS AND METHODS

Survey and sampling was carried out in the different locations of the rivers Gomti, Ghaghra, Betwa, Ken and Rapti (Figure 1). Effort was made to cover all the stretches of these rivers and experimental fishing was carried out both by members of the project team as well as by using the expertise of local fisher folk. Different types of gears of varying mesh sizes such as cast nets, gill nets, drag nets and other local contrivances were used for collecting fishes.

Representative specimens ($n = 10$) of all fishes were fixed in 10 per cent formaldehyde and transferred to the laboratory for storing in glass bottles. Fish markets

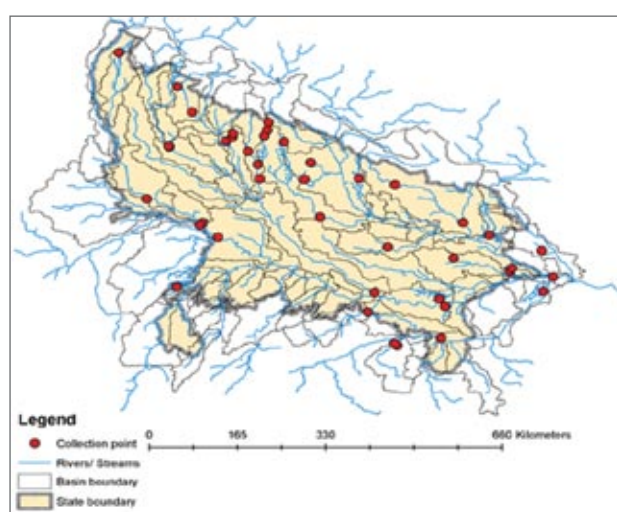


Figure 1: Sampling sites for the collection of fish samples in different rivers/ tributaries

and landing centres attached to these rivers were also visited to observe for the presence of species which were not caught during our experimental fishing.

The collected fish specimen were identified by following the works of Srivastava (1980), Talwar and Jhingran, (1991), Jayaram (1999) and validated as per Fish base (Froese and Pauly 2010). Data regarding threats faced by the fish fauna were obtained from both primary (direct observations and interactions with local stakeholders and fishermen) and secondary (journal articles, reports, books, and internet search tools). Fishes were measured using dial calipers to the least count error 0.1 mm. Counts and measurements were taken on the left side of the specimen. The geographical position of the selected sampling locations was recorded using Global Positioning System (GPS) receiver. ArcGIS with ARCInfo 10.0 software of ESRI Inc. USA was used for spatial data set preparation and mapping.

CALCULATION OF BIOLOGICAL INDICES

Different biological indices were calculated during studies which are as follows.

a: Community Dominance Index (CDI) =

$$(Y1 + Y2 / Y) \times 100$$

Where:

$Y1 + Y2$ = Abundance of two dominant species
 Y = Total species abundance

b: Relative abundance (RA) = N/S

Where:

N = Total number of individuals of species
 S = Total number of fishes

c: Diversity Index (Shannon and Wiener, 1963) (H')

$$= -\sum p_i \ln p_i$$

Where:

p_i = N_i/N (N_i = Total number of individuals of species i)

N = Total No. of individuals of all species

H' = Diversity index

RESULTS

Fish Diversity

Systematic explorations of the freshwater fish diversity in the rivers of Uttar Pradesh represented 124 indigenous fish species belonging to 74 genera and 28 families. Among the studied rivers, river Ganges represented highest diversity (90 fish species) followed by the river Ghaghara and Gerua in which 85 species were recorded.

Figure 2 shows the diversity of fish species recorded in the different rivers. The Shannon-Weiner diversity index indicated a distinct relationship with overall species richness for all the studied rivers. The Shannon-Weiner biodiversity index of 12 rivers showed highest diversity of species in the river Ganges (4.21) followed by the river Gerua (4.17), Ghaghara (4.16) and Gomti (4.10).

Distribution of Families and Genera

The freshwater fish fauna in the studied rivers represented rich families and genera diversity which was found distributed throughout in all the rivers. The most abundant family was Cyprinidae (52 species), followed by Bagaridae (10 species), Sisoridae (eight species) and Channidae (six species). Cyprinids

contributed almost 41.9 per cent of the total fish diversity followed by Bagaridae (8.06 per cent), Sisoridae (6.45 per cent species) and Channadae (4.8 per cent).

Out of the 27 families recorded, the highest families in terms of number were recorded from the River Ganges followed by the rivers Ghagra, Gerua, Gomti and Betwa. In the River Gomti, 16 families were recorded and they were found evenly distributed in all the sampling locations whereas 14 families were recorded in the River Ganges. The River Gerua reported 12 families and the River Betwa represented only eight families.

Abundance and Community Dominance

Relative abundance of species is one of the major components of biodiversity and refers to the evenness of distribution of individuals among species in a community. The study revealed that 93 species had an abundance of around 100 individuals out of the total samples collected. The Community Dominance Index (CDI) showed differences in the abundance of fish communities among sampled rivers (Figure 3) and recorded highest in the River Ganges (52.34 per cent) followed by Ghaghara (41.2) and Gerua (41.2).

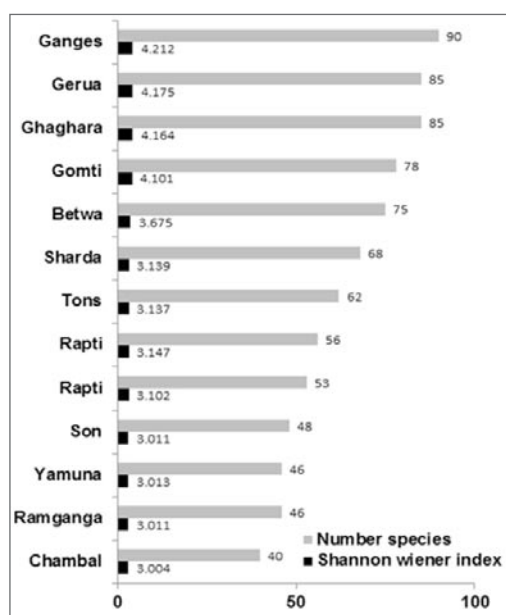


Figure 2: Number of species recorded and Shannon-Weiner diversity index of the studied rivers

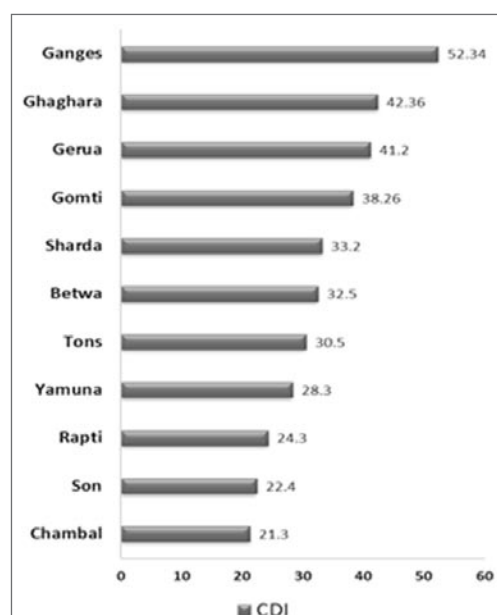


Figure 3: Community dominance index of different rivers

The relative abundance of some major groups revealed that the major Carps comprised of about four per cent whereas other Carps comprised of 24 per cent followed by Catfishes (54 per cent) and other small indigenous fishes (45.5 per cent).

Occurrence and Distribution

The occurrence frequency and per cent times were recorded for few important species (n=25). Species that showed considerable occurrence were *Clupisoma garua*, *Rita rita*, *Sperata aor*, *S. seenghala*, *Bagarius spp*, *Labeo boggut* (Figure 4).

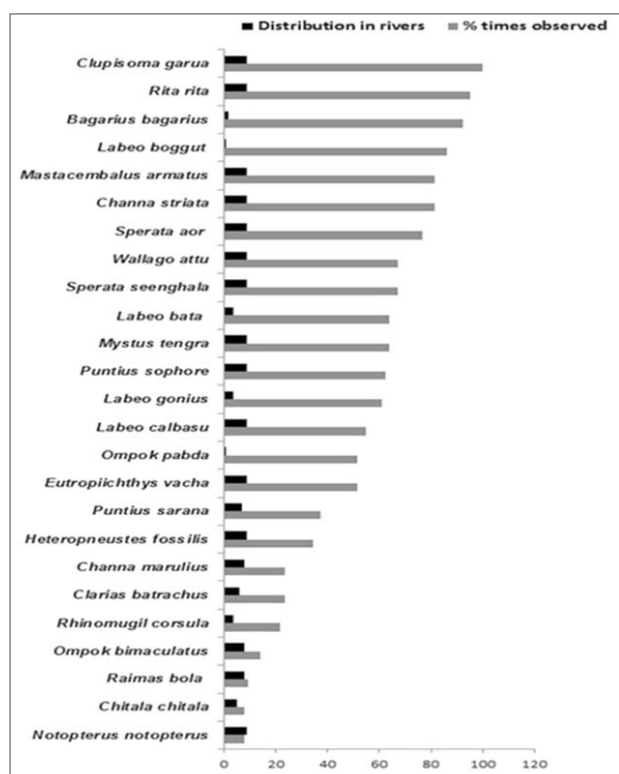


Figure 4: Species occurrence (n = 25) in 12 major rivers and per cent of times observed during the study period

Besides, *Mastacembalus armatus* and *Channa striatus* showed more than 75 per cent occurrence frequency in eight rivers. Some of the species that showed least frequency of occurrence were *Labeo bata*, *Chitala chitala*, *Ompok bimaculatus* and *Notopterus notopterus*.

The distribution pattern of the total species (n= 124) revealed that a total of 37 species showed wide distribution and found common in 11 rivers viz. Gomti,

Betwa, Ghaghara, Ganges, Son, Tons, Yamuna, Sharda, Gerua, Rapti and Chambal whereas species like *Glyptothorax brevipinnis*, *Amblyceps mangois*, *Silonia silonidia* and *Tetraodon cutcutia*, *Tetraodon fluvitaus*, *Botia dario*, *B. lohachata*, *Esomus danricus*, and *Barilius barna*, *Bagarius yarelli* were recorded with restricted distribution.

Similarity in Species Composition

The similarities in species compositions as per Jacquard's index in eleven different rivers depicted that Chambal and Son rivers were the most similar in their species composition whereas Betwa and Rapti were least similar (Figure 5). The three groups were differentiated of which Gerua and Sharda were in group 1. The rivers Rapti, Tons, Yamuna, Chambal, Son, Ganges, Ghaghara and Betwa belonged to group 2 whereas the River Gomti was in group 3.

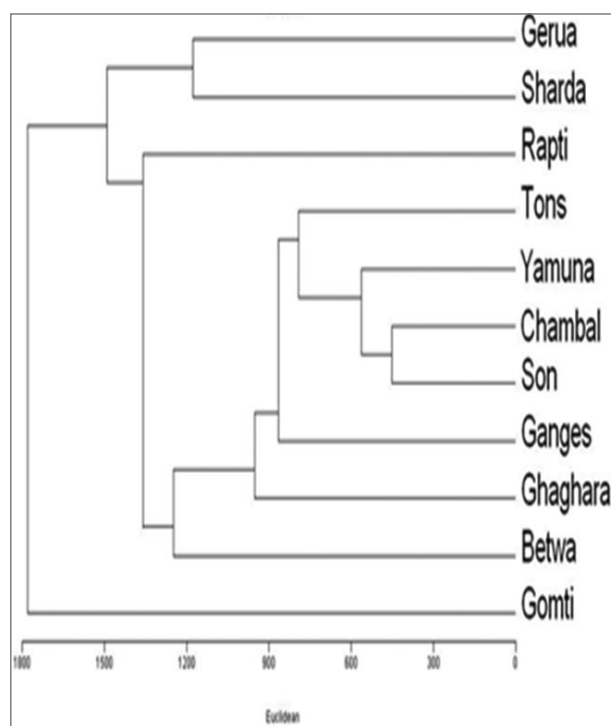


Figure 5: Similarity in species composition in different rivers

Sites Prioritisation

The three large tributaries of the Ganges basin in Uttar Pradesh viz. Ken, Betwa and Gomti were assessed for determining potential areas for conservation and restoration based on indices like rarity (RI) and origin index (OI).

The values of each index between zones as per Bray-Curtis similarity were compared. Based on the composition of the fish fauna and Bray-Curtis analyses, the study sites in the three rivers form three groups with a similarity cut-off value of 0.6. Group I was formed by study sites: K2, B3, B2, K4, G1, K3 and G3. Group II was formed by the sites K5, B5, B4 and G2 while group III was formed by K5, B5, B4 and G2 (Figure 6).

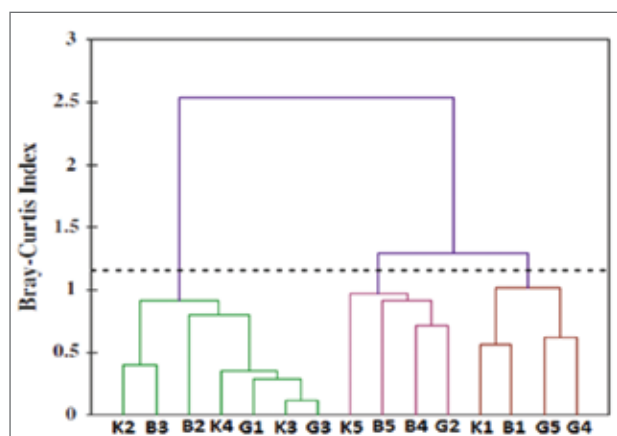


Figure 6: The similarity dendrogram of different sampling sites

GIS Mapping

Geographical information system (GIS) allows one to assess the spatial influence of physiological and climatic characteristics on fish distribution. This information will provide managers with the tools to evaluate the importance of particular parameters on the distribution of fish species over a wide range of rivers and its tributaries of Uttar Pradesh.

The occurrence points provided sufficient information on the distribution of Indian fish after mapping and it was possible to identify the diversity of fish according to eco-region, river basin and political boundary at a coarse scale.

GIS maps were prepared by taking into account the different sampling locations in the different rivers and a schematic representation was laid down after analysis that represented species diversity in the different rivers and tributaries flowing through different districts of Uttar Pradesh (Figure 7).

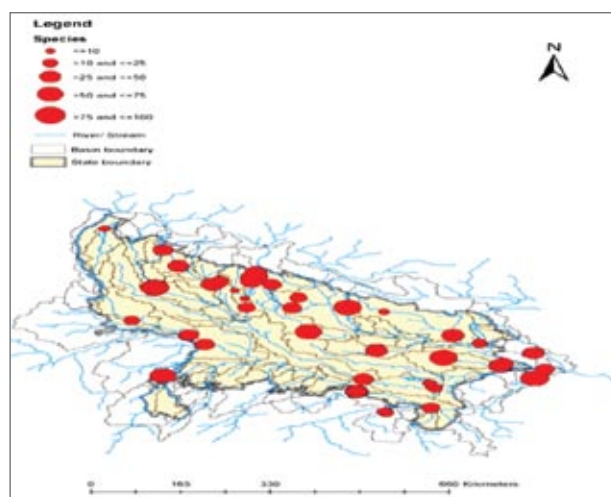


Figure 7: Diversity of freshwater fish species in different rivers arranged in GIS

DISCUSSION

In this study, recording and validation of 124 fish species representing 74 genera and 28 families in the tributaries of the river Ganges is comparable to the fauna of other adjoining states such as Bihar (Srivastava 1988), and Madhya Pradesh (Lakra and Sarkar 2007).

In earlier studies, the significant contribution in exploring freshwater fish fauna of Uttar Pradesh was made by Srivastava (1968). A recent study by Sarkar et al. (2012) reports that the Gangetic system alone accounts 143 fish species and contributes around 20 per cent of freshwater fish of the total fishes reported in India.

In addition, some of the major tributaries of river Ganges basin such as Gomti, Ghaghara, Betwa, Ramganga, Ken and Gerua also harbors rich species spectrum of migratory and commercially important fishes with wide distribution of species, families and genera (Sarkar et al., 2008, 2010, 2012, Joshi et al. 2009 and Lakra et al. 2010).

The above report on fish diversity shows distribution of 62 species in the River Ghagra, 63 in Betwa, 68 in Gomti, 57 in Ken, 43 in Ramganga and 46 from the lake of Samaspur Bird Sanctuary in Uttar Pradesh. Other studies in other tropical rivers of India

revealed that the threatened species recorded in the drainage basins were facing various anthropogenic disturbances and their lower abundance could be reached to the extinction for those rivers in the near future (Lakra et al. 2011).

The higher diversity index in the River Ganges followed by the rivers Gerua and Ghaghra shows the existence of a balance between total species and total individual of every species. The rich fish diversity in these rivers may be attributed to the significant contributions of larger numbers of tributaries and presence of protected areas. Sarkar et al. (2007) reported a significant increase in species richness, presence of many threatened species, and distinct stocks in the water bodies of the wildlife-protected areas than the fished areas of a lotic water body.

The present study showed a changing pattern in the bio-geographical distribution of the several freshwater fishes which might be due to the changes in the hydrology as well as increase in the water temperature possibly because of global warming (Kannan and James 2009).

This study revealed that many of the commercially important species showed different level of abundance pattern. Interestingly, considerable occurrence of some species viz. *Clupisoma garua*, *Rita rita* and *Bagarius bagarius*, *Mastacemblus armatus*, *Channa striatus* and *Labeo boggut* was recorded during the study period. However, *Chitala chitala* and *Ompok pabda*, were recorded in low abundance in most of the tributaries which may be due to several anthropogenic factors.

Planning conservation of freshwater fish biodiversity at regional scale requires mapped information on current pattern of fish diversity and conservation targets at a relatively fine scale (Fitz Hugh 2005). The developed schematic representation in this study represented species in different rivers and tributaries flowing through different districts of Uttar Pradesh indicating variation of species occurrence among different rivers.

The researchers have used GIS not only in documenting and mapping the biodiversity but also locating potential fishing grounds, determining fishing patterns, identifying and prioritizing conservation areas, examining aquatic habitat and underlying habitat characteristics for management and restoration, managing resources and many more. Identification of critical habitat is a priority to many fisheries managers, especially those trying to manage large river fisheries resources (Raibley et al. 1997).

Thus, this study presents knowledge about the current pattern of freshwater fishes, their distribution, and abundance, new distribution of species and potential areas/ rivers in the state of Uttar Pradesh. The information on species composition of each river supports an exceedingly rich species spectrum of threatened, migratory and commercially important fishes with wide distribution of species, families and genera.

In addition, the study represented new areas which were less well -known till date in the northern part of India that have emerged as high quality examples of biodiversity rich areas. (e.g. Chambal, Sone, Tons and Rapti rivers etc.). Information on the abundance pattern, community dominance and similarity composition are intended to facilitate a coordinated approach to freshwater biodiversity protection by providing the baseline data for future assessments of conservation action.

ACKNOWLEDGEMENTS

The authors would like to thank the Director, National Bureau of Fish Genetic Resources, Lucknow, for providing the necessary facilities and suggestions. The authors are also indebted to Uttar Pradesh Biodiversity Board, Lucknow, for providing financial assistance to carry out the biodiversity and exploration study.

The authors would also like to acknowledge the contribution of all the research scholars involved in the project in carrying out explorations.

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Freshwater Fish Diversity of the Ganges-Brahmaputra-Meghna River Basin

W. Vishwanath

Department of Life Sciences,
Manipur University, Canchipur - 795003,
Imphal, Manipur, India
E-mail: wvnath@gmail.com

ABSTRACT

The Ganges-Brahmaputra-Meghna River basin consisting of the freshwater eco-regions, viz., Ganges delta and plain, Ganges Himalayas foothills, upper and the middle Brahmaputra has a species richness of about 500 freshwater fish species. Many of them are important food fishes and are potential candidates as ornamental fishes. More than 20 genera of fishes are endemic to this region.

The IUCN has found four species of fishes critically endangered, 11 endangered and 25 vulnerable in the Ganges-Brahmaputra-Meghna basin. As many as 27 per cent of the species are found to be data deficient, some of these might turn out to be under threat category after obtaining more data.

While the freshwater biodiversity is in crisis because of pollution, invasive species, habitat degradation, over-exploitation and the climate change, the vision of the Central Electrical Authority to tap majority of hydropower for the country from these basins by flow modification is a great concern to the conservationists.

Key words: Fish fauna, Ganges-Brahmaputra-Meghna, threats

INTRODUCTION

The Eastern Himalaya region, which is drained by the rivers of the Ganges-Brahmaputra-Meghna River basins, is a biodiversity rich bio-region. The diversity is attributed to the recent geological history and the Himalayan orogeny which played an important role in the speciation and evolution of groups inhabiting mountain streams (Kottelat 1989).

In addition, the region has unique geomorphology, consisting of the hills, plateaus and valleys, resulting in the occurrence of a variety of torrential hill streams, rivers, lakes and swamps, drainage pattern which include the Ganges, the Brahmaputra and the Meghna systems. Abell et al. (2008) presented a global map of 426 freshwater eco-regions based on the distributions and compositions of the freshwater

fish species which represents an invaluable resource for global and regional conservation planning efforts.

The region falls under the *Ganges Delta and Plain*, *Ganges Himalayan Foothills* which are expected to contain respectively 28-40 endemic freshwater fish species and *Upper Brahmaputra*, *Middle Brahmaputra* ecoregion, 20-27 respectively as inferred from Abell et al. (2008).

The evolution of the river drainages in this part of the world has been the subject of several studies that utilise geological evidence to reconstruct the palaeodrainage patterns. Molecular phylogenetic studies of the fishes of this region (e.g. Guo et al. 2005; Ruber et al. 2004) have indicated that vicariance

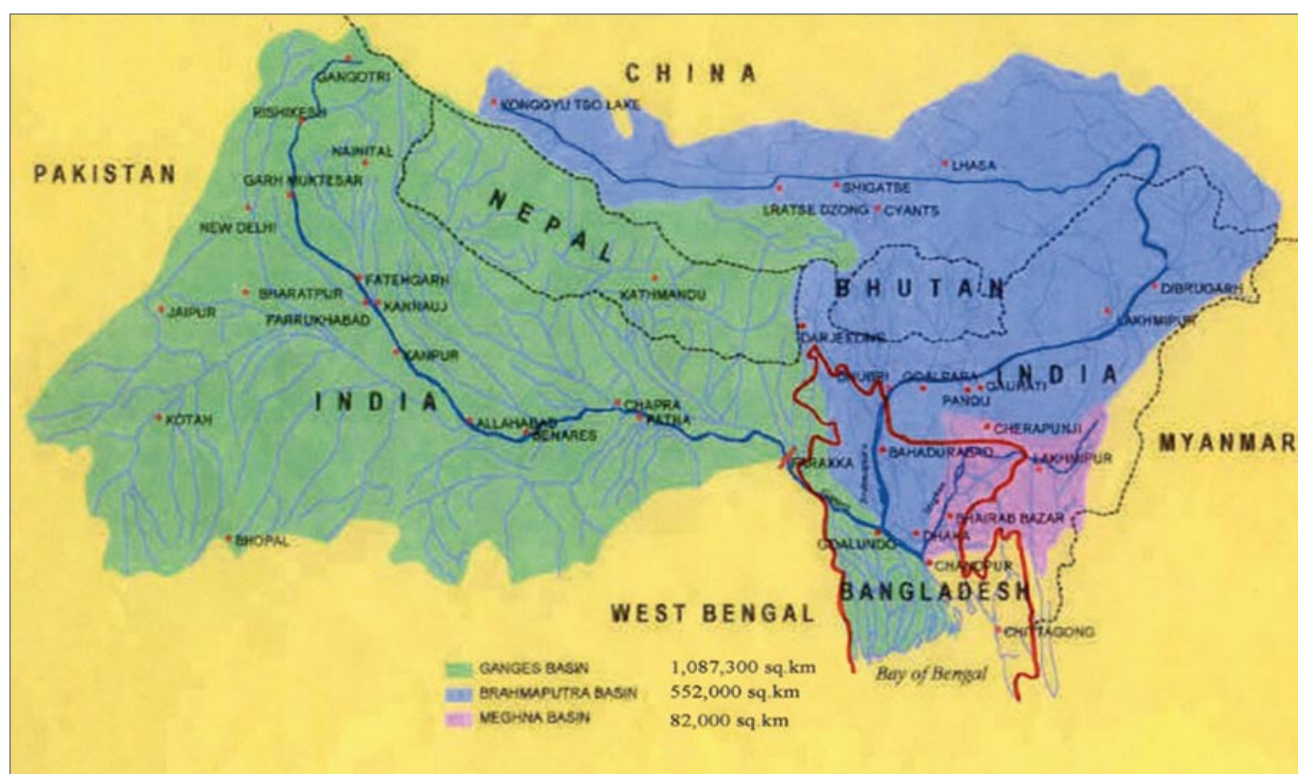


Figure 1: Ganges-Brahmaputra-Meghna basin © IUCN

events in the Miocene (23.0 to 5.3 million years ago) may have played a substantial role in shaping the current distribution pattern of the freshwater fishes of the region.

MATERIALS AND METHODS

Fish collection trips were conducted in the different rivers of the Ganges-Brahmaputra-Meghna basins. For sampling of fishes, electrofishing equipment was used. Fishes caught by local fishing techniques were also collected. Fishes were preserved in 10 per cent formalin and deposited in the Manipur University Museum of Fishes (MUMF).

Fishes were identified using original references and comparison with types and non-types in the Zoological Survey of India (ZSI), Kolkata, ZSI-Eastern Regional Station, Shillong and MUMF. New species were described. The new species described from the GBM basin are listed here based on published information. Endemic genera of fishes are identified and IUCN threat criteria of the fishes are identified based on Vishwanath et al. (2010).

RESULTS

Since the pioneering work of Hamilton (1822) on the fishes of the river Ganges and its tributaries, who discovered about one hundred new species from the Ganges and its tributaries, hundreds of research papers have been published describing hundreds of new fish species.

Further species inventory by Gray, J.E., McClelland, J., Muller, S. & Troschel, F.H.; Playfair, R.L., Chaudhuri, B.L., Menon, A.G.K., Hora, S.L. & Mukerji, D.D.; Prasad, B., Jayaram, K.C., Barman, R.P., Vishwanath, W. and co-workers and some workers from elsewhere have added new species to the list of fishes of the region.

However, the fish fauna is still in the discovery survey state. Many of the remote hilly areas have never been surveyed by an ichthyologist. Many new species have been discovered in the past few years. These are arranged family-wise in phylogenetic order. Genera and species are arranged alphabetically as follows:

Cyprinidae

<i>Garra arunachalensis</i> Nebeshwar & Vishwanath 2013	Brahmaputra
<i>G. birostris</i> Nebeshwar & Vishwanath 2013	Brahmaputra
<i>G. quadratirostris</i> Nebeshwar & Vishwanath 2013	Brahmaputra

Psilorhynchidae

<i>Psilorhynchus amlicecephalus</i> Arunachalam et al. 2007	Meghna
<i>P. arunachalensis</i> (Nebeshwar et al. 2007)	Brahmaputra

Nemacheilidae

<i>Physoschistura dikrongensis</i> Lokeshwor & Vishwanath 2012	Brahmaputra
<i>P. tuivaiensis</i> Lokeshwor, Vishwanath & Shanta 2012	Meghna
<i>Schistura fasciata</i> Lokeshwor & Vishwanath 2011	Meghna
<i>S. obliquofascia</i> Lokeshwor et al. 2012	Ganges
<i>Schistura ferruginea</i> Lokeshwor & Vishwanath 2013	Meghna
<i>S. papulifera</i> Kottelat et al. 2008	Meghna
<i>S. paucireticulata</i> Lokeshwor, Vishwanath & Kosygin 2013	Meghna

Siluridae

<i>Pterocryptis barakensis</i> Vishwanath & Nebeshwar 2009	Meghna
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Sisoridae

<i>Erethistoides senkhiensis</i> Tamang, L. et al. 2008	Brahmaputra
<i>Exostoma barakensis</i> Vishwanath & Joyshree 2007	Meghna
<i>Glyptothorax pantherinus</i> Anganthoibi & Vishwanath 2012	Brahmaputra
<i>Oreoglanis majusculus</i> Linthoingambi & Vishwanath 2011	Brahmaputra
<i>Pseudecheneis sirenica</i> Vishwanath & Darshan 2007	Brahmaputra
<i>Pseudolaguvia assula</i> Ng & Conway 2013	Meghna
<i>P. ferruginea</i> Ng 2009	Brahmaputra
<i>P. ferula</i> Ng 2006	Brahmaputra
<i>P. flavida</i> Ng 2009	Meghna
<i>P. innornata</i> Ng 2005	Meghna
<i>P. muricata</i> Ng 2005	Meghna
<i>P. spicula</i> Ng & Lalramliana 2010	Meghna
<i>P. vigrulata</i> Ng & Lalramliana 2010	Meghna
<i>P. viriosa</i> Ng & Tamang 2012	Brahmaputra
<i>Sisor barakensis</i> Vishwanath & Darshan 2005	Meghna

Badidae

<i>Badis dibruensis</i> Geetakumari & Vishwanath 2010	Brahmaputra
<i>B. singenensis</i> Geetakumari & Kadu 2011	Brahmaputra
<i>B. tuivaiei</i> Vishwanath & Shanta 2004	Meghna

Ambassidae

<i>Parambassis bistigmata</i> Geetakumari 2012	Brahmaputra
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Channidae

<i>Channa melanostigma</i> Geetakumari & Vishwanath 2011	Brahmaputra
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The region has also some endemic genera of fishes as follows:

<i>Aborichthys</i> Chaudhuri	<i>Mesonoemacheilus</i> Banarecu & Nalbant
<i>Acantopsis</i> va Hasselt	<i>Myersglanis</i> Hora & Silar
<i>Akysis</i> Blyth	<i>Neonoemacheilus</i> Zhu & Guo
<i>Amblyceps</i> Blyth	<i>Olyra</i> McClelland
<i>Badis</i> Hamilton	<i>Oreoglanis</i> Smith
<i>Bangana</i> Hamilton	<i>Parachiloglanis</i> Wu, He & Chu
<i>Chaca</i> Gray	<i>Physoschistura</i> Banarecu & Nalbant
<i>Conta</i> Hora	<i>Poropuntius</i> Smith
<i>Creteuchiloglanis</i> Zhou, Li & Thomson	<i>Pseudecheneis</i> Blyth
<i>Erethistes</i> Muller & Troschel	<i>Pseudolaguvia</i> Misra
<i>Erethistoides</i> Hora	<i>Psilorhynchus</i> M'Clelland
<i>Exostoma</i> Blyth	<i>Semiplotus</i> Bleeker

However, correct species identification is the basic starting point for any type of biological study, particularly one on wild populations. For research, it is important that each name applies to only a single species, and each species is known by a single name (Rainboth 1996).

In other words, it makes the diversity accessible to other biological disciplines and remains the basis for further study (Wilson 2000). About 1.7 million species have been named since Linnaeus and it is estimated that only around five to 10 per cent of the world's biota has been described so far.

Fortunately, during the last years, some progress has been made. The general interest about biodiversity conservation, the advances of internet and web pages, the progress in molecular techniques, the development of statistics in phylogeny, and the new taxonomic funding initiatives and global projects are giving some light.

Taxonomy is getting fashionable again and topics such as Phylocode and Bar Coding are among the most controversial and discussed subjects in taxonomy today (Guerra-García et al. 2008).

Biodiversity within freshwater ecosystems in the Eastern Himalaya region is both highly diverse and of great regional importance to livelihoods. However,

development activities are not always compatible with the conservation of this diversity, and the ecosystem requirements of biodiversity are frequently not considered in the development planning process.

One of the main reasons cited for inadequate representation of biodiversity is a lack of readily available information on the status and distribution of inland water taxa. The aim of the assessment is to present the conservation status and distribution of freshwater fish diversity to inform conservation and development policy and decision making across the region (Allen et al., 2010).

As many as 520 freshwater fish species of the Eastern Himalaya were assessed for conservation status. In addition to the Ganges-Brahmaputra-Meghna, species from Kaladan and Chindwin basins were also assessed. The assessment found four species of fishes critically endangered, 11 endangered and 24 vulnerable in the Ganges-Brahmaputra-Meghna basin.

Critically Endangered

Schizothorax integrilabiatus Xixong Lake, Tibet, China

Schizothorax nepalensis Rara Lake, Nepal

S. raraensis Rara Lake, Nepal

Schistura papulifera Meghalaya, India

Endangered

Amblyceps arunchalensis Brahmaputra
Badis tuivaiei Brahmaputra
Clarias magur Ganges-Brahmaputra
Devario horai Brahmaputra
Lepidocephalichthys arunachalensis Brahmaputra
Pillaia indica Brahmaputra
Pterocryptis barakensis Brahmaputra
Schistura minutus Brahmaputra
Schistura sijuensis Brahmaputra
Schistura tigrinum Brahmaputra
Tor putitora Ganges-Brahmaputra

Vulnerable

Aborichthys garoensis Brahmaputra
Gymnocypris scleracanthus Brahmaputra
Aborichthys tikaderi Brahmaputra
Bangana almorae Brahmaputra
Barilius chatricensis Brahmaputra
Nemacheilus pavonaceus Brahmaputra
Barilius dimorphicus Brahmaputra
Physoschistura elongata Brahmaputra
Pseudecheneis sirenica Brahmaputra
Botia rostrata Brahmaputra
Cirrhinus cirrhosus Brahmaputra
Puntius chelynoides Ganges
Danio jaintianensis Brahmaputra
Devario anomalus Brahmaputra
Devario assamensis Brahmaputra
Puntius shalynius Brahmaputra
Semiplotus semiplotus Ganges-Brahmaputra
Schistura chindwinica Brahmaputra
Schistura inglisi Brahmaputra
Schistura reticulofasciata Brahmaputra
Schistura singhi Brahmaputra
Schizothorax richardsonii Ganges
Gymnocypris dobula Brahmaputra
Sisor barakensis Brahmaputra

Dudgeon et al. (2006) pointed out the global freshwater biodiversity under five headings: overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species.

Their combined and interacting influences have resulted in population decline and range reduction of freshwater biodiversity worldwide. In addition, the global climate change has also given more impact on fishes, particularly on the cold water fishes, whose habitat have become restricted and warm water fishes have invaded their territory.

Northeast India is one of the potential hydro-power regions of the country. India's vision to be a developed nation by 2020 is hugely dependent on uninterrupted supply of power and the North-Eastern region which has the huge water resources carried by the Brahmaputra-Barak would play a vital role.

The surface water resource of the region is near about 652.3 billion cubic meters that shares 34 per cent of country's total water wealth whereas this entire region occupy only eight per cent of Indian land mass. Hydro potential of this region is 63257 megawatt, but only 1911 megawatts has been harnessed so far — a mere 3.02 per cent of its hydro potential.

Harnessing this huge hydro potential, the Northeast could become, "The Power House of India" (Das 2013). The region has the Himalaya and Indo-Burma hotspots and also been identified as the freshwater biodiversity hotspot (Kottelat and Whitten 1996). While the taxonomists are yet to discover many undescribed species and conservationists are planning to identify species under threat, flow modifications on these major river systems would bring drastic impacts on the existence of the endemic species.

Over the years, the fish catch per kilometre stretch in the river has declined significantly and species composition has changed more in favour of non-major carp and miscellaneous species. It has also been observed that some exotic fishes have gained a foothold in the ecosystem at favourable stretches, where flows have drastically reduced as a result of abstraction of water from the main river.

Changing hydrology, apart from deteriorating environmental conditions, has been to a large extent responsible for change in the fishery scenario in the river. This change has also affected the income levels of riparian fishers.

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Ichthyofaunal Diversity of the Ganges River System in Central Himalayas, India: Conservation Status and Priorities

A. K. Singh, Prem Kumar and Shahnawaz Ali

Directorate of Coldwater Fisheries Research,
Bhimtal - 263136, Nainital, India
E-mail: aksingh56@rediffmail.com

ABSTRACT

The ichthyofaunal diversity of different river stretches of the Ganges River System in the central Himalayas was studied. Data on the fish diversity in different streams of the Ganges revealed the presence of 52 fish species in the Alaknanda; 32 in Bhagirathi; 29 in Bhilangana; 48 in Pinder and 41 in Ramganga streams. Considering the various threats such as illegal methods of fishing, poisoning, dynamiting, biological invasions, a species specific long term conservation plan has been proposed in this paper, highlighting the conservation priorities. Habitat improvement and protection of nursery and spawning grounds, stock enhancement through natural stocking, strict enforcement to prevent illegal introductions and destructive fishing methods are some of the important conservation measures suggested.

Key words: Ichthyofaunal diversity, Ganges River system, Central Himalayas, exotic fishes

INTRODUCTION

The mighty River Ganges rises in the Garhwal Himalayas of Uttarakhand; it flows south and east through the Gangetic plain in North India and drains into the Bay of Bengal. The River occupies a unique position and therefore, has been bestowed with the status of a national river because of its geographical, historical, socio-cultural and economical importance (MoEF 2009).

The Ganges is the global frontier of rich freshwater fish diversity having endemism (Sarkar et al. 2012; Bhatt et al. 2012). The riverine ecosystem is the biological engine for life and livelihood of local communities. Ecological information on aquatic resources, in terms of fish diversity, is still lacking in the area of sustainable fishery resource utilisation planning.

Species and habitat as concepts have been accorded importance quite recently, when fish biodiversity and their conservation priority are receiving attention. In the present paper, we describe the fish diversity in different streams of the Ganges in central Himalayas and propose the conservation measures, including checking the illegal methods of fishing such as poisoning and dynamiting, management of biological invasions, identifying ecologically significant areas, and crucial breeding habitats for habitat specific and species specific long term plan.

STUDY AREA AND METHODS

The Ganges in the Central Himalaya has five source rivers, viz. the Bhagirathi, the Mandakini, the Alaknanda, the Dhauliganga and the Pinder (Figure 1). The combined waters of the Alaknanda, the Dhauliganga and the Pinder join the Bhagirathi

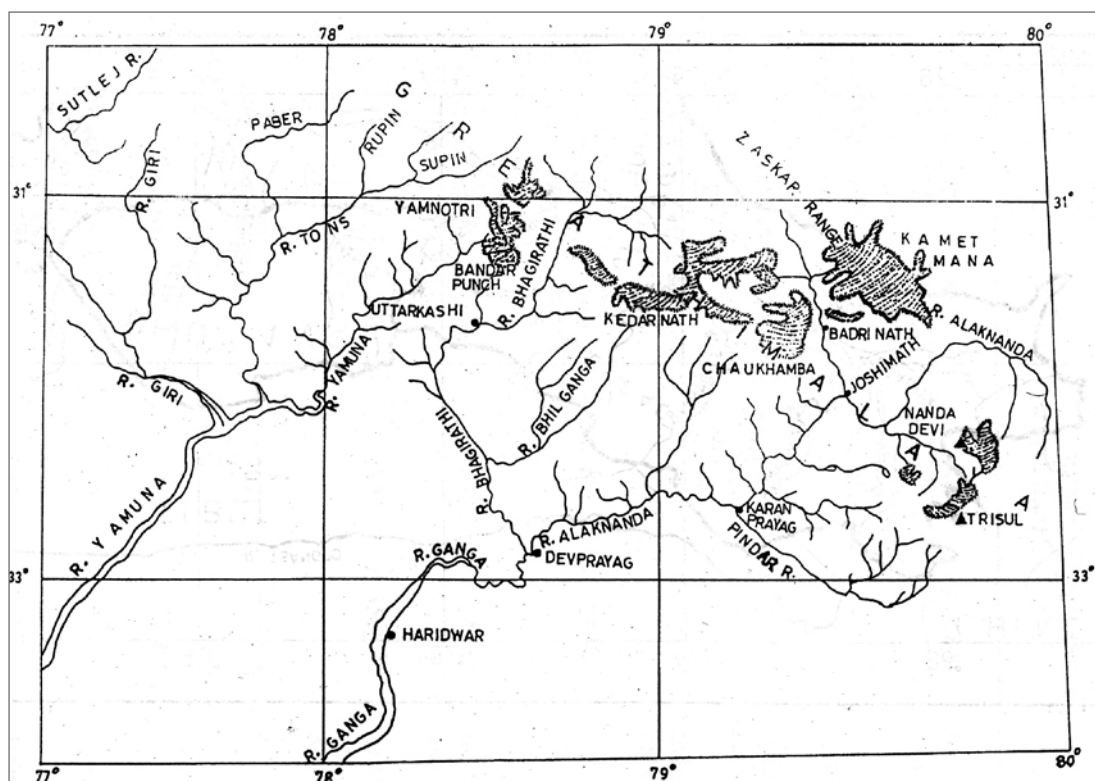


Figure 1: The Ganges and Yamuna drainage in the Central Himalaya (Sehgal, 1999)

at Devprayag to form the Ganges which emerges from the mountains at Rishikesh and flows down to Haridwar and to the northern plains of India (Sehgal, 1999).

The ichthyofaunal diversity of different river stretches was worked out by field surveys, available literature, and also based on experimental fishing. Information was also collected through survey of local fish markets. Sampling for fish fauna was carried out using cast net in the sampling sites to represent wide range of habitat conditions within the study area. The cast net had a diameter of 2.7 metres; mesh size 15 millimetres (near centre) and four millimetres (near the circumference). Fish specimens collected from different sources were brought to the laboratory for identification with the help of keys given in Jayaram 1999; Menon 1987; and Talwar and Jhingran 1991.

ICHTHYOFAUNAL DIVERSITY AND DISTRIBUTIONAL PATTERN

Less than 53 species were recorded in the study in different streams. The major fish species in the

Ganges River flowing in the Central Himalaya were the *Bangana dero*, *Barilius bendelisis*, *B. barila*, *B. bola*, *Crossocheilus diplochilus*, *Garra gotyla*, *L. dyocheilus*, *Schizothoracichthys progastus*, *Schizothorax richardsonii*, *S. plagistomus* and *Tor putitora*. As per the sampling records, the distribution of fish species were 52 in the Alaknanda; 32 in Bhagirathi; 29 in Bhilangana; 48 in Pindar and 41 in Ramganga streams of the Ganges River (Figure 2).

The available fish species were distributed in the streams of the River Ganges depending on the flow rate, nature of substratum, water temperature,

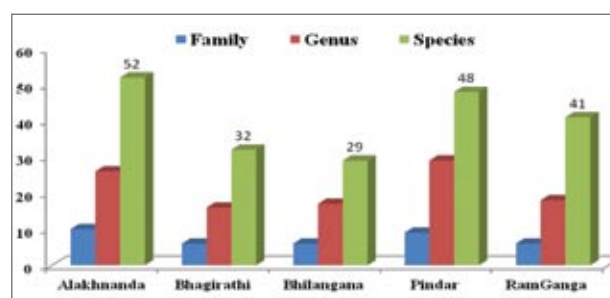


Figure 2: Distribution of different fish species in various streams of the Ganges in Central Himalayas

availability of food, and the elevational gradient, thus contributing differentially to the ichthyofaunal diversity in the ecosystem. However, it is interesting to mention that many exotic fish species were also found in the River Ganges. Some of them were *Onchorhynchus mykiss*, *Salmo trutta fario*, *Cyprinus carpio* var. *specularis*, *C. carpio* var. *communis*, *C. Carpio* var. *nudus*, *Carrasius carrasius*, *Carrasius auratus*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Ctenopharyngodon idella*, *Gambusia affinis*.

The study recorded the presence of *Salmo trutta fario* (Brown trout) and *Cyprinus carpio* (Common carp) at Asiganga, a tributary of Bhilangana stretch and Alaknanda and River Yamuna stretches, where *Cyprinus carpio* was common at most of the studied streams. The details of the exotic fish species available in different streams are presented here (Table 1).

IMPORTANT FISHERY FOR SUBSISTENCE AND LIVELIHOOD

The fish fauna of the central Himalayan Ganges, dominated by the snow trout, is composed of nine species of *Schizothoracids*, *Golden mahseer*, and *Tor putitora*; nine species of *Noemacheilus* spp.; seven species of *Glyptothorax* spp.; six species of *Puntius* spp.; six species of *Barilius* spp.; three species of *Labeo* spp.; three species of *Garra* spp., and three species of *Botia* spp.

These species serve as subsistence fishery, or as ornamental fishery. Distribution of fishery within

the area has been species of categorised in five zones: i) the upper most zone has resources above 2400-3600 metres altitude where availability of fish species has yet to be properly explored, ii) the second lower zone had resources in the elevation of 1800-2400 metres which harbour mainly *Glyptothorax* sp. and *Pseudecheneis* sp., iii) same third lower zone covered 1200-1800 metres elevation which harbours *snow trout* iv) the fourth zone lies between 600-1200 metres where the important fish, *mahseer*, thrives, and v) the fifth zone existed between 300-600 m elevation where *Crossocheilus* dominates.

Snow trout, *lesser barils* sp. and *mahseer* formed the main food fishery of the region (Figure 3). *Schizothorax* fishery was mainly constituted by the presence of *S. richardsonii* constituting 85 per cent of the total catch in upper stretches of Alaknanda and Bhagirathi.

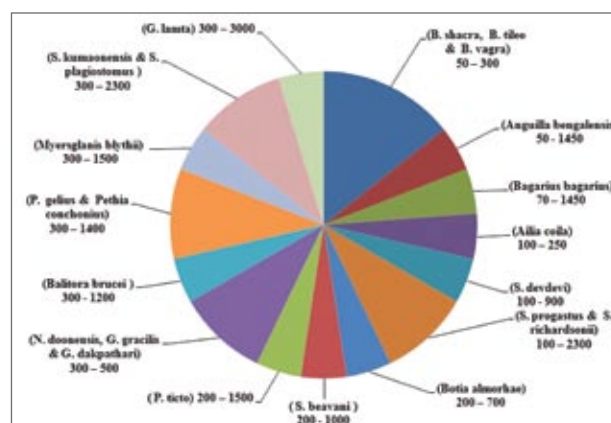


Figure 3: Elevation gradient and distribution pattern of coldwater fish diversity modified after Bhatt et al. 2012

Table 1: Status of exotic fishes in the Ganges River-Garhwal region of Uttarakhand

River streams	Presence of exotic species recorded
Bhagirathi	Salmo trutta fario (Brown trout), Cyprinus carpio (Common carp)
Alaknanda	Salmo trutta fario (Brown trout), Cyprinus carpio (Common carp)
Mandakini	Cyprinus carpio (Common carp)
Tons-(Rupin and Supin)	Salmo trutta fario (Brown trout), Cyprinus carpio (Common carp)
Ramganga	Cyprinus carpio (Common carp)
Pinder	Cyprinus carpio (Common carp)
Ganges at Hardwar	Cyprinus carpio (Common carp), Hypophthalmus molitrix (Silver carp), Hypophthalmus nobilis (Bighead), Ctenopharyngodon idella (Grass carp)

At the foothills of River Ganges from Rishikesh onwards, *Mahseer T. tor* and *T. putitora* formed the main fishery, along with *Barilius*, *Puntius*, *Labeo* and *Mastacembelus* (Figure 4).

The River Ganges flows for 220 kilometres in the State of Uttarakhand before descending to the plains at Haridwar and harbours coldwater fishes all along its course. Fishery resources within the system are mainly formed by *Schizothoracid* and *mahseer* in different streams (Figure 4). Schizothoracids, notably *Schizothoracichthys esocinus*, *S. progastus*, *Schizothorax richardsonii*, *S. longipinnis*, *S. nasus*

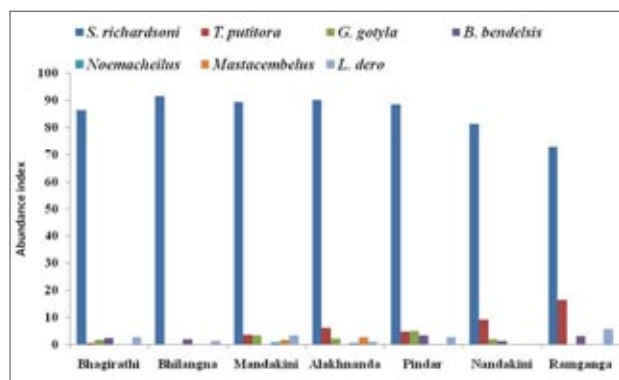


Figure 4: Fish abundance index of different streams in the Ganges, Uttarakhand

and *S. hugelii* are the most important endemic species of fish occurring in the Himalayan waters; yet in the present study we mainly recorded the presence of *S. richardsonii*.

Schizothoracines ranged from 200 to 450 millimetres in total length and from 300 to 1200 grams in weight. The main spawning, however, was found to take place when the stream water reaches temperatures of 10.0-21.5° Centigrade. These fish species were found to spawn in several batches. The fecundity of *S. richardsonii* ranged from 30,000 to 40,000 eggs per kilograms body weight. The coldwater fish differed considerably in their feeding habits feeding mainly on microbiota growing on the bottom stones and rocks with a rasping action of the ventrally-placed mouth. Some of the associated smaller, soft-bodied insect larvae also find their way into the gut.

DISCUSSION

The first account of fishes inhabiting cold regions of India was given by Hamilton (1822). Day (1878-79) described fishes inhabiting mountain streams and lakes in *Fauna of British India*. Menon (1962) has listed 218 species for the whole Himalayas while recent publications documented 298 fish species in the Himalayan rivers (Bhatt et al. 2012).

Out of the total fish fauna available in India, 17 per cent of the fishes were documented from the mountain ecosystem establishing the status of the area as a centre of origin and evolution of biotic forms (Ghosh 1997). The rich fish diversity of the Ganges river has been reported to be over 143 species (Sarkar et al. 2012) having 6.8 per cent endemic fish species including over 10 exotic species (Bhatt et al. 2012; Singh et al. 2013).

About 36 species of freshwater fishes are endemic to the Himalayan region (Ghosh 1997). Nautiyal et al. (2013) has reported 63 fish species from six orders and 12 families in the mountain section. In the Bhagirathi from Gangotri to Devprayag 39 fish species from 15 genera and five families were reported in upper mountain section (Singh and Sharma 1998). The distribution of majority of fish fauna in mountainous region of River Ganges belongs to family Cyprinidae followed by Balitoridae, Bagridae, Sisoridae and Gabiidae.

Menon (1962) gave a distributional list of fishes of Himalaya; thereafter, the fish fauna in this catchment area was studied by many workers, and finally 66 species have been reported occurring in various streams of the region belonging to 25 genera (Singh et al. 1987, 1991; Singh et al. 2005). However, results of this study delineated presence of 52 fish species in Alaknanda, 32 in Bhagirathi, 29 in Bhilangana, 48 in Pinder, and 41 in Ramganga streams of the Ganges River which could be attributed to changing hydrology, deteriorating environmental conditions, over-fishing, destructive methods of fishing and even biological invasions (Vass et al. 2010; Bhatt et al. 2012).

The natural fish populations in the hill streams are declining both quantitatively and qualitatively (Joshi 1994; Sarkar et al. 2012). Presence of *Schizothorax* species in rivers such as Sarju, Kosi, Ramganga and Bhadargarh was reported as 21.48, 24.87, 4.80 and 16.66 per cent, respectively and that of *Tor* spp. to the tune of 10.74, 14.92, 24.03 and 10.0 per cent respectively (Pathani 1994; Nautiyal et al. 1998, 2013). *Mahseer* has been reported to decline from 40.5 to 15.2 per cent for the last 15 years in Kumaon waters (Pathani 1994; Bhatt et al. 2004; Nautiyal et al. 2013). These Himalayan fishery resources are not only diverse and endemic but also threatened due to various anthropogenic activities and need conservation through policy intervention (Sarkar et al. 2012).

The main threat to the coldwater fisheries of the region is from rapid environmental degradation, loss of habitats due to river impoundments, excessive fishing and use of destructive fishing methods which is creating enormous pressure on resources, in general, and fish stocks, in particular (Singh and Sharma 1998; Sarkar and Margule 2002; Sharma 2003; Sarkar et al. 2012).

The species richness and distribution are known to be driven by ecological processes (mainly climate, resource availability, water discharge and productivity) and environmental variables (habitat heterogeneity, disturbances, physiological tolerance, dispersal limitations etc.) and vary along the geographic gradients (Mittelbach et al. 2007; Oberdorff et al. 2011; Bhatt et al. 2012). In the Himalayan rivers the unique diversity and distribution of fish fauna are also driven by ecological factors such as water discharge, temperature and physico-chemical parameters which influence species richness (Carter et al. 1980; Moza 2002). Construction of dams, shifting cultivation and destructive fishing have been reported as the major threats to the *Pseudecheneis sulcatus* (Sucker throat Catfish), a small predatory species distributed in the foothills of the Himalayan River Ganges (IUCN 2011).

Recent invasion of exotic fishes have further worsened the situation adversely affecting the richness of the fish diversity (Singh et al. 2013). The human mediated bio-invasion cause economic or environmental damage resulting from spread and establishment of exotic fish species (Singh et al. 2013). Recent observations over the last five to 10 years indicate drastic declines of *Scizothorax richardsoni* in many areas of its range due to introduction of exotics (especially Salmonids and common carp), while in some areas the declines are more than 90 per cent (IUCN 2011).

CONSERVATION PRIORITIES

Decline in biodiversity is much greater in freshwater than most affected terrestrial ecosystem (Sala et al. 2000). The threats to global freshwater biodiversity can be grouped under five interacting categories: 1. Overexploitation; 2. Water pollution; 3. Flow modification; 4. Destruction or degradation of habitat; 5. And, Invasion by exotic species (Naiman and Turner 2000; Jackson et al. 2001; Revenga et al. 2005; Dudgeon et al. 2006; Singh et al. 2013).

The vulnerability increases in the Himalayan region due to its fragile nature when compounded with anthropogenic activities such as impoundment of rivers, indiscriminate killing and overfishing using destructive methods and bioinvasion. Any change in habitat, flow pattern or discharge further pose new threat to the fish species under changing environmental factors. The rivers of the Himalayan region differ from the other rivers in carrying much larger sediment loads and having more frequent floods. These natural and anthropogenic factors have led to the decline of native fish fauna in the Himalayan rivers.

The declining population of various fish species, in general, and *Tor putitora*, in particular, is evident from various parts of the Himalayan region (Bhatt et al. 2004).

In order to protect the piscine population in Himalayan streams, conservation measures are inevitable and should be adopted at the earliest. Habitat improvement and protection of nursery and spawning grounds, stock enhancement through natural stocking, strict enforcement to prevent illegal introductions and destructive fishing methods are also needed to protect the piscine population.

Campaigning for mass awareness through public participation would be an effective management tool for conservation of the fish population. An understanding of biodiversity distribution and studies on habitat requirement to assess impact assessment of various natural and anthropogenic activities on fish population helps in devising appropriate methods of conservation. It also helps in enhancing our abilities in ecological studies of fishes and resource management.

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Conserving Trans-boundary Migratory Hilsa (*Tenualosa ilisha*) Fish: A Review of Bangladesh Experience

M. Niamul Naser

Department of Zoology, Faculty of Biological Sciences,
University of Dhaka, Dhaka, Bangladesh
E-mail: mnaser@du.ac.bd

ABSTRACT

Ilish or Hilsa Shad (*Tenualosa ilisha*) is a marine fish found in the Bay of Bengal. The fish migrate from the Bay of Bengal to the inland freshwater rivers of Myanmar, Bangladesh and East coast of India i.e. Hooghly-Bhagirathi estuary to spawn.

At present, the major migratory route for the Hilsa Shad in Bangladesh is Meghna-Padma (Ganges) River System. The Bangladesh Fisheries Research Institute formulated a Hilsa Management Plan in 2001, which actually started in 2003 when its catch declined between 2001 and 2003.

An awareness programme of not to catch “*Jatka*” or “juvenile Hilsa” fish was introduced. Consequently, five Hilsa sanctuaries were established. Ban on fishing of spawning Hilsa along with other fish species in the river system for 11 days was ordained.

To support the livelihoods of Hilsa-fishers “vulnerable group feeding” and alternative income generation support and training were given. Besides various activities such as awareness programmes through seminars, film shows, posturing along with strict supervision on fish act in Hilsa river areas, penalties and imprisonment etc. been introduced.

As a benefit the Hilsa fish catch has improved in the country from 2004 onward. This paper discusses the strategy of Hilsa conservation in Bangladesh.

Keywords: Ilish, Hilsa shad, *Tenualosa ilisha*, conservation and management, trans-boundary issues

INTRODUCTION

There is a common saying in rural Bangladesh that *Rokkya Korley Jatka maach, Ilish pabey baro mash* i.e. in English *You save the Jatka (Juvenile Hilsa),*

you can have Ilish for the year! Ilish or Hilsa Shad (*Tenualosa ilisha*) is a clupeid fish inhabiting the Bay of Bengal and migrates every year to the freshwater to spawn and rear its juvenile.

Again for maturity, they migrate back to the sea (Rahman et al. 2012) with the size ranging from 15 to 20 centimetres. The Hilsa Shad is considered as a prized fish for a country like Bangladesh due to its social, cultural and economic values. About five lakh people of Bangladesh are directly involved for their livelihoods and the market chain expands to an involvement of 25 lakh of people (DoF 2012, 2013).

These are the most acceptable fish for several occasions of Bengali culture such as *Pohela Boishak* i.e. the first day of Bengali New Year and even religious festivals of West Bengal such as *Jamai Shosti* when the son-in-law is offered the fish with other special food items. From the economic point of view, the fish solely contributes about 11-12 per cent of the total fish production of Bangladesh and the value in 2013 was about 5,000 crore BDT (1 US Dollar = 78 BD Taka) for one per cent of GDP. The fish harvested from Bangladesh water is more than 60 per cent catch of the world Hilsa catch (DoF 2012).

Like many species of the world, the exploitation of such fish causes decline in the catch in the early millennium. The Government of Bangladesh has come forward with some measures for protection and regulated exploitation of the fish over the recent decade which resulted in some positive impact on the fish stock. This is considered one of the first of conservation efforts on migratory clupeid fish.

METHODOLOGY

For this study, both primary and secondary data and documents were collected and reviewed. Fieldwork took place from February to December 2011 and September to November in spawning season in 2012. The survey was conducted to the entire migratory route of the Hilsa fish in six reference sites at different ecological regions from River Meghna estuary to the upper Padma River System close to the Farraka Barrage of India.

Special emphasis was given to various trans-boundary areas between Bangladesh and India at

Rajshahi region. Several fisher villages were selected according to multiple criteria, such as communities, willingness to be part of the study and communities belonging to the ethnic categories. This selection implies a clear sociological differentiation that is important for understanding how local institutional differences affect potential implementation of conservation mechanism. Documents from the Department of Fisheries, Government of the People's Republic of Bangladesh, Bangladesh Fisheries Research Institutes, and research works of University of Dhaka were collected.

RESULTS

The Life Cycle of the Hilsa Shad in Bangladesh Water

The fish migrate from the sea to the freshwater for spawning (Figure 1). The maximum spawning takes place during the full moon of the Bengali month of *Asween* (October) of each year (Rahman et al. 2012). The larva hatch and within one-to-two months convert in to juvenile called *Jatka*.

The *Jatka* forage in to the freshwater rivers in schools and visits various part of the river top up to the river Padma (Ganges). After six to eight months due to the anadromous nature they migrate back towards the Bay of Bengal. After maturation, the fish again migrate back to the same spawning ground i.e. Padma(Ganges)-Meghna river system to breed (Rahman et al. 2012; Ahsan et al. 2014).

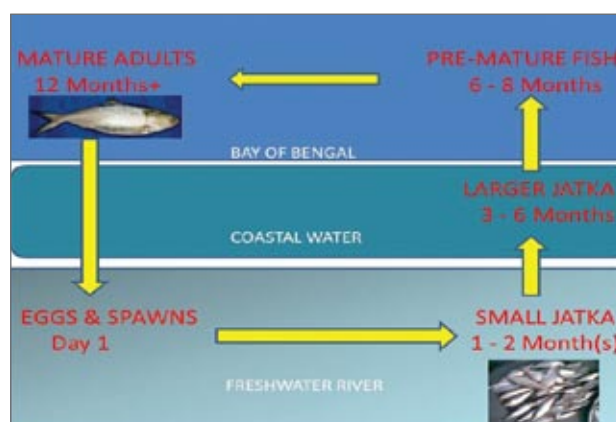


Figure 1: Life cycle of Hilsa shad (*Tenualosa ilisha*) in Bangladesh water

Considering the biology and migration pattern of the fish, several conservational actions were taken by the Department of Fisheries (DoF), People's Republic of Bangladesh (GoB). These are: protection of the Hilsa fish brood, Hilsa spawning grounds and juveniles i.e. *Jatka*.

Regulations Through Act and Rules

The government of the People's Republic of Bangladesh on September 29, 2011 issued a rule through a gazette (no. 14005) making a significant change in the regulation for Hilsa catch. It was acted by the sub-section (GoB 2011) of section three of Protection and Conservation of Fish Act, 1950 (East Bengal Act No. XVIII of 1950) to replace rule 13. The regulation prohibits the catch spawn, juvenile or adult fish in the restricted period in the sanctuary area (see below). It also prohibits carry, transport, offer, sell, exposure or possesses of Hilsa fish throughout the country as well as spawning grounds demarked by the governmental agencies (GoB 2011).

Protection of Brood and Spawning Area

The protection of brood or mother fish was exclusively for 11 days. The full moon of the Bengali month *Asween* each year is considered as the peak spawning period. Considering the full moon day, five days earlier and the five days after, in total 11 days are deliberated as complete ban on Hilsa fish catch from about 5000 sq. km coastal water areas. The boundary is given in Table 1. Some of the major activities during this protection period were mass scale awareness build-up, publicity by loudspeakers and leaflets, radio and television talk-shows and jingles, press releases to media, special inspections and mobile courts in the store, markets, boats and whole sale markets (Zahid Habib 2013).

Protection of *Jatka*

The protection of juveniles i.e. *Jatka* is made by ban on catch, possession and carrying of the item with punishment or jail in place. Any Hilsa under 25 centimetres (10 inches) size is considered as *Jatka* or juvenile. The prohibition of carrying, transportation, offering, selling, exposure or possessing of juvenile fish throughout the country is restricted by the governmental agencies (GoB 2011).

Protection Through Sanctuary

The GoB has declared five sanctuaries to protect the fish from exploitation for two-three months during their migration, breeding and nursing period. This could be rather *fish-refugee* in nature. Following the biology and migration of the fish, two months i.e. March and April of restriction are made at the lower Padma and the upper catchments of the river Meghna.

Later, when the fish stock moves towards the estuary, i.e. the lower Meghna basins, November to January, a three months restriction is made (Appendix 1). During the restricted period, catch of all kinds of fishes in the area is prohibited.

Incentive-based Hilsa Conservation

The GoB had come forward with a programme called *Jatka Fishers Rehabilitation Programme* in 2007-08 fiscal years. It ran for threeyears and ended at 2009-10 with an expenditure of BDT 60 million. It covered 45,698 families as beneficiaries. It provided at least BDT 1000 as grant and alternate income generating training. Later, another project entitled, *Jatka Conservation, Alternate Income Generation for the Jatka Fishers and Research* was taken by the Ministry. It was for 2008 to 2013 fiscal year with BDT 247.7 million. Except BDT 40.6 million for

Table 1: Hilsa spawning grounds boundary (GoB 2011)

Hilsa spawning ground periphery/ demarcation		GPS point
1.	Mayani Point, Mirsarai, Chittagong in the Northeast	91°32.15' E and 22°42.59'N
2.	Paschim Syed Awlia Point, Tajimuddin, Bhola in the Northwest	90°40.58' E and 22°31.16'N
3.	North Kutubdia Point, Kutubdia, Cox's Bazar in the Southeast	90°52.51' E and 21°55.19'N
4.	Lata Chapali Point, Kalapara, Patuakhali in the Southwest	90°12.59' E and 21°47.56'N

research, the rest of the money was used for various activities in four districts and 21 upazillas (Zahid Habib 2013).

The various activities of the project involved, mass awareness development about Hilsa conservation,

and increase of the grain allotment from 10 kilograms/ month/ family in 2007 to 30 kilograms/ month/ family for four months, in 2012-13, the allotment was increased to 24,747.48 mt of grains to support 206,229 families. The cumulative grain distribution and family coverage for 2008 to 2013 are given in

Table 2: Coverage area of the second Hilsa conservation and research project (Zahid Habib 2013)

S. N.	Districts	Upazilla covered
1.	Chandpur	Chandpur Sadar, Haimchar, Matlab (North) and Matlab (South)
2.	Laxmipur	Laxmipur Sadar, Ramgati, Komolnagar and Raipur
3.	Bhola	Bhola Sadar, Daulatkhan, Borhanuddin, Tojumuddin, Lalmohon, Char fashion and Monpura
4.	Patuakhali	Ptuakhali Sadar, Kalapara, Pauphal, Dasmina, Galachipa and Mirzagonj

training on alternate income generation (AIG) activities, support for executing AIG programmes, Fish Act implementation and vulnerable group feeding. The AIG activities included support for rickshaw/ van, goat or cow fattening, sewing appliance, net making, duck or chicken rearing, vegetable growing and plant nursery, cage fish culture and small business etc.

For AIG activities in 2009-10, only 30 million BDT was spent covering 4300 households of Hilsa fishery dependent communities. In the succeeding year, the expenditure was increased to a total of 152.75 million BDT covering in total 20,654 households in 2013 (Figures 2 and 3). They all were given training as well as support of any kind mentioned earlier (Zahid Habib 2013).

Vulnerable Group Feeding (VGF) Programme

The DoF persuades to include the Hilsa fishers to VGF Programme run by the GoB. The programme started with 5730.08 mT food grain covering 0.143 million families in 2008-09. The gradual persuasion

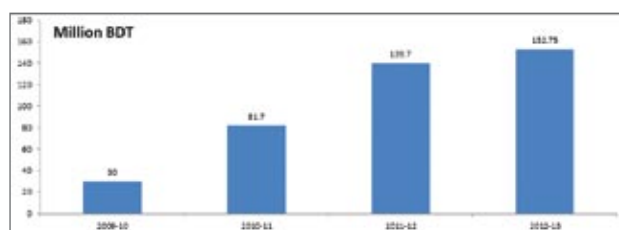


Figure 2: Cumulative cost investment by the GoB from 2009 to 2013 (Zahid Habib 2013)

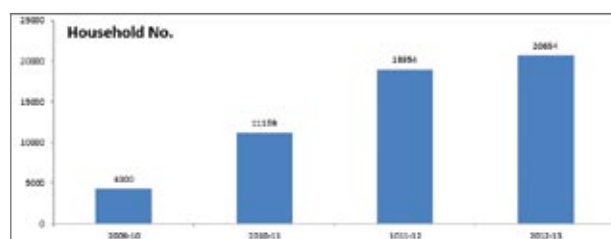


Figure 3: Cumulative Hilsa dependable household coverage by the GoB from 2009 to 2013

Figures 4 & 5. In 2013-2014, the VGF programme extended up to 16 districts and 88 upazillas (Zahid Habib 2013).

Other Activities

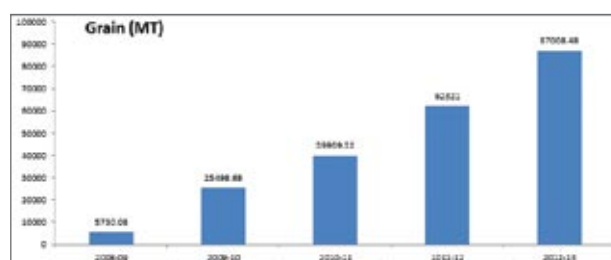


Figure 4: Cumulative amount of food grain distributed during 2008-2013 under VGF programme

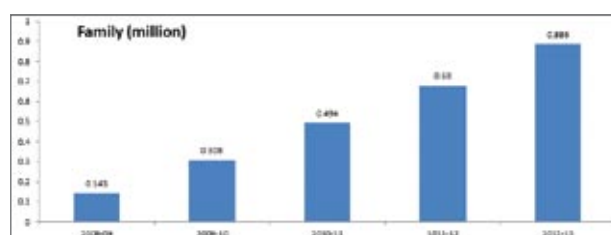


Figure 5: Cumulative number of families (in million) covered for food grain distribution during 2008-2013 under VGF programme

The government has increased several activities to make people aware for the conservation. Till 2012, 1192 a total of juvenile *Jatka* and adult Hilsa conservation seminars were conducted, whereas three small films, 45000 posters and 48000 leaflets were distributed. About 32 central and national seminars were conducted. In addition, to date more than 2700 mobile court have been conducted to prevent any illegal activities to catch Juvenile Hilsa or *Jatka*.

Other Organisational Involvement

Besides Department of Fisheries, GoB, several educational institutions are involved in education and research on Hilsa. For the export of Hilsa, others ministries and governmental agencies such as commerce ministries, revenue department and export promotion bureau are also concerned.

Other agencies such as Bangladesh Frozen Food Association, Aquaculture Alliances etc. are also involved. To conduct surveillances and monitoring the river and sea, Bangladesh Navy, Coast Guard, Bangladesh Police and Rapid Action Battalion (RAB) are deployed.

Catch and Conservation of Hilsa Shad

Various efforts started from 2004 have apparently resulted in increased Hilsa Shad catch (Figure 6).

Issues not Addressed

There are several issues not addressed so far by the government which could be detrimental to conserve the Hilsa fisheries.

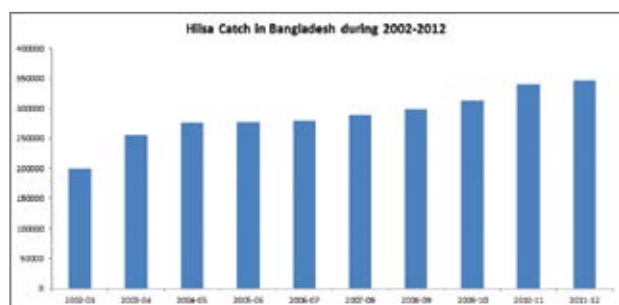


Figure 6: Hilsa Shad catch statistics in Bangladesh during 2002-2012, showing increasing production each year (Source: DoF 2013)

Habitat destruction is the one of the major issues which needs to be considered. Due to the Farraka Barrage, less water flow through the River Padma shifted the breeding ground downwards.

The major breeding was performed at the lower Meghna estuary (Ahsan et al. 2014) but not at the Meghna River at Chandpur district.

Habitat fragmentation due to the low water flow is also evident. Hilsa needs deep water to migrate. At Rajshahi and at the confluence of Padma and Jamuna rivers, sedimentation caused development of char lands (Figures 7-10). The water in many cases of the then mighty River Padma flows like a small channel (Figures 7-10). The Hilsa does not migrate upwards to its previous migratory site upstream of the River Padma at Godagari (Figure 8). The water flow is an important issue for the habitat improvement and the survival of the Hilsa Shad (Halder and Islam 2008).

As in the lower Meghna River the retention time of the eggs to be hatched and swim in freshwaters is very critical (Ahsan et al. 2014). No information is available on how much loss is at present due to their carrying out to the marine water.

Harvesting the stock at the Bay of Bengal is not assessed. Overharvesting of the main stock at the Bay of Bengal is not known. Hilsa marine stock like other marine fishes should enjoy several treaties and laws of the sea. They are discussed below in separate forms.

INTERNATIONAL COMMITMENTS

Bangladesh is a signatory of several international commitments. Of them, United Nations Convention on the Law of the Sea (UNCLOS) in 1982, International Tribunal for the Law of the Sea (ITLOS) in 1995, United Nations Fish Stocks Agreements and the FAO Code of Conduct for Responsible Fisheries are notable.



Figure 7: Sampling sites (1-3) shown in circle (Source: Google Map)



Figure 8: Godagari site 1 of Rajshahi where the Ganges enters Bangladesh to become Padma river (Source: Google Map)



Figure 9: Confluence of rivers Padma (site 3) before meeting Jamuna at Pabna. The rivers often dry up due to water withdrawal at upstream (Source: Google Map)

Hilsa is a trans-boundary fish (Ahsan et al. 2014). The management and conservation of the fish needs to be approached jointly by Bangladesh, India and Myanmar. The stock assessment in the Bay of Bengal needs to be done.

The number of fishes required to be kept at the spawning ground needs to be calculated. This will help in formulating policy for the fish harvesting. In addition trans-boundary conflicts (Ahsan et al. 2014) and climate change issue need to be addressed (Naser 2014).

The capacities of DoF to handle Hilsa issue needs to be increased. The migration route of Hilsa fish up to Rajshahi as happened before early 70's should be reestablished by increasing the water flow from

the Ganges river system. River Padma water flow as well as suitable ecological flow is a necessity for maintaining the river life. Thus, a trans-boundary agreement is essential for Farakka Barrage water flow for Bangladesh. More allocation in alternative livelihoods approaches as well as Hilsa research is required for Bangladesh.

ACKNOWLEDGEMENTS

The author extends his thanks and gratitude to the Department of Fisheries, GoB, and Bangladesh Fisheries Research Institute for providing their published materials and information.

The support from the *Ecosystems from Life* (E4L) of IUCN for field work is highly appreciated.

Personally, I would like to thank Dr. Arif Azad, DG, DoF; Mr. A. B. M. Jahid Habib, PD-Hilsa Project, DoF; Ms Masud Ara Momi, Hilsa Project, DoF, Ms Bushra Nishat, Project Manager, E4L, IUCN Bangladesh, Mr. Shahad Chowdhury, E4L, IUCN Bangladesh, Dr. Anisul Islam, Hilsa Scientist, BFRl to share their ideas with me at various stages of this work.

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Appendix 1: Hilsa fish sanctuary area, their boundary and ban fishing period (Source: GoB, 2011).

Appendix 1: Hilsa fish sanctuary area, their boundary and ban fishing period (Source: GoB, 2011)

S. N.	Hilsa sanctuary	Demarcation	All fishing ban period
1.	100 km stretch of Lower Meghna river	From Shatnol of Chandpur district to Char Alexander of Laxmipur district Shatnol point (90°37.12'E and 23°28.19'N) Char Alexander Point (90°49.30'E and 22°40.92'N)	March to April= 2 months
2.	90 km stretch of Shahbazpur channel, a tributary of Meghna river	Char Ilisha to Char Pial of Bhola district Char Ilisha Mosque Point (90°38.85' E and 22°47.30'N) Char Pial point (90°44.81' E and 22°5.10'N)	March to April = 2 months
3.	100 km stretch of Tetulia river	Bheduria of Bhola district to Char Rustam of Patuakhali district Bheduria Ferryghat Mosque Point (90° 33.89'E and 22°42.31'N) Mandolbazar (Char Rustam) (90°31.40'E and 21°56.32'N)	March to April = 2 months
4.	40 km stretch of Andhermanik river in Kalapara Upazilla of Patuakhali district	Kalapara Upazilla of Patuakhali district Golbunia Point (90°19.20'E and 21°57.68'N) Confluence of Bay of Bengal and Andhermanik river (90°3.91'E and 21° 49.43'N)	November to January = 3 months
5.	20 km stretch of Lower Padma river, the confluence of Padma and Meghna river	Naria-Bhedorganj Upazilla of Shariatpur in the north and Matlab upazilla of Chandpur and Bhedorganj upazilla of Shariatpur in the south Kachikata point of Bhedorganj upazilla of Shariatpur district in the northeast (90°32.6'E and 23°19.8'N) Bhomkara point of Naria Upazilla of Shariatpur district in the northwest (90°28.8'E and 23°18.4'N) Beparipara point of Matlab upazilla of Chandpur district in the southeast (90°37.7'E and 23°15.9'N) Tarabunia point of Bhedorganj Upazilla of Shariatpur District in the southwest (90°35.1'E and 23°13.5'N)	March to April = 2 months

Fish Diversity and Population Dynamics of Roktodaha Beel, a Floodplain of North-western Region of Bangladesh

Md. Amimul Ehshan¹ and Abdus Salam Bhuiyan²

¹Department of Fisheries Bangladesh, Sadar, Chapainawabganj, Bangladesh

²Department of Zoology, University of Rajshahi, Bangladesh

¹E-mail: amisan72@yahoo.com

ABSTRACT

An investigation on fish population of Roktodaha Beel, a floodplain of northwest Bangladesh was done for one complete flood cycle between May 2008 and February 2009. A total of 46 fish species including eight exotic species were recorded. Perches (30.82 per cent) were the most dominant group followed by catfish (26.23 per cent), minnows (16.21 per cent), prawns (16.04 per cent), eels (04.23 per cent), others (2.42 per cent), murrels (1.73 per cent), gouramies (1.3 per cent) and carps (1.02 per cent).

Among fish species, *Chanda nama* indicated the maximum abundance (21.70 per cent) followed by *Neotropius atherinoides* (21.26 per cent). Among trophic groups higher presence of predators was a negative factor for sustaining the natural biodiversity.

In tropho-spatial assemblage, higher number of bottom feeder species also indicated possible decline of species biodiversity of other tropho-spatial level. Only one riverine fish species, *Botia Dario*, in Roktodaha Beel indicated the poor fish diversity of the feeder river Tulshi Ganges. From the study it was obvious that within the last 15-20 years about 25 per cent fish species had become at the verge of disappearance in this floodplain.

Key words: Floodplain, river, fish biodiversity, Shannon-Wiener index

INTRODUCTION

The inland aquatic habitats of Bangladesh are rich in fish diversity with 265 finfish and 63 species of palaemonid prawns (Rahman 2005).

During the 1970s Bangladesh was described, possibly, as the richest country in the world so far as inland fishery resources are concerned (FAO 1973). During the early 1960s, open water contributed around 90 per cent of the total fish production in the country, which drastically declined to 30–40 per cent (Mazid and Hossain 1995).

According to Dudgeon (2005), freshwater biodiversity is under threat worldwide, but the intensity of threat in the oriental biogeographic region of tropical Asia is exceptional. Floodplains which inundate during monsoons are nutrient rich and play a significant role as breeding and nursery grounds for a large number of fish larvae and juveniles (Welcomme 1985).

In Bangladeshi floodplains, most of the rural people fish professionally, seasonally, or for subsistence. Thus, floodplain fishery is important in terms of environment, economic and social issues. Hossain

et al. (1999) investigated the fish biodiversity of three Beels of Bangladesh with particular reference to artificial stocking. Mostafa et al. (2009) studied the habitat, biodiversity degradation and management aspect of Chalan Beel. Present investigation was carried-out in Roktoda Beel, a floodplain of Bogra district for one complete flood cycle year from May 2008 to February 2009. The area of the floodplain is 105ha in dry season which expands up to 1000ha in rainy season and acts as a major source of natural fish supply in the region.

MATERIALS AND METHODS

Sampling and Data Analysis

Fish sampling was done weekly at three selected spots. Number of fishers engaged in a particular day of sampling was estimated through interview and direct observation. Species-wise catch composition by number was done and in case of *katha* (brush/ vegetation park) fishery weight-based catch composition was also done. Fish biodiversity was studied both qualitatively and quantitatively. Identification of fishes was done following Day (1975-78), Doha 1973, and Rahman 2005. Talwar and Jhingran 1991 was followed for prawn identification. Temporal and spatial abundances were recorded, too. Shannon-Wiener diversity index (H') was calculated as a measure of diversity with combined aspects of species richness and evenness following Seaby and Henderson 2006. Data were also analysed to find out the monthly variation, dominant and rare species using MS Excel.

A total of 46 species of fish belonging to 18 families were recorded and out of which eight species were exotic. Monthly fluctuation of fish abundance in percentage composition is shown in Figure-1. Highest abundance was recorded in the month of January while the lowest was recorded in the month of May.

From May, fish abundance increased gradually and it became steady in the months of July to September. There was a decline of fish catches in the month

of October while in November it showed a distinct increase, which remained steady up to February. According to flood pulse concept by Junk et al. 1989 the pulsing of the river discharge, the flood pulse, is a major force controlling biota in river-floodplains.

Assemblage of fish and prawn species were classified into nine common groups viz., i. Carps ii. Catfish iii. Eels iv. Minnows v. Murrels vi. Gouramies vii. Perches viii. Prawns, ix. and others (including Gobies, Loach, Feather-Back and Gars). Perches (30.82 per cent) were the most dominant groups followed by Cat Fishes (26.23 per cent), Minnows (16.21 per cent), Prawns (16.04 per cent), Eels (04.23 per cent), other (02.42 per cent), Murrels (1.73 per cent), Gouramies (1.3 per cent) and Carps (1.02 per cent).

Among Perches (70.73 per cent) *Chanda nama* alone contributed 21.70 per cent. Similarly, 45.73 per cent of Perches were reported in Gawha Beel by Saha (2007). Catfish was found to be the second most dominant group (26.23 per cent) followed by Minnows (16.21 per cent) and Prawns (16.04 per cent). *Neotropius atherinoides* (21.26 per cent) was found to be the second dominant species, a small migratory Catfish.

Catfishes were found to be the most dominant group contributed by riverine and migratory cat fishes in the beels of the Mymensingh-Sylhet basin (Haroon et al. 2002). In Boro Beel small Cat fishes showed dominancy of which *Mystus tengera* was the most dominant species (Saha et al. 2005a). Alam and Ahmed (2005) observed *Chanda nama* and *Parambassis ranga* as the most frequently occurring fish species in the fish pass between the River Kushiyara and Kawadighi Haor.

Contribution of Minnows was at the third position. Among Minnows *Pethai ticto* was at the fourth positions whereas Hossain et al. (1999) reported *Puntius spp.* as the most available fish in Chanda, BSKB and Halti Beel. Prawns represented the fourth dominant group.

According to de Graaf and Marttin (2003) disappearing of Beel resident species and becoming small prawns more dominant were phenomenon indicating the loss of fish biodiversity. The Carps were in the bottom position (1.02 per cent); it was obvious that they entered with flood water and escaped from the adjacent captivities and not from natural recruitment.

According to de Graaf (2003), it is a general belief in Bangladesh that major Carps disappeared from the catch due to the construction of flood control drainage and irrigation schemes over the past decades.

Welcomme 1985 and Hoggarth et al. 1999 opined that in over-exploited floodplains, with high fishing pressure, the large, slow-growing species and the species that start to reproduce after two-three years were replaced by quick-growing and fast-reproducing species such as barbs (*Barbodes spp.*), gouramies (Anabantidae) and spiny eels (Mastacembelidae). Not unlikely fish diversity pattern in Bangladeshi open-water is changing over the years that need attention to conserve native fish fauna.

Monthly variation of fish species groups availability based on number abundance is shown in Figure 2. Cat fishes were significantly higher in the water receding months i.e. November to February which might be because of their high involvement in the brush-parks. Perches were significantly higher in the months of monsoon.

Murrels and minnows did not show significant temporal fluctuation except murrels which were higher only in the month of June. Carps were available mainly in monsoon. Eels were particularly found in the catch of low water period. Prawns showed two peaks, one in May and another in October. Gouramies showed more or less similar trend except in the month of May. Higher catch of *Chanda nama* and *Neotropius atherinoides* was specifically contributed by *katha* catch.

Trophic Groups of Fish and Prawn Species

A trophic level represents the step in the dynamics of energy flow through an ecosystem. Following trophic level fishes and prawns were classified into eight groups.

Considering species richness, predators (32.60 per cent) was found to be the most dominant group followed by planktivores (28.26 per cent), detritivores (21.73 per cent), benthivores (6.52 per cent), insectivores (4.34 per cent), herbivores (2.17 per cent), omnivores (2.17 per cent) and larvivores (2.17 per cent). On the other hand, according to numerical abundance, planktivore (35.04 per cent) was the most dominant group followed by insectivores (30.11 per cent), detritivores (21.27 per cent), predators (6.66 per cent), benthivores (5.68 per cent), herbivores (1.10 per cent), larvivores (0.11 per cent) and omnivores (0.03 per cent).

Table 1: Top ten dominant and least ten available fish species recorded in Roktoda Beel

S. N.	Most dominant species	%	S. N.	Least available species	%
1	<i>Chanda nama</i>	21.79	1	<i>Labeo calbasu</i>	0.010
2	<i>Neotropius atherinoides</i>	18.52	2	<i>Oreochromis niloticus</i>	0.030
3	<i>Macrobrachium sp.</i>	16.04	3	<i>Clarias magur</i>	0.047
4	<i>Pethia ticto</i>	10.93	4	<i>Notopterus notopterus</i>	0.065
5	<i>Parambassis ranga</i>	08.35	5	<i>Pangasius hypophthalmus</i>	0.080
6	<i>Mystus tengra</i>	05.00	6	<i>Labeo bata</i>	0.081
7	<i>Macrogathus pancalus</i>	02.63	7	<i>Hypophthalmichthys nobilis</i>	0.085
8	<i>Channa punctata</i>	02.39	8	<i>Channa gachua</i>	0.109
9	<i>Lepidocephalichthys guntea</i>	01.49	9	<i>Aplocheilichthys panchax</i>	0.110
10	<i>Glossogobius giuris</i>	01.20	10	<i>Cirrhinus mrigala</i>	0.113

In trophic level predators, detritivores or benthivores lie at the bottom while planktivores lie at the top. So a higher number of predators either in species richness or numerical abundance were not a good indicator for the natural biodiversity. Detritivores (29.43 per cent), omnivores (54.74 per cent) and insectivores (47.75 per cent) were found to be the most dominant groups in terms of their numerical abundance in Boro Beel, Borobila Beel and Gawha Beel respectively (Saha 2007).

Tropho-spatial Assemblage of Fishes and Prawns

Tropho-spatial levels are food zone or particular grazing layer viz., surface feeder, column feeder

and bottom feeder. In term of species richness, bottom feeders (50.0 per cent) observed to be the most dominant group followed by surface feeders (41.3 per cent) and column feeders (8.7 per cent), while surface feeders (64.8 per cent) were the most dominant groups followed by bottom feeders (31.56 per cent) and column feeders (3.63 per cent) in terms of numerical abundance.

In both cases, column feeders were subdominant. As higher number of species belonged to bottom feeders, it can be assumed that there might be the decline of species biodiversity at other tropho-spatial level. Borobila Beel was dominated by bottom feeders (65.15 per cent) by numerical abundance

Table 2: Percentage composition of fish species of various groups in Raktadaha Beel

S. N.	Scientific name	Per cent	S. N.	Scientific name	Per cent
Carp			Minnows		
1.	<i>Cyprinus carpio</i>	22.62	1.	<i>Pethia ticto</i>	67.40
2.	<i>Hypophthalmichthys molitrix</i>	18.66	2.	<i>Systemus sarana</i>	14.74
3.	<i>Ctenopharyngodon idellus</i>	13.90	3.	<i>Barbonymus gonionotus</i>	6.76
4.	<i>Labeo rohita</i>	12.67	4.	<i>Amblypharyngodon mola</i>	4.81
5.	<i>Catla catla</i>	11.58	5.	<i>Salmophasia bacaila</i>	3.37
6.	<i>Cirrhina mrigala</i>	11.17	6.	<i>Esomus danricus</i>	2.23
7.	<i>Hypophthalmichthys nobilis</i>	8.45	7.	<i>Aplocheilichthys panchax</i>	0.69
8.	<i>Labeo calbasu</i>	0.95	Others (Gobies, Loach, Feather-back and Gars)		
Catfish			1.	<i>Lepidocephalichthys guntea</i>	44.33
1.	<i>Neotropius atherinoides</i>	70.62	2.	<i>Glossogobius giuris</i>	44.23
2.	<i>Mystus tengra</i>	19.07	3.	<i>Xenentodon cancila</i>	9.03
3.	<i>Ompok bimaculatus</i>	5.29	4.	<i>Notopterus notopterus</i>	2.41
4.	<i>Wallago attu</i>	3.00	Perches		
5.	<i>Heteropneustes fossilis</i>	1.53	1.	<i>Chanda nama</i>	70.73
6.	<i>Pangasius hypophthalmus</i>	0.31	2.	<i>Parambassis ranga</i>	27.09
7.	<i>Clarias magur</i>	0.18	3.	<i>Badis badis</i>	0.93
Eels			4.	<i>Anabas testudineus</i>	0.85
1.	<i>Macrogathus pancalus</i>	62.14	5.	<i>Anabas sp.</i>	0.40
2.	<i>Mastacembelus aculeatus</i>	23.62	Gouramies		
3.	<i>Macrogathus armatus</i>	8.25	1.	<i>Trichogaster fasciata</i>	69.75
4.	<i>Monopterus albus</i>	5.99	2.	<i>Trichogaster chuna</i>	30.25
Murrels			Prawns		
1.	<i>Channa punctata</i>	86.12	1.	<i>Macrobrachium malcomsoni</i>	76.30
2.	<i>Channa striata</i>	7.54	2.	<i>Macrobrachium rosenbergii</i>	23.70
3.	<i>Channa gachua</i>	6.34			

(Saha et al. 2005b). Saha et al. (2005a) described that bottom feeders were the most dominant group in Bukbhara (61 per cent), Rajganj (62 per cent) and Kapotakkhya (83 per cent) lakes respectively while Kannyadaha, Nasti and Marufdia were dominated by surface feeders @ 65 per cent, 70 per cent and 74 per cent, respectively.

Habitat Preference Groups of Fishes and Prawns

On the basis of habitat preference, fish species were classified into three groups: i) Riverine ii) Migratory, and iii) Resident. Exotic fish species were kept separate in this classification. Species richness on the basis of habitat preference is shown in Figure 3. Irrespective of species richness and number abundance resident (63.04 per cent, 77.63 per cent) fish species was found to be the most dominant group followed by migratory (17.39 per cent, 20.26

per cent), exotic (17.39 per cent, 1.97 per cent) and riverine (2.17 per cent, 0.14 per cent) fish and prawn species.

Among resident species, *Chanda nama* (28.01 per cent), *Macrobrachium* spp. (15.73 per cent), and *Pethia ticto* (14.04 per cent) were the top three dominant species. The least three species were *Clarias magur* (0.06 per cent), *Notopterus notopterus* (0.08 per cent) and *Channa gachua* (0.14 per cent) while among migratory species *Neotropius atherinoides* (91.21 per cent), *Wallago attu* (3.87 per cent) and *Salmophasia bacaila* (2.69 per cent) were in the top three dominant species.

The least three species were *Labeo calbasu* (0.05 per cent), *Labeo bata* (0.40 per cent) and *Cirrhinus mrigala* (0.56 per cent). Saha (2007) observed

Table 3: List of fish species recorded in Roktadaha Beel during May 2007 to February 2008

S. N.	Resident		Resident
1.	<i>Esomus danricus</i>	25.	<i>Monopterusuchia</i>
2.	<i>Amblypharyngodon mola</i>	26.	<i>Heteropneustes fossilis</i>
3.	<i>Puntis sophore</i>	27.	<i>Macrobrachium rosenbergii**</i>
4.	<i>Pethia ticto**</i>	28.	<i>Macrobrachium malcomsoni</i>
5.	<i>Systomus sarana **</i>		Migratory
6.	<i>Anabas testudineus</i>	29.	<i>Labeo bata*</i>
7.	<i>Badis badis</i>	30.	<i>Catla catla</i>
8.	<i>Channa gachua *</i>	31.	<i>Salmophasia bacaila</i>
9.	<i>Channa striates</i>	32.	<i>Labeo calbasu*</i>
10.	<i>Channa punctata **</i>	33.	<i>Cirrhinus mrigala*</i>
11.	<i>Mastacembelus aculeatus</i>	34.	<i>Labeo rohita</i>
12.	<i>Macrognathus pancalus**</i>	35.	<i>Neotropius atherinoides**</i>
13.	<i>Macrognathus armatus</i>	36.	<i>Wallago attu</i>
14.	<i>Chanda nama **</i>	37.	<i>Mystus tengra**</i>
15.	<i>Parambassis ranga **</i>		Riverine
16.	<i>Lepidocephalichthys guntea**</i>	38.	<i>Botia dario</i>
17.	<i>Trichogaster fasciatus</i>		Exotic
18.	<i>Trichogaster chuna</i>	39.	<i>Hypophthalmichthys nobilis*</i>
19.	<i>Ompok bimaculatus</i>	40.	<i>Cyprinus carpio</i>
20.	<i>Aplocheilichthys panchax *</i>	41.	<i>Ctenopharyngodon idellus</i>
21.	<i>Xenentodon cancila</i>	42.	<i>Hypophthalmichthys molitrix</i>
22.	<i>Clarias magur*</i>	43.	<i>Barbonemus gonionotus</i>
23.	<i>Glossogobius giuris**</i>	44.	<i>Anabas sp.</i>
24.	<i>Notopterus notopterus*</i>	45.	<i>Pangasius hypophthalmus*</i>
		46.	<i>Oreochromis mossambicus*</i>

Note: **→among top ten abundant species; *→among least ten available species

that abundance of resident fish communities were dominated by *Mystus tengera* (Boro Beel), *Parambassis baculis* (Borobila Beel) and *C. nama* (Gawha Beel).

He also recorded a total of nine and three riverine species in Boro Beel with a dominance of *Corica soborna* and Borobila Beel respectively, no riverine species was found in Gawha Beel. Only one riverine fish species *Botia dario* in Roktodaha Beel indicated the poor fish diversity of the feeder river Tulshi Ganges.

Monthly variation of resident and migratory fish species is shown in Figure 4 (including *Katha* catch) and in Figure 5 (excluding *katha* catch). Abundance of resident fishes was the highest in the month of January and lowest in the months of May, June and October. Including *katha* catch migratory fishes were higher in abundance in *katha* fishing period. A sharp increase was observed from November and onward which revealed that brush parks were the congenial habitat for migratory fishes viz., *Neotropius atherinoides*, *Wallago attu*, *Salmosphasias bacaila* etc.

Temporal Variation of Fishes and Prawns Diversity

Temporal variation of fish and prawn diversity was observed during the study period. Resident or local species showed two distinct peaks of species richness diversity. One in July-August-September and another in November-December-January, whereas the migratory species showed only the second peak (Figure 4). But if the *katha* catch was excluded from this calculation the resident species showed only the first peak and the migratory species showed only the second peak upto February (Figure 5).

Saha (2007) observed lower catch during winter and dry season in Boro Beel and Borobila Beel but the abundance of resident fishes was more or less same round the year. He also observed a peak of migratory fish in November-December which may

be due to outstanding catch of brush-parks. It was also found that the exclusively dominant migratory species *Neotropius atherinoides* was the highest in the brush-park catch.

Temporal variation in the occurrence of tropho-spatial characteristics groups largely fluctuated during the study period (Figure 6). Except May, June and October, surface feeders dominated around the study period whereas column feeders remained steady with a lower contribution. On the basis of food habit it was observed that the planktivores dominated in dry seasons, insectivores dominated in monsoon i.e. July-August-September and least in May-June.

Omnivores and predators also had notable contribution with a little temporal fluctuation during the entire investigation period. While other groups viz., benthivores, larvivores, herbivores showed little temporal fluctuation. Detritivores were slightly higher in May and June, from July onward which showed a sharp decline (Figure 7). Monthly variation of numerical abundance of local and exotic fish species is shown in Figure 8.

In personal interview and focus group discussion, fishermen claimed that five to 10 years, back they frequently caught some fish species which were not found in their recent catches. It also happened once that around 15-20 years back, the national fish *Tenualosa ilisha* was seen every year but now it is totally absent.

Out of species which have disappeared, 43.75 per cent were migratory, 18.75 per cent riverine and 37.50 per cent were resident fishes. From the study it is obvious that within last 15-20 years about 25 per cent fish species has moved to the verge of disappearance or became critically rare (Table 4).

The gradually deteriorating condition of the feeder river Tulshi Ganges might be one of the major causes of this species diversity decline. Fishermen opined that significant catch of previously called

Table 4: Fishes which were once seen but absent now in the Raktodaha Beel

S. N.	Local name	Scientific name	S. N.	Local name	Scientific name
i.	Potka	<i>Chelonodon patoca</i> ¹	ix.	Fasha	<i>Setipinna phasa</i> ²
ii.	Boali pabda	<i>Ompok pabda</i> ¹	x.	Bacha	<i>Eutropiichthys vacha</i> ²
iii.	Gozar	<i>Channa marulius</i> ¹	xi.	Chapila	<i>Gudusia chapra</i> ²
iv.	Baluchata	<i>Acanthocobitis botia</i> ¹	xii.	Gulsha	<i>Mystus bleekeri</i> ²
v.	Dhela	<i>Osteobrama cotio cotio</i> ¹	xiii.	Raikhori	<i>Cirrhinus reba</i> ²
vi.	Bheda	<i>Nandus nandus</i> ¹	xiv.	Banspata	<i>Ailia coila</i> ³
vii.	Chital	<i>Chitala chitala</i> ²	xv.	Ilish	<i>Tenualosa ilisha</i> ³
viii.	Aire	<i>Sperata aor</i> ²	xvi.	Kanchki	<i>Corica soborna</i> ³

1-> resident; 2-> migratory; 3-> riverine

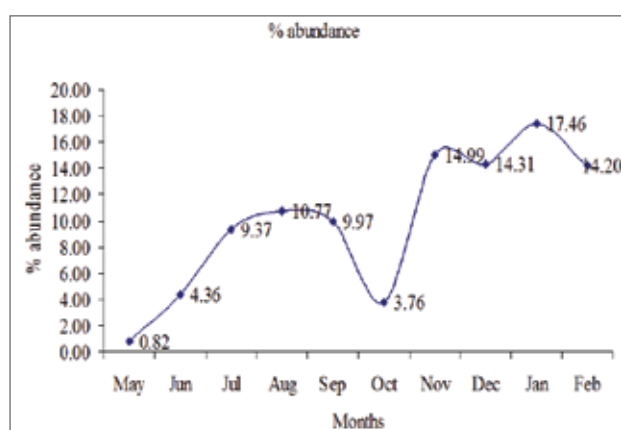


Figure 1: Monthly fluctuation of fish availability in per cent abundance

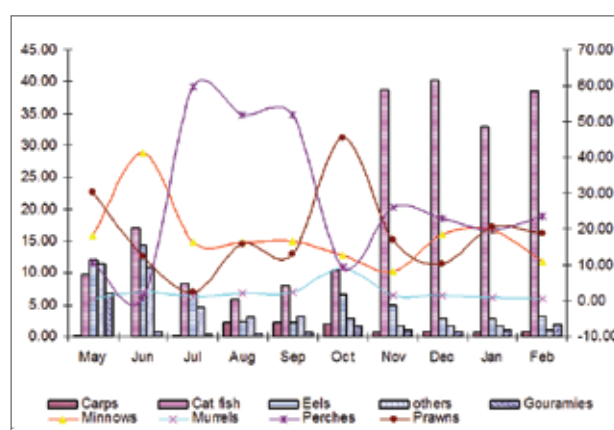


Figure 2: Monthly variation of various fish groups basis on number abundance

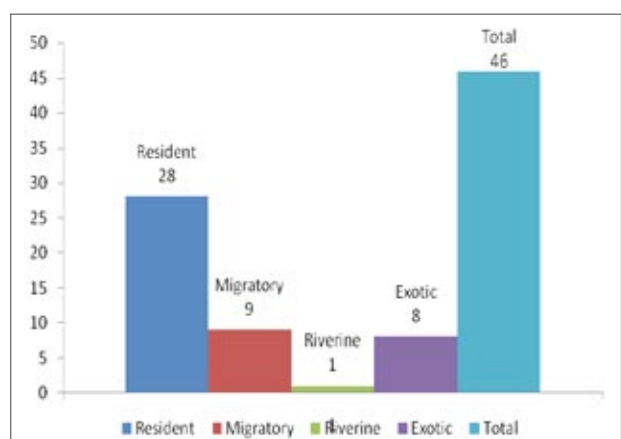


Figure 3: Species richness on the basis of habitat preference

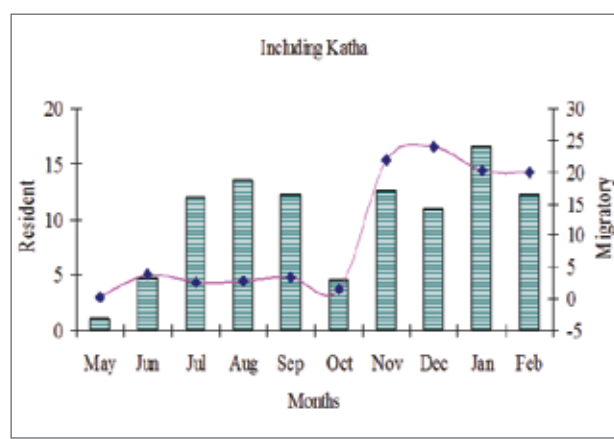


Figure 4: Monthly variation of resident and migratory (including katha catch) fish species

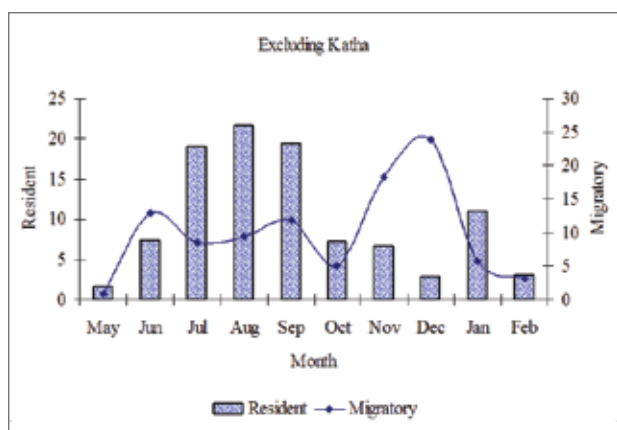


Figure 5: Monthly variation of resident and migratory (excluding *katha* catch) fish species

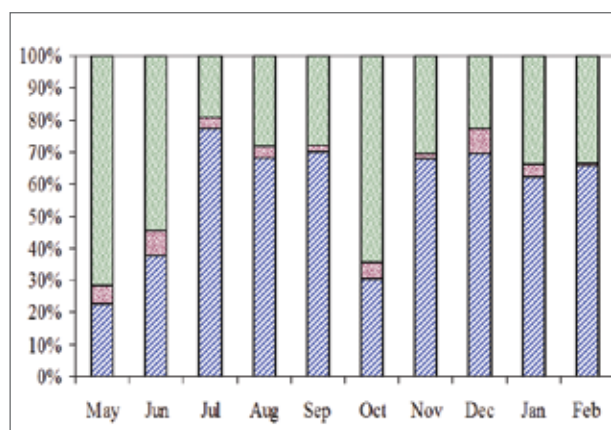


Figure 6: Monthly fluctuation of various trophio-spatial level groups

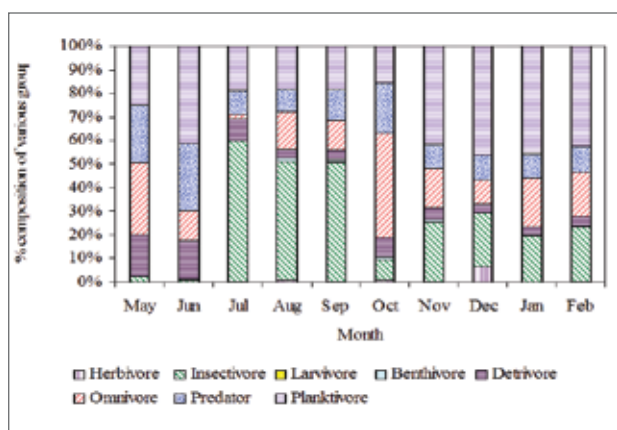


Figure 7: Monthly fluctuation of various trophic level groups

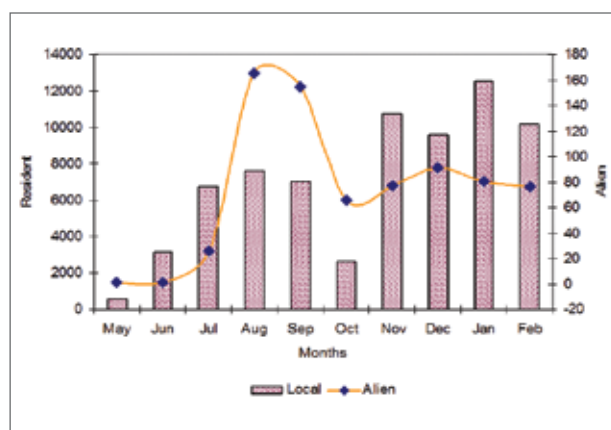


Figure 8: Monthly variation of resident and exotic fish species

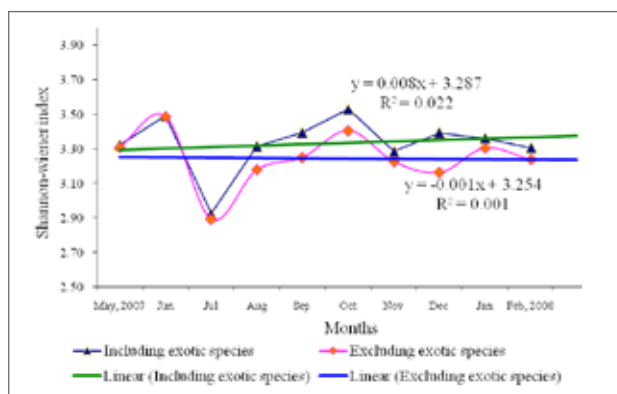


Figure 9: Temporal variation of Shannon-wiener diversity index



Plate 1: Road-cum-embankment constructed by local government in the Raktodaha Beel area



Plate 2: Sanctuary in Roktodaha Beel established by the Department of Fisheries



Plate 3: Fishes of Roktodaha Beel



Plate 4: Fishes of Roktodaha Beel

missing species of *Neotropius atherinoides*, *Ompok bimaculatus* and *Heteropneustes fossilis* were thought to be the contribution of the sanctuary established by the Department of Fisheries. Water hyacinth used in the sanctuary facilitated breeding of *Cyprinus carpio*. In the breeding season, a good number of *C. carpio* fingerlings were found in the sanctuary area.

Shannon-Wiener Diversity Index

Temporal variation of Shannon-Wiener diversity index is shown in Figure 9. The lowest (2.92) index was recorded in July which indicates sudden uneven movement (inward and/ or outward of the beel) of various fish species with the new flood water. While in October it was the highest (3.53) which indicates symmetric distribution of fish and prawn fauna through natural recruitment viz., spawning. The index remained more or less steady in the rest months. Hossain et al. (1999) found that the Chanda Beel showed the highest index (5.96) at the third

consecutive year of artificial stocking and a declining trend in Haldi Beel. Siqueira-souza and Freitas (2004) estimated the Shannon index estimated for fish diversity in Amazonian aquatic environments values which ranged from 0.97 to 5.35.

In the present study the average index was 3.33 which can be mentioned as a moderately rich biodiversity ecosystem.

CONCLUSION

Floodplain fish biodiversity is important both from economic and environmental points of view. A healthy floodplain acts as natural environmental balance between connected river and the adjacent land. It also offers notable amount of animal protein to the neighboring people. However, anthropological impact and poorer condition of feeder river are emerging as potential threats for its fish biodiversity.

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Salinity Regime and Fish Species Distribution in the Hooghly-Matlah Estuary

R. K. Manna, C. M. Roshith, S. K. Das, V. R. Suresh and A. P. Sharma

Central Inland Fisheries Research Institute,
Barrackpore, Kolkata - 700120, India
E-mail: rkmanna@rediffmail.com

ABSTRACT

The Indian part of the Sundarbans, a mosaic of 102 islands, is separated by about 1750 square kilometres water area, including tidal rivers, creeks and brackish water lagoons which form a major capture fishery resource of the area. A study was conducted to understand present fish species distribution in different rivers inside Sundarbans in reported increased salinity regime of these rivers.

Salinity was much higher in the Matlah river system as compared to the Hooghly river system. Also, parameters related to salinity such as specific conductivity, total hardness etc. were found differ widely between the Hooghly and the Matlah river system.

Higher salinity has its influence on estuarine fish species distribution in the Matlah river system. Many euryhaline fish species such as *Bregmaceros maclellandi*, *Lutjanus johni*, *Macrospinoso cuja*, *Therapon jarbua*, *Harpadon nehereus* etc. are present in plenty in the Gosaba-Sajnekhali area in the Matlah river system whereas they were absent in the Hooghly river at Diamond Harbour.

Roychak in the Hooghly estuary and Canning in the Matlah estuary revealed similar phenomenon of occurrence of *Eleutheronema tetradactylum*, *Anodontostoma chacunda*, *B. maclellandi*, *Upeneus sulphureus* etc. in bag net catch at Canning whereas Roychak bag net catch was dominated by *Otolithoides pama*, *Setipinna phasa* etc. A major difference was noted in the landing of the prized *Tenualosa ilisha* which is scarcely available in the rivers of the Matlah river system.

Key words: Indian Sundarbans, fish species distribution, salinity regime

INTRODUCTION

The Indian part of the Sundarbans, covered with thick mangrove forest, located in the coastal area of West Bengal, is a unique gift of nature covering an area of about 4200 sq km forest and 5400 sq km of inhabited area. This largest estuarine mangrove forest in the world is tidally fed by several rivers, canals and creeks forming a network of water channels.

The seven major rivers in the Indian Sundarbans are Hooghly, Muriganga (Bartala), Saptamukhi, Thakuran, Matlah, Gosaba and Harinbhanga (Ichhamati/ Raimangal). Out of them only Hooghly and Muriganga are connected with the parent river Ganges originating from the Himalayan glaciers and flushed by freshwater. Other rivers have almost lost their freshwater connectivity.

Sundarbans, the largest deltaic tropical plain of India, was formed by the deposition of sediment carried by three great rivers, viz. Ganges, Brahmaputra and Meghna. Indian Sundarbans occupies about 38 per cent of total Sundarbans area and are located between 21°32" and 22°40" N latitude and 88°05" and 89°00" E longitude within the districts of 24 Parganas comprising 19 blocks.

It is surrounded by Bangladesh in the east, Dampier Hodges line to the north and west, and Bay of Bengal to its south. It has a total area of 9629 square kilometres comprising 102 islands of which 54 islands (4493 km²) are inhabited by human beings and the rest are reserve forest. About 4.5 million people live in the habituated area of Indian Sundarbans. About 1750 square kilometres is under the tidal rivers, creeks and brackish water lagoons that form the major capture fishery resource of the area, whereas about 50,000 ha water area is under prawn and crab farming.

Sundarbans have seven major estuaries viz. Hooghly, Muriganga, Saptamukhi, Thakuran, Matlah, Gosaba and Harinbanga from west to east. Out of these seven estuaries, only Hooghly and Muriganga are presently connected with the parent river Ganges and flushed by huge amount of freshwater infused by Farakka barrage at the upstream. Freshwater discharge by Farakka Barrage changed the salinity

regime of Hooghly estuary affecting fish species distribution (Manna et al. 2013).

However, higher salinity regime was noted in sampling centres inside rivers of Sundarbans Matlah/ Saptamukhi/ Thakuran etc. Reports of fish species available in Sundarbans were made by Annandale (1907) and Kemp (1917). Fish species available in rivers of Sundarbans was recently reviewed by Mandal et al. (2013), where a checklist of 267 fishes was prepared based on all previous works on Indian Sundarbans.

Very few attempts were made to link habitat parameters with fish and fisheries of Sundarbans (Giri and Chakraborti 2012). However, no information is available on distribution of fish species in relation to water quality of different rivers of Sundarbans. To understand the impact of salinity of fish species distribution, a study was undertaken during 2010-12 at various places of Hooghly-Matlah estuary. A comparative account of fish sampling Centres located in Hooghly estuary and the sampling centres located in rivers inside Sundarbans, at similar distance from sea is made in this study.

MATERIALS AND METHODS

Water samples were collected from different centres in different rivers located at five different distances (10-20 km, 30-40 km, 50-60 km, 70-80 km and 90-100 km) from the sea (Table 1 and Figure 1) and analysed as per standard methods (APHA, 1998). Physico-chemical parameters of water were determined on-board immediately after collections.

Information on fish species distribution was collected by analysis of representative samples out of a total catch by non-selective fishing gear *Beenti jal* (bag net) being operated in all the sampling centres.

Identification of fish species was performed following Jayaram (1981, 1999), Talwar and Jhingran (1991). The relative abundance (percentage of catch) of fish species by numbers across different centres was determined.



Figure 1: Sampling centres in Hooghly-Matlah estuary

Centres located at 90-100 kilometres distance from the sea inside the Sundarbans were Canning in Matlah River, Chunakhali in Pathankhali River and, Dhamakhali-Sandeshkhali in Raimangal River. In Hooghly River, data were collected from Roychak-Nurpur area which was located around 96 kilometres from the sea.

At a distance of 70-80 kilometre from sea, sampling was performed from the Kantakhali and Masjidbari area in the Bidya River system near Gosaba. Sampling was also performed from bag net catch near Bagna forest, Satjelia and Melmelia-Ganral river crossing etc. which are located around 70-80 kilometre distance from the sea. Corresponding sampling centre in Hooghly estuary was at Diamond Harbour. Centres located around 50-60 kilometre distance were Raidighi and Amlamethi inside Sundarban whereas corresponding centre in Hooghly estuary was Nischintapur. Sampling Centres located between 30-40 kilometre distances from sea were Pathar Pratima area inside Sundarbans and Kakdwip in Hooghly River. Between 10-20 kilometre distance, Centres were Bankim Nagar in the Hooghly estuary and Curzon creek area between Saptamukhi and Thakuran River inside the Sundarbans.

Hierarchical clustering techniques using 'Primer' software was employed to understand the difference in catch composition between the Hooghly and Matlah estuary.

RESULT AND DISCUSSION

Observations related to water quality parameters especially transparency, salinity and its related parameters are given in Table 2. Sampling centres in the Sundarbans were much more saline in nature as compared to those in the Hooghly estuary (similar latitude) due to lack of freshwater influx. In most of the cases, sampling centres in the Sundarbans were more transparent as compared to sampling Centres in the river Hooghly (except in Ichhamati/ Raimangal River).

This was due to mangrove vegetation in the Sundarbans preventing turbidity by tidal action during high tide. The parameters which are influenced by saline water like total hardness, specific conductivity were also observed to be comparatively much higher in rivers inside Sundarbans as compared to those in Hooghly estuary.

FISH SPECIES DISTRIBUTION

Fish species distribution at sampling centres located in the Hooghly estuary and those inside the Sundarbans at similar distance are given in graphical form for understanding dominated fish species. Due to very small mesh size of bag net especially at cod end, catches mostly consisted of juveniles. Prawns and crabs catch composition has not described in the present paper. Only fish catch composition were compared and contribution of dominant species are given below.

Fish Species Comparison Between Sampling Centres Located at 90-100 Kilometre Distance

Marine migrant species such as *Escualosa thoracata*, *Eleutheronema tetradactylum* etc. has a significant contribution in sampling Centres inside Sundarbans like Canning, Chunakhali or Sandeshkhali etc. (Figures 2a, 2b and 2c), whereas freshwater species such as *Setipinna phasa* dominated at Roychak (Figure 2d). Also, estuarine mullets such as *Liza parsia*, *Liza tade* etc. contributed significantly at Canning, Sandeshkhali etc. whereas *Otolithoides pama* (juveniles) had a significant share at Roychak. Significant presence of *Otolithoides pama* in lower freshwater zone of Hooghly estuary was reported by Roshith et al. (2013). Even, high saline water ribbon fish like *Trichiurus* sp. were part of the catch at Chunakhali.

Fish Species Comparison Between Sampling Centres Located at 70-80 Kilometre Distance

In this zone at Sundarbans, high saline water species *Harpadon nehereus* had an overwhelming contribution around Bagna forest or Satjelia region indicating higher salinity regime of the region (Figure

Table 1: Sampling centres in Hooghly-Matlah estuary

S. N.	Distance range from sea (km)	Matlah River system	Geographical coordinates	Approx. distance (km) from sea	Hooghly River system	Geographical coordinates	Approx. distance (km) from sea
1.	90-100	Canning area	22°18'19.9"N 88°40'43.4"E	95	Nurpur-Roychak	22°12'42.6"N 88°04'11.4"E	95.7
2.		Chunakhali area	22°16'37.8"N 88°47'41.9"E	90			
3.		Dhamakhali-Tushkhali-Sandeshkhali area	22°21'09.0"N 88°52'50.0"E	100			
4.	70-80	Kantakhali-Gosaba-Masjidbari area	22°09'23.0"N 88°47'49.2"E to 22°10'49.4"N 88°46'11.3"E	71	Diamond Harbour	22°10'06.0"N 88°11'46.0"E	75.6
5.		Bagna-Satjelia-Melmelia-Ganral river Crossing area	22°11'25.4"N 88°56'18.8"E to 22°09'57.4"N 88°53'18.6"E to 22°09'54.4"N 88°53'34.9"E	72			
6.	50-60	Raidighi	21°59'34.0"N 88°26'36.3"E	57	Nischintapur	21°59'55.0"N 88°11'05.0"E	56.3
7.		Amlamethi	21°04'00.1"N 88°45'02.6"E	57			
8.	30-40	Pathar Pratima area	21°47'43.8"N 88°21'52.4"E	30	Kakdwip	21°53'24.0"N 88°09'31.0"E	36.5
9.		Dakhin Sibnagar	21°45'26.7"N 88°23'41.9"E				
10.		Banashyam Nagar	21°47'59.3"N 88°25'58.2"E				
11.	10-20	Curzon creek	21°43'13.3"N 88°25'15.7"E	13.7	Bankim Nagar	21°42'00.0"N 88°09'39.0"E	12

3c). Sizable presence of it was also observed at Masjidbari near Gadkhali (opposite of Gosaba) (Figure 3b). At Diamond Harbour in Hooghly estuary, dominance of marine migrant *Escualosa thoracata*, *Polynemus paradiseus* (mostly juveniles) and *Otolithoides pama* (juveniles) was observed (Figure 3d). Presence of freshwater species such as *Setipinna phasa* is an indication of seasonal freshwater regime of Diamond Harbour.

Fish Species Comparison Between Sampling Centres Located at 50-60 Kilometre Distance

Saline water clupeid *Anadontostoma chakunda*, mullet *Liza parsia*, etc. dominated at Raidighi, marine migrant such as *Coilia ramcarati*, *Stolephorus indicus* dominated at Amlamethi region (Figure 4a and 4b), whereas Nischintapur in Hooghly zone was dominated by *Coilia dussumieri*, besides juveniles of sciaenid *Otolithoides pama*, or estuarine gobid like *Odontamblyopus rubicandus* etc (Figure 4c).

Fish Species Comparison Between Sampling Centres Located at 30-40 Kilometre Distance

Overwhelming dominance of marine migrant *Escualosa thoracata* was observed in bag net catch at sampling centres around Pathar Pratima region (Figure 5a). Catch at Kakdwip in Hooghly estuary was dominated by *Coilia dussumieri* besides sizable presence of *Escualosa thoracata* (Figure 5b). Significant contribution of *Harpodon nehereus* at Kakdwip is an indication of similar salinity regime of Gosaba-Sajnekhali region of Sunderban that

are located around 70-80 kilometre distance from sea. Significant occurrence of Bluestripe herring (*Herklotsichthys quadrimaculatus*) was also recorded at Pathar Pratima region.

Fish Species Comparison Between Sampling Centres Located at 10-20 Kilometre Distance

Escualosa thoracata dominated in bag net catch at Curzon creek area whereas very small juveniles of Sciaenid like *Pennahia anea* or *Panna microdon* dominated at Bankim Nagar area (Figures 6a &

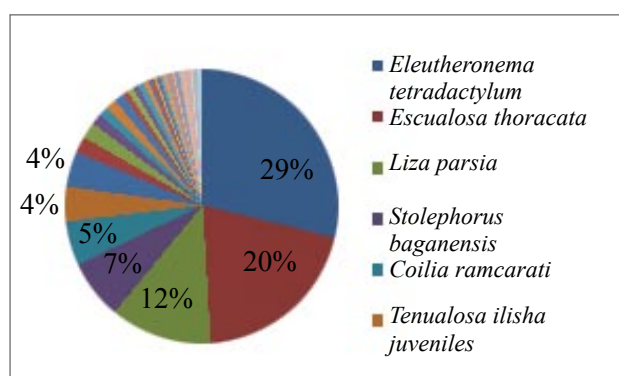


Figure 2a: Fish species abundance at Canning

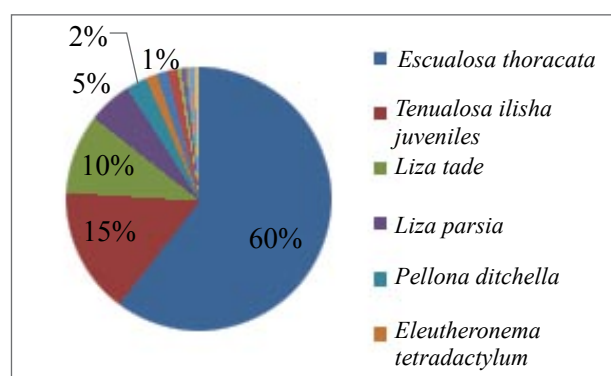


Figure 2b: Fish species abundance at Sandeshkhali area

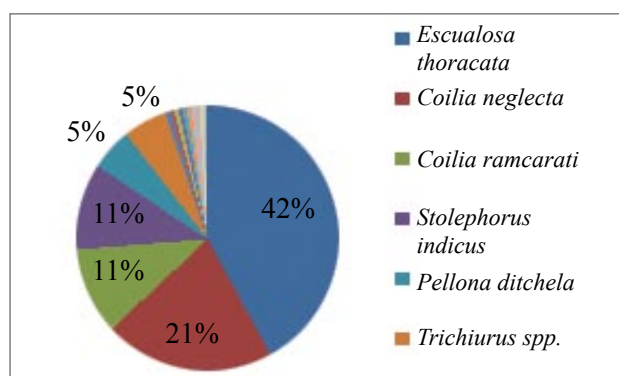


Figure 2c: Fish species abundance at Chunakhali

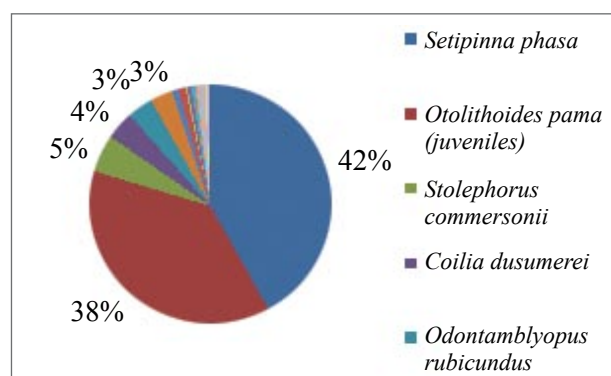


Figure 2d: Fish species abundance at Roychak

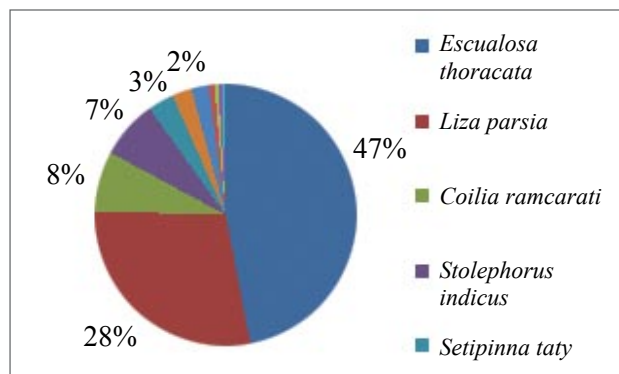


Figure 3a: Fish species abundance at Kantakhali

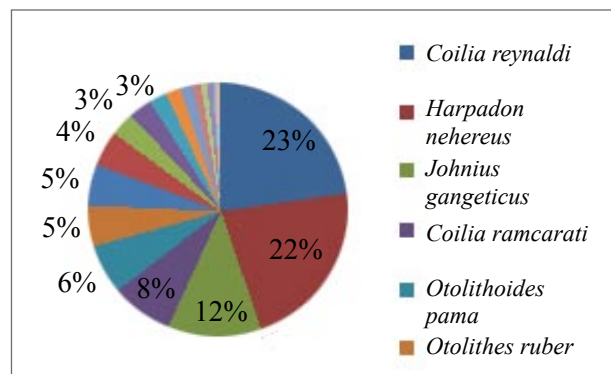


Figure 3b: Fish species abundance at Masjidbari

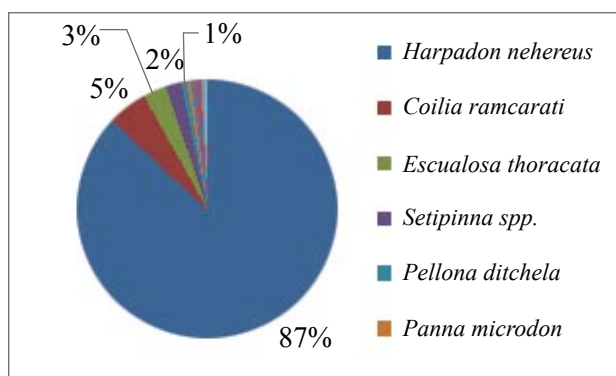


Figure 3c: Fish species abundance at Bagna-Satjelia-Melmelia-Ganral river crossing

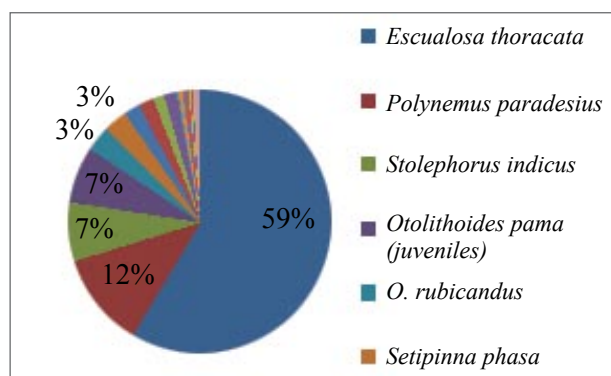


Figure 3d: Fish species abundance at Diamond Harbour

Table 2: Comparison of water quality parameters between Hooghly with Matlah-Thakuran-Raimangal estuary

S. N.	Matlah River system	Salinity (ppt)	Hardness (mg l-1)	Trans- parency (cm)	Sp. cond. (mS/cm)	Hooghly River system	Salinity (ppt)	Hardness (mg l-1)	Trans- parency (cm)	Sp. cond. (mS/cm)	Month of sampling
Centres located around 90-100 km distance from sea											
1.	Canning area	27.34-29.75	5200-5600	30-34	44.3-47.9	Roychak	2.90-3.2	730-800	12.5-16	5.5-6.48	May
2.	Chunakhali area	22-23	3100-3150	39.5	26.3-26.5	Roychak	0.12	88	12	0.277	July
3.	Dhamakhali-Tushkhali-Sandeshkhali area	1.3-1.5	400-500	4-5	2.06-2.47	Roychak	0.06	84	18	0.265	Sep
Centres located around 70-80 km distance from sea											
4.	Kantakhali-Gosaba-Masjidbari area	19.9-27.8	3450-4200	78-80	29.6-35.3	Diamond Harbour	0.16	90	15	0.307	July
5.	Bagna-Satjelia-Melmelia-Ganral river Crossing	14.8-21.7	2700-4100	90-94	22.1-33.8	Diamond Harbour	0.08	88	11	0.298	Sep
Centres located around 50-60 km distance from sea											
6.	Raidighi	28.88	5460	15	46.6	Nischintapur	5.36	1200	24	12.1	May
7.	Amlamethi area	14.8-15.2	2150-2500	18-24	24.9	Nischintapur	0.08	88	16.5	0.306	Sep
Centres located around 30-40 km distance from sea											
8-10.	Pathar Pratima-DakhinSibnaga-Banashyam Nagar area	25.68-26.01	4800-5100	15-27	41.8-42.3	Kakdwip	13.9	2150	30	18.1	Feb
Centres located around 10-20 km distance from sea											
11.	Curzon creek area	25.88-25.94	4900-5100	45-50	42.1-42.2	Bankim Nagar	13.0	2600	57	22.4	Dec

6b). Ribbon fishes (*Lepturacanthus* sp. or *Trichiurus* sp.) had a sizable presence in catches at both the places.

Salinity vis-à-vis Fish Species Distribution in Rivers

Sampling centres in Sundarbans are much more saline in nature as compared to those in Hooghly estuary (at similar latitude) due to lack of freshwater influx. This is due to the fact that most of the rivers of Sundarbans (such as Saptamukhi, Thakuran, Matlah, Gosaba etc) have lost their connectivity with the parent river, the Ganges. Higher salinity regime had a direct influence on fish species

johni, *Macrospinosa cuja*, *Terapon jarbua*, *Upeneus sulphureus* etc. are present in significant numbers in Gosaba-Sajnekhali-Bagna forest area whereas they are almost absent at Diamond Harbour.

Due to less freshwater discharge, rivers of the Sundarbans such as Matlah, Saptamukhi, Thakuran etc. have less occurrence of Hilsa (*Tenualosa ilisha*). Increased salinity in Indian Sundarbans is often linked with reduced growth or mortality of mangroves in Sundarbans. Also, swarming of jellyfish, *Pleurobrachia globosa* was a common phenomenon at most of the sampling centres inside Sundarbans throughout the year while in Hooghly

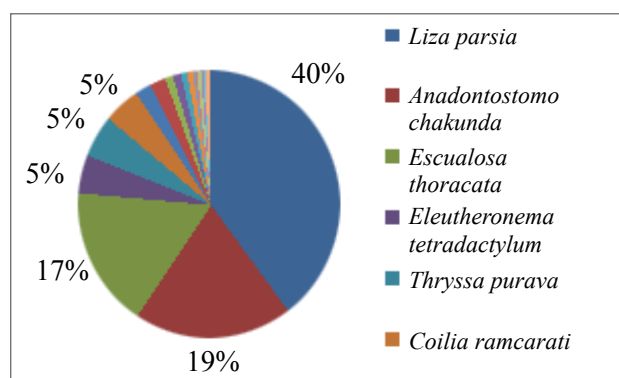


Figure 4a: Fish species abundance at Raidighi

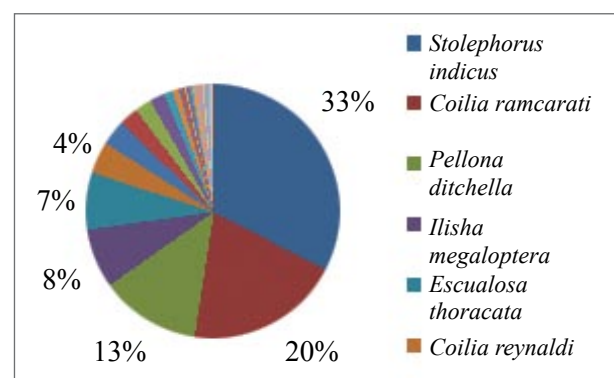


Figure 4b: Fish species abundance at Amlamethi

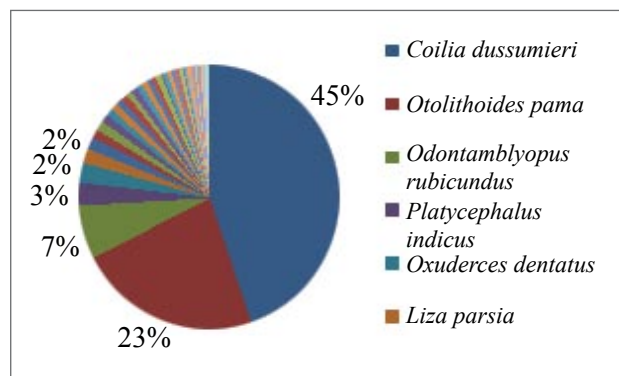


Figure 4c: Fish species abundance at Nischintapur

distribution in rivers inside Sundarbans. That can be best understood when compared with centres located in Hooghly estuary; those are flushed by freshwater from Ganges through Bhagirathi River. Beside *Harpadon nehereus*, many marine fish species such as *Bregmaceros maclellandi*, *Lutjanus*

River, it is available only up to Nischintapur area. This is also an impact of higher salinity regime in rivers inside Sundarbans.

Hierarchical clustering techniques were employed for grouping of sites based on the presence/ absence of fish species. It was observed that centres located in Hooghly estuary such as Kakdwip, Nischintapur, Diamond Harbour, Roychak form a separate group except Bankim Nagar which is close to sea.

Dhamakhali has some influence of fresh water from upstream Ichhamati River and hence grouped with centres of Hooghly River. Zonal variation of Sundarbans is also evident from clustering of nearby centres such as Gosaba-Chunakhali-Amlamethi, Canning-Raidighi, Pathar Pratima-Curzon creek etc. (Figure 7).

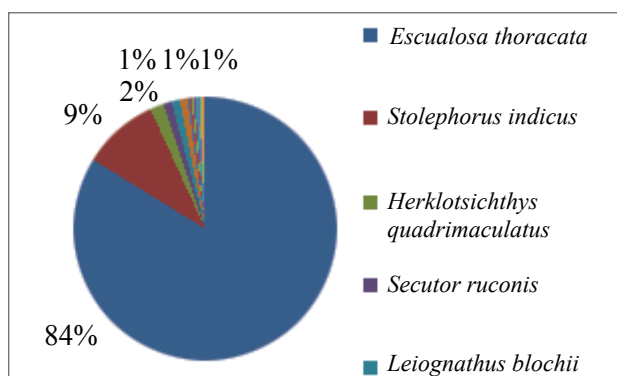


Figure 5a: Fish species abundance at Pathar Pratima area

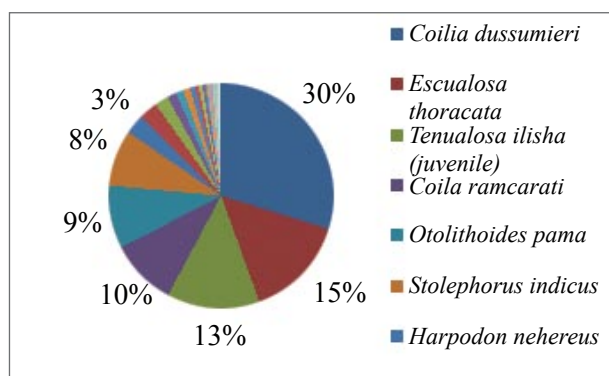


Figure 5b: Fish species abundance at Kakdwip

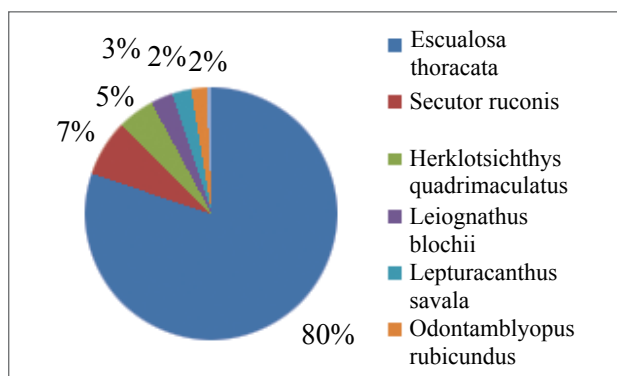


Figure 6a: Fish species abundance at Curzon creek area

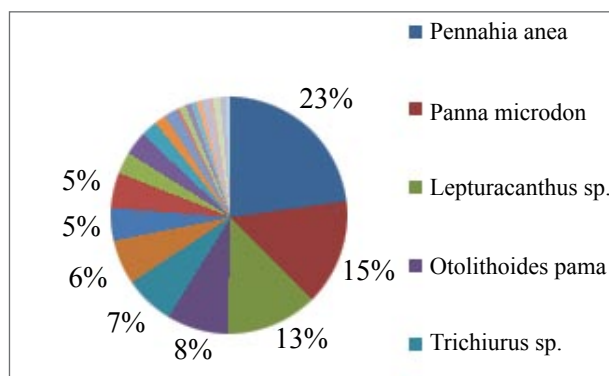


Figure 6b: Fish species abundance at Bankim Nagar

CONSERVATION ISSUES

During the surveys, it was observed that fish component of bag net catches mostly consisted of fish juveniles having very less or no commercial value. Not only *Beenti jal* (bag net), nonselective fishing gears such as *chorpata/ kharpata jal* (set barrier), *ghono chhandi jal* (small mesh gill net) etc. are highly detrimental to sustainable fisheries from rivers of Hooghly-Matlah estuary as they are responsible for indiscriminate destruction of fish larvae and juveniles.

Huge destruction of fish larvae/ juveniles during natural collection of targeted fish/ prawn seeds such as *Paeneus monodon*, *Macrobrachium rosenbergii* etc. through *meen jal* (shooting net) was also reported. Fishers who collect fish seed generally do not give much attention about other fish larvae except targeted species. This causes havoc through wanton destruction of fish larvae/ juveniles. Most of the fishing gears are made of zero or very small mesh size net. As the by-catch has meager or no

commercial value, it is simply thrown away or fed to *Clarias gariepinus* culture ponds in some places.

It was even observed that fishers use small mesh gill net along with large mesh gill net catching both adult and juveniles simultaneously. In fresh water zone of the Hooghly estuary, catch of shore seine (large drag net with zero mesh size net) also catch mainly juvenile fishes. Also, various other gears are used to collect fish seed in rivers of Sundarbans for stocking in *bheri* (ponds or coastal wetlands).

Collection of juveniles of *Lates calcarifer*, *Scatophagus argus*, mullets, are performed using zero mesh drag net, causing destruction of larvae of other fishes.

CONCLUSION

Increased freshwater discharge through Sundarbans rivers by desilting the connecting channels with River Ganges will certainly lower the salinity status of the rivers of Sundarbans and thus may provide

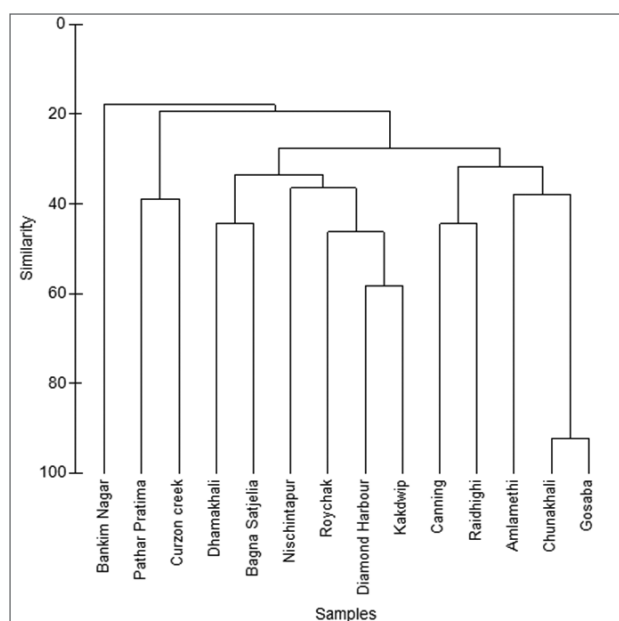


Figure 7: Distinct cluster of sampling Centres located in Hooghly estuary

the required salinity regime which may trigger the migration of Hilsa and other estuarine fishes leading to abundance of *T. ilisha* in rivers of Sundarbans.

Mangroves may get more congenial environment for better survival and growth especially of *Heriteara fomes*, i.e. Sundari which are in reduced density in the Indian Sundarbans, at present. Controlled use of destructive fishing gear through provision of alternative livelihood is also the need of the hour for sustainable open water fisheries of the Hooghly-Matlah estuary.

ACKNOWLEDGEMENT

The authors are extremely grateful to technical officers and support staff viz., R. C. Mandi, C. N. Mukherjee, D. Sanfui, A. Roy Choudhury, A. Mitra, A. Sengupta, B. N. Das, D. Saha, A. Barui, S. Mandal, A. Prasad, D. Das for their help in sampling and analysis of samples collected from the estuary. Financial help from Indian Council of agricultural Research, New Delhi is gratefully acknowledged.

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Spatial and Temporal Variation in Ichthyofaunal Diversity in the Middle-Lower Stretch of the River Ganges

Rajesh K. Sinha¹, Ravindra K. Sinha² and Dilip K. Kedia²

¹ Department of Biological Science,
Yaduvanshi College of Technology, Rewari, Haryana, India

²Environmental Biology Laboratory
Department of Zoology, Patna University, Patna – 800005, India

ABSTRACT

The Ganges has been the abode of rich ichthyofaunal diversity and source of livelihood for millions of fishermen who inhabit the river bank. The study was carried out to assess the spatial and temporal variation in ichthyofaunal diversity in the lower middle stretch of the River Ganges between Patna and Rajmahal (380 kilometres) during December 2007 to May 2009.

A total of 106 fish species belonging to 73 genera, 30 families and 10 orders were recorded. Occurrence of five exotic fish species, completely absent during 1993-95 study in the Ganges at Patna, indicates recent invasion of the exotic species in the Ganges system.

Though the Ganges sustains rich diversity of fishes in the stretch, presence of the exotic species is a matter of great concern and needs immediate attention of the scientific community and government authorities. There is an urgent need for sound conservation measures to sustain the ichthyofaunal diversity.

Key words: Ganges, fishing gears, cast nets, gill nets, *Clupisoma garua*, *Eutropiichthys vacha*

INTRODUCTION

The River Ganges has a total drainage area of about 1,060,000 km², out of which 816,000 square kilometres is in India; it is the fifth largest river basin in the world. The River Ganges originates in the Garhwal Himalayas at Gaumukh (30°55'N/70°7'E) from Gangotri glacier at an elevation of 4100 metres under the name of Bhagirathi.

During its seaward journey of over 2700 kilometres from the origin to the Bay of Bengal (Sinha and Kannan 2014), the river passes through densely

populated north Indian states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal (Sinha and Kannan 2014). The river breaks into a number of interlaced channels in the plains forming meanders, oxbow lakes and swamps in its northern tributaries. The basin (70° to 88°30'E longitude 22° to 31°N latitude) receives an annual run off of 48.96 million ha m from a catchment area of 96.6 million square kilometres and carries an annual load of 1.46 million tons of sediment (Natarajan 1989), second only to the Yellow River of China (Lisitzen 1972). The Ganges basin covers about 26 per cent of the Indian

territory but sustains about 43 per cent (540 million) of the Indian population (Sinha and Kannan 2014).

Biodiversity is essential for stabilisation of ecosystems, protection of overall environmental quality, for understanding intrinsic worth of all species on the Earth (Ehrlick and Wilson 1991). The fish diversity is greatly affected by a series of changes such as loss of lateral and longitudinal connectivity, habitat alteration, water current, turbidity levels, fishing pressure, introduction of exotic species, loss of breeding grounds and changes in the fish food organisms due to channelisation, anthropogenic impacts and reservoir formation.

The River Ganges is no exception to these environmental aberrations. The river has suffered environmental degradation and erosion of its ecological integrity due to declining flow owing to unsustainable abstraction of river water for irrigation and other purposes, pollution from both point and non-point sources, siltation due to loss of vegetation in the catchment area, hydroelectric projects mainly in the Himalayan region, and construction of embankments as flood control measures snapping the lateral connectivity of the river with its flood plains and wetlands, and construction of dams and barrages as water resource developments resulting in loss of longitudinal connectivity of the rivers.

The River Ganges is also suffering with irreversible changes in natural population by introduction of exotic species and diseases (Dudgeon et al. 2005; Arthington and Welcomme 1995; Arthington et al. 2004; De Silva and Abery 2007). The fish diversity of the River Ganges and its tributaries is also known to be highly threatened due to indiscriminate fishing pressure as well as juvenile fishing.

Fish diversity is adversely affected, both qualitatively and quantitatively, by habitat destruction and defragmentation (Fu et al. 2003), water abstraction, industries and private use (Szollosi-Nagy, 2004; Ricciardi and Rasmussen 1999; Gibbs 2000; Dawson et al. 2003) exotic species introduction (Copp et al.

2005), pollution (Lima-Junior et al. 2006) and global climate change impacts (Leveque et al. 2005; Mas-Marti et al. 2010).

Talwar (1991) recorded 375 species of fish from the entire stretch of the Ganges, whereas Payne et al. (2004) reported 181 fish species for the whole freshwater stretch of the river in India and Bangladesh indicating rich fish diversity.

In an earlier study during 1993-95 in the Ganges in and around Patna (30 kilometres), 106 species were recorded (Hassan 1999). Nineteen species recorded during 1993-95 could not be recorded in the current study of 2007-09. Presence of a number of exotic fish species in this stretch documented during the study will attract attention of the fishery managers. Research is being pursued globally to develop conservation planning to protect freshwater biodiversity (Pusey et al. 2010; Margules and Pressey 2000; Lipsey and Child 2007).

In India, sufficient knowledge of the river biota is lacking. In this connection, the current study was carried out to:

- 1) Determine the current status of spatial and temporal variation in fish diversity.
- 2) To review the threats to fish diversity.
- 3) To suggest measures for fish diversity conservation and management.

MATERIALS AND METHOD

Study Area

Five different locations — Patna, Munger, Bhagalpur, Kahalgaon and Rajmahal — with 11 landing sites: Digha Ghat, Adalat Ghat, Ghagha Ghat, Gai Ghat (all at Patna), Lallupokhar Ghat, Kastaharni Ghat (both at Munger), Hanuman Ghat, Barari Ghat (both at Bhagalpur), LCT Ghat (Kahalgaon), Mahajan Toli Ghat, Gudara Ghat (both at Rajmahal) were selected for the study of ichthyofaunal diversity in the stretch of the River Ganges (Figure 1).

All these sites were located at the right bank of the River Ganges where intense fishing activities



Figure 1: Map of the middle-lower stretch of the River Ganges showing study sites

were observed. The geographical coordinates ranged from 85°06'55"E/25°40'06"N (Patna) to 87°50'21"E/25°03'21"N (Rajmahal) of the study area. The fishers are migratory in nature and they migrate seasonally/ monthly/ daily from one segment of the river to another for best catch of the fishes. Since they are well aware about the fish density in different sections of the river, they switch over fishing from one stretch of the river to the other stretch of the river for a higher catch. The present study covered approximately 380 kilometres in the middle-lower stretch of the River Ganges.

Sampling

Seasonal field surveys at Munger, Bhagalpur, Kahalgaon and Rajmahal and monthly field surveys at Patna were conducted to study the ichthyofaunal diversity of the River Ganges. A total of five seasonal surveys (during December 2007 to February 2008; April to June, 2008; October-November, 2008; December 2008 to February 2009 and March to June 2009) were conducted to know the spatial and temporal variations of fish diversity of the river Ganges.

Fish samples and other relevant data were collected from the fishermen at different landing sites. Altogether one hundred and six fish species were collected during the study period with the help of skilled fishermen as well as experimental netting was also conducted using cast net to assess the fish diversity at the same sampling sites.

Fishing gears and devices used in fishing operation were moving nets (drag nets/ seine nets, gill nets, a monofilament drift nets, multifilament gill nets, lift nets, dip nets, purse nets, scoop nets, and split bamboo cage), hooks and lines (iron hooks and Kos) to catch fish species in different seasons. Gill nets were laid in the evening and fishes hauled up next morning by the fishers. Specimens were identified in the field itself and those which could not be identified in the field were brought to the Environmental Biology Laboratory, Patna University, Patna and preserved in 10 per cent formalin solution where they were identified following Talwar and Jhingran (1991), Srivastava (1988), and Vishwanath (2007).

PHYSICO-CHEMICAL PARAMETERS

The river water samples were collected and analysed for physico-chemical parameters as per standard methods (APHA 1998). Temperature of sub-surface water was recorded at sampling sites with the centigrade (°C) mercury thermometer of 0.1° centigrade graduation and air temperature also taken with the same thermometer keeping it in shade. pH of water samples were determined immediately after collection at sampling sites with the help of pen-type portable pH meter (pH testr⁻², pHScan1). Turbidity was measured by Nephelo-turbidity meter in laboratory (Systronics Nephelo-Turbidity Meter, Model-132).

The specific conductivity and TDS were measured by the Electrical Conductivity Meter (Century Water Analyses Kit, Model No. CK-710). Dissolved Oxygen (DO) of water samples were determined by the Winkler's Azide modification method as per standard methods. The BOD was estimated by calculating the difference of initial DO of the sample and DO of the

same sample after incubation in the dark at 20°C for five days

BOD, mg/l = [Initial DO – Final DO]

RESULTS

Ichthyofaunal Diversity

The surveys were conducted in winter, summer and post-monsoon seasons between December 2007 and May 2009. During this period, 106 species were recorded belonging to 73 genera, 29 families and 10 orders (Table 4).

Spatial Diversity

During the investigation, 106 species were recorded in the stretch of the River Ganges. Maximum diversity (100 species) belonging to 71 genera, 29 families and 10 orders were recorded at Patna, whereas minimum diversity (40 species) belonging to 32 genera, 15 families and eight orders were recorded at Kahalgaon (Table 4). Highest ichthyofaunal diversity recorded at Patna might be due to extensive and intensive sampling conducted at four sampling sites.

Rajmahal is the second most diversified sampling site where 69 species belonging to 51 genera, 19 families and nine orders were encountered. Among all recorded species, 31 species viz, *Ailia coila*, *Bagarius bagarius*, *Botia dario*, *Cabdio morar*, *Crossocheilus latius*, *Clupisoma garua*, *Eutropiichthys vacha*, *Johnius coitor*, *Gudasia chapra*, *Glossogobius giuris*, *Gagata cenia*, *Labeo bata*, *Labeo calbasu*, *Macrognathus pancalus*, *Mastacembalus armatus*, *Mystus cavasius*, *Mystus tengara* or *carcio*, *Osteobrama cotio*, *Ompok papda*, *Parambasis nama*, *Neotropius antherinoides*, *Puntius sophore*, *Rita rita*, *Rhinomugil corsula*, *Salmophasia bacaila*, *Setipinna phasa*, *Sicamugil cascasia*, *Sperata aor*, *Sperata seenghala*, *Systemus sarana* and *Xenentodon cancila* were common at all the sampling sites.

Nandus nandus was found only at Munger; however, it has low commercial value and the total number of individuals encountered was almost 130 per day.

Two individuals of *Pterigoplichthys anisitsi*, a South American sailfin fish, were recorded from Patna only (Sinha et al. 2010). *Hemibagarus menoda* was collected from Munger and Bhagalpur. The local fishermen informed that this fish comes in the River Ganges from small tributaries like Kiul and Ghogha Rivers joining from south (Table 1).

Though 31 species were common at all locations, 23 fish species viz: *Anguilla bengalensis*, *Barilius bendelisis*, *Clarias magur*, *Channa striatus*, *Chela atpar*, *Chela laubuca*, *Tetraodon fluviatalis*, *Devario devario*, *Esomus danricus*, *Glyptothorax botia*, *G. cavia*, *G. telchitta*, *Heteropneustus fossilis*, *Hypophthalmichthys nobilis*, *Monopterusuchia*, *Nangra nangra*, *Oreochromis mossambicus*, *Ompok bimaculatus*, *Pangio pangia*, *Pterigoplichthys anisitsi*, *Pethia phutino*, *Salmophasia phulo* and *Sisor raddophorus*, were encountered at Patna only in the present survey. This might be the result of extensive and intensive survey at Patna. *Monopterusuchia* and *Channa gachua* were recorded from Rajmahal only (Table 1).

Temporal Diversity

During the study different species were recorded in different seasons. Five surveys were conducted during the study period. In the first survey (Survey I) in the winter season (December 2007 to February 2008), 47 species; in the IInd survey in summer (April to June 2008), 50 species; in the IIIrd survey (October-November 2008) 81 species; in the IVth survey (December 2008 to February 2009), 77 species; and in the Vth survey (March to June 2009), 63 species were recorded as depicted in Table 2.

In the first survey, 47 species were collected out of which 18 species belonged to order Siluriformes, three species from Clupeiformes and two species of Synbranchiformes were recorded. Single species of each order Mugiliformes, Tetraodontiformes and Beloniformes were encountered (Table 2). In the second survey, 50 species were recorded in which Siluriformes with 19 species was found to be the most diversified order.

Table 1: Spatial variation in the ichthyofaunal diversity in middle-lower stretch of the River Ganges during the study (December 2007- May 2009)

S. N.	Name of fish species	Patna	Munger	Bhagalpur	Kahalgaon	Rajmahal
1.	<i>Acanthocobitis botia</i>	+				
2.	<i>Ailia coila</i>	+	+	+	+	+
3.	<i>Amblyceps mangois</i>	+				
4.	<i>Amblypharyngodon gora</i>	+	+	+	+	
5.	<i>Amblypharyngodon microlepis</i>	+	+	+		
6.	<i>Amblypharyngodon mola</i>	+			+	+
7.	<i>Anabas testudeni</i>	+				+
8.	<i>Anguilla bengalensis</i>	+				
9.	<i>Aspidoparia jaya</i>	+		+		+
10.	<i>Bagarius bagarius</i>	+	+	+	+	+
11.	<i>Bagarius yarellii</i>	+				+
12.	<i>Barilius bendelisis</i>	+				
13.	<i>Botia almohrea</i>		+			
14.	<i>Botia dario</i>	+	+	+	+	+
15.	<i>Botia lohachatta</i>	+	+			
16.	<i>Cabdio morar</i>	+	+	+	+	+
17.	<i>Catla catla</i>	+	+			+
18.	<i>Chagunius chagunio</i>	+	+			+
19.	<i>Channa gachua</i>					+
20.	<i>Channa marulius</i>	+	+	+		+
21.	<i>Channa punctata</i>	+		+		+
22.	<i>Channa striata</i>	+				
23.	<i>Chela atpar</i>	+				
24.	<i>Chela laubuca</i>	+				
25.	<i>Chitala chitala</i>	+	+			+
26.	<i>Cirrhinus mrigala</i>	+	+	+		+
27.	<i>Cirrhinus reba</i>	+	+		+	+
28.	<i>Clarias magur</i>	+				
29.	<i>Clupisoma garua</i>	+	+	+	+	+
30.	<i>Crossocheilus latius</i>	+	+	+	+	+
31.	<i>Cyprinus carpio</i>	+	+			+
32.	<i>Devario devario</i>	+				
33.	<i>Erithistes hara</i>	+	+			
34.	<i>Esomus danricus</i>	+				
35.	<i>Eutropiichthys murius</i>	+	+			+
36.	<i>Eutropiichthys vacha</i>	+	+	+	+	+
37.	<i>Gagata cenia</i>	+	+	+	+	+
38.	<i>Garra gotyla</i>	+	+		+	+
39.	<i>Glossogobius giuris</i>	+	+	+	+	+
40.	<i>Glyptothorax botia</i>	+				
41.	<i>Glyptothorax cavia</i>	+				
42.	<i>Glyptothorax telchitta</i>	+				
43.	<i>Gogangra viridescense</i>	+	+			+
44.	<i>Gonialosa manmina</i>	+	+			+

S. N.	Name of fish species	Patna	Munger	Bhagalpur	Kahalgaon	Rajmahal
45.	<i>Gudasia chapra</i>	+	+	+	+	+
46.	<i>Hemibagrus menoda</i>		+	+		
47.	<i>Heteropneustus fossilis</i>	+				
48.	<i>Hypophthalmichthys nobilis</i>	+				
49.	<i>Hyporhamphus limbatus</i>			+		+
50.	<i>Johnius coitor</i>	+	+	+	+	+
51.	<i>Labeo bata</i>	+	+	+	+	+
52.	<i>Labeo calbasu</i>	+	+	+	+	+
53.	<i>Labeo gonius</i>	+	+		+	+
54.	<i>Labeo rohita</i>	+	+			+
55.	<i>Leiodon cutcutia</i>	+			+	+
56.	<i>Lepidocephalichthys guntea</i>	+	+			+
57.	<i>Macrognathus aral</i>	+	+		+	+
58.	<i>Macrognathus pancalus</i>	+	+	+	+	+
59.	<i>Mastacembelus armatus</i>	+	+	+	+	+
60.	<i>Monopterus albus</i>	+				
61.	<i>Monopterus cuchia</i>					+
62.	<i>Mystus bleekery</i>	+	+	+		+
63.	<i>Mystus cavasius</i>	+	+	+	+	+
64.	<i>Mystus carcio</i>	+	+	+	+	+
65.	<i>Mystus tengara</i>	+				+
66.	<i>Nandus nandus</i>		+			
67.	<i>Nangra nangra</i>	+				
68.	<i>Nangra punctata</i>	+	+			
69.	<i>Neimacheilus aureus</i>	+	+			
70.	<i>Neotropius antherinoides</i>	+	+	+		+
71.	<i>Notopterus notopterus</i>	+	+			+
72.	<i>Ompok pabo</i>	+	+	+	+	+
73.	<i>Ompok bimaculatus</i>	+				
74.	<i>Ompok papda</i>	+	+	+	+	+
75.	<i>Oreochromis mossambicus</i>	+				
76.	<i>Osteobrama cotio</i>	+	+	+	+	+
77.	<i>Pangasius pangasius</i>	+				+
78.	<i>Pangio pangia</i>	+				
79.	<i>Panna microdon</i>	+	+	+		+
80.	<i>Parambassis baculis</i>	+	+			
81.	<i>Parambassis nama</i>	+	+	+	+	+
82.	<i>Parambassis ranga</i>	+	+	+		+
83.	<i>Tetraodon fluviatilis</i>	+				+
84.	<i>Trichogaster fasciatus</i>	+	+			
85.	<i>Pethia phutino</i>	+				
86.	<i>Pethia ticto</i>	+	+		+	+
87.	<i>Pterigoplichthys anisitsi</i>	+				
88.	<i>Puntius chola</i>	+	+	+		+
89.	<i>Puntius conchoniis</i>	+			+	

S.N.	Name of fish species	Patna	Munger	Bhagalpur	Kahalgaon	Rajmahal
90.	<i>Puntius sophore</i>	+	+	+	+	+
91.	<i>Rhinomugil corsula</i>	+	+	+	+	+
92.	<i>Rita rita</i>	+	+	+	+	+
93.	<i>Salmophasia bacaila</i>	+	+	+	+	+
94.	<i>Salmotoma phulo</i>	+				
95.	<i>Securicula gora</i>	+	+	+		+
96.	<i>Setipinna brevifilis</i>	+	+			+
97.	<i>Setipinna phasa</i>	+	+	+	+	+
98.	<i>Sicamugil cascasia</i>	+	+	+	+	
99.	<i>Silonia silondia</i>	+	+			+
100.	<i>Sisor raddophorus</i>	+				
101.	<i>Sperata aor</i>	+	+	+	+	+
102.	<i>Sperata seenghala</i>	+	+	+	+	+
103.	<i>Systomus sarana</i>	+	+	+	+	+
104.	<i>Tenualosa ilisha</i>	+		+		+
105.	<i>Wallago attu</i>	+	+	+		+
106.	<i>Xenentodon cancila</i>	+	+	+	+	+
Total		100	68	48	40	69

In the third survey, a total of 81 species were encountered. The ichthyofaunal diversity was the highest in this survey (i.e. in post-monsoon). In the fourth survey, a total of 77 species were encountered in which Cypriniformes with 33 species was the most diversified order. As the cyprinids attain their maximum size in this period so the skilled fishers prefer to use 10-16 millimetres mesh size gill nets to catch these fishes. In the fifth survey, a total of 63 species were recorded and Siluriformes (25 species) was the most diversified order followed by Cypriniformes (23 species) and Perciformes (six species).

In overall, temporal variation, the cypriniformes was the most dominant order and mugiliformes was the smallest order as depicted in Figure 2.

Amongst all five surveys, 24 species (*Ailia coila*, *Botia dario*, *Catla catla*, *Clupisoma garua*, *Crossocheilus latius*, *Eutropiichthys vacha*, *Glossogobius giuris*, *Labeo calbasu*, *Labeo bata*, *Lepidocephalichthys guntea*, *Macrognathus pancalus*, *Mastacembelus armatus*, *Mystus cavasius*, *Parambassis nama*,

Puntius sophore, *Neotropius antherinoids*, *Osteobrama cotio*, *Rita rita*, *Sperata aor*, *Sperata seenghala*, *Tenualosa ilisha*, *Tetraodon cutcutia*, *Wallago attu* and *Xenentodon cancilla*) were recorded common in all the surveys during the study whereas 8 species *Botia almorhea*, *Channa gachua*, *Channa striatus*, *Clarias magur*, *Heteropneustus fossilis*, *Hyporhamphus limbatus*, *Monopterus cuchia* and *Monopterus albus* were encountered only once in the entire surveys.

Fish Dominance

Ailia coila, *Cabdio morar*, *Bagarius bagarius*, *Clupisoma garua*, *Crossocheilus latius*, *Eutropiichthys vacha*, *Gudusia chapra*, *Johnius coitor*, *Salmophasia bacaila*, *Gagata cenia*, *Mystus cavasius*, *Mystus carcio*, *Puntius sps.* and *Setipinna phasa* abundantly found species in the stretch of the river. This stretch is hotspot for *Ailia coila*, *Cabdio morar*, *Clupisoma garua*, *Crossocheilus latius* and *Eutropiichthys vacha*. In summer, these species were abundantly available. In winter, *Cabdio morar*, *Crossocheilus latius*, *Glossogobius giuris*, *Johnius coitor*, *Gagata cenia*, *Gudusia chapra*, *Mystus sp.*,

Table 2: Temporal variation in fish diversity in middle-lower stretch of the River Ganges during the study (December 2007-May 2009)

S. N.	Name of fish species	Survey Number				
		I	II	III	VI	V
A.	Anguiliformes					
1.	<i>Anguilla bengalensis</i> (Gray)			√		
B.	Beloniformes					
2.	<i>Xenentodon canalla</i> (Hamilton-Buchanan)	√	√	√	√	√
C.	Cypriniformes					
3.	<i>Amblypharyngodon gora</i> (Hamilton)	√		√	√	
4.	<i>Amblypharyngodon microlepis</i> (Bleeker)			√		
5.	<i>Amblypharyngodon mola</i> (Hamilton-Buchanan)		√		√	
6.	<i>Aspidoparia jaya</i> (Hamilton)				√	√
7.	<i>Acanthocobitis botia</i> (Hamilton)					√
8.	<i>Barilius bendelisis</i> (Hamilton)			√		√
9.	<i>Botia dario</i> (Hamilton)	√	√	√	√	√
10.	<i>Botia almorhea</i> (Gray)			√		
11.	<i>Botia lohchatta</i> (Hamilton)			√		
12.	<i>Cabdio morar</i> (Hamilton)	√		√	√	
13.	<i>Catla catla</i> (Hamilton)	√	√	√	√	√
14.	<i>Cirrhinus mrigala</i> (Hamilton)	√		√	√	√
15.	<i>Cirrhinus reba</i> (Hamilton)		√	√	√	√
16.	<i>Chela laubuca</i> (Hamilton)				√	√
17.	<i>Chela atpar</i> (Hamilton)				√	√
18.	<i>Crossocheilus latius</i> (Hamilton)	√	√	√	√	√
19.	<i>Cyprinus carpio</i> (Linnaeus)			√	√	√
20.	<i>Chagunius chagunio</i> (Hamilton)			√	√	√
21.	<i>Devario devario</i> (Hamilton)				√	√
22.	<i>Esomus danricus</i> (Hamilton)				√	√
23.	<i>Garra gotyla</i> (Gray)		√	√	√	
24.	<i>Hypophthalmichthys nobilis</i> (Valenciennes)				√	
25.	<i>Labeo calbasu</i> (Hamilton)	√	√	√	√	√
26.	<i>Labeo bata</i> (Hamilton)	√	√	√	√	√
27.	<i>Labeo gonius</i> (Hamilton)				√	
28.	<i>Labeo rohita</i> (Hamilton)	√		√	√	√
29.	<i>Lepidocephalichthys guntea</i> (Hamilton)	√	√	√	√	
30.	<i>Nemacheilus aureus</i> (Bleeker)		√	√	√	√
31.	<i>Pangio pangia</i> (Hamilton-Buchanan)				√	√
32.	<i>Puntius chola</i> (Hamilton)			√	√	
33.	<i>Puntius conchonius</i> (Hamilton-Buchanan)			√		√
34.	<i>Puntius sophore</i> (Hamilton-Buchanan)	√	√	√	√	
35.	<i>Pethia phutino</i> (Hamilton)				√	√
36.	<i>Pethia ticto</i> (Hamilton-Buchanan)				√	
37.	<i>Osteobrama cotio</i> (Hamilton)	√	√	√	√	√
38.	<i>Securicula gora</i> (Hamilton)	√		√	√	
39.	<i>Salmophasia bacaila</i> (Hamilton)	√	√	√	√	
40.	<i>Salmophasia phulo</i> (Hamilton)			√	√	

S. N.	Name of fish species	Survey Number				
		I	II	III	VI	V
41.	<i>Systomus sarana</i> (Hamilton - Buchanan)	√		√	√	√
D.	Clupeiformes					
42.	<i>Gudasia chapra</i> (Hamilton)	√	√		√	√
43.	<i>Gonialosa manmina</i> (Hamilton)			√	√	√
44.	<i>Setipinna brevifilis</i> (Hamilton)		√		√	√
45.	<i>Setipinna phasa</i> (Hamilton)	√		√		√
46.	<i>Tenuialosa ilisha</i> (Hamilton)	√	√	√	√	√
E.	Mugiliformes					
47.	<i>Rhinomugil corsula</i> (Hamilton)	√	√	√	√	√
48.	<i>Sicamugil cascasia</i> (Hamilton)		√	√	√	
I.	Osteoglossoformes					
49.	<i>Chitala chitala</i> (Hamilton)				√	√
50.	<i>Notopterus notopterus</i> (Pallas)		√	√	√	
F.	Perciformes					
51.	<i>Anabas testudineus</i> (Bloch)	√	√	√		
52.	<i>Channa punctatus</i> (Bloch)	√		√	√	√
53.	<i>Channa gachua</i> (Hamilton)			√		
54.	<i>Channa marulius</i> (Hamilton)			√	√	
55.	<i>Channa striatus</i> (Bloch)			√		
56.	<i>Glossogobius giuris</i> (Hamilton)	√	√	√	√	√
57.	<i>Johnius coitor</i> (Hamilton)	√	√	√	√	√
58.	<i>Oreochromis mossambicus</i> (Peters)			√		
59.	<i>Parambassis baculis</i> (Hamilton)		√			√
60.	<i>Parambassis ranga</i> (Hamilton)		√	√	√	√
61.	<i>Parambassis nama</i> (Hamilton)	√	√	√	√	√
62.	<i>Panna microdon</i> (Hamilton)			√	√	
63.	<i>Nandus nandus</i> (Hamilton)			√	√	
64.	<i>Trichogaster fasciatus</i> (Bloch & Schneider)	√	√	√	√	
G.	Siluriformes					
65.	<i>Ailia coila</i> (Hamilton)	√	√	√	√	√
66.	<i>Amblyceps mangois</i> (Hamilton)				√	√
67.	<i>Bagarius bagarius</i> (Hamilton)	√	√	√		√
68.	<i>Bagarius yerelli</i> (Sykes)				√	
69.	<i>Clarias magur</i> (Linnaeus)			√		
70.	<i>Clupisoma garua</i> (Hamilton)	√	√	√	√	√
71.	<i>Eresthistes hara</i> (Hamilton)			√	√	
72.	<i>Eutropiichthys murius</i> (Hamilton)		√	√		√
73.	<i>Eutropiichthys vacha</i> (Hamilton)	√	√	√	√	√
74.	<i>Gagata cenia</i> (Hamilton)	√		√	√	√
75.	<i>Glyptothorax botius</i> (Hamilton)				√	√
76.	<i>Glyptothorax cavia</i> (Hamilton)					√
77.	<i>Glyptothorax telchitta</i> (Hamilton)	√	√		√	

S. N.	Name of fish species	Survey Number				
		I	II	III	VI	V
78.	<i>Gogangra viridescense</i> (Hamilton)		√			√
79.	<i>Heteropneustus fossilis</i> (Bloch)			√		
80.	<i>Hemibagarus menoda</i> (Hamilton)	√		√	√	
81.	<i>Hyporampus limbatus</i> (Valenciennes)			√		
82.	<i>Mystus bleekeri</i> (Day)		√	√	√	√
83.	<i>Mystus cavasius</i> (Hamilton)	√	√	√	√	√
84.	<i>Mystus tengara</i> (Hamilton)			√		√
85.	<i>Mystus carcio</i> (Bloch)			√	√	√
86.	<i>Nangra nangra</i> (Hamilton)				√	√
87.	<i>Nangra punctata</i> (Hamilton)	√	√	√		
88.	<i>Neotropius atherinoides</i> (Bloch)	√	√	√	√	√
89.	<i>Ompok bimaculatus</i> (Bloch)			√		√
90.	<i>Ompok pabda</i> (Hamilton)		√		√	√
91.	<i>Ompok pabo</i> (Hamilton)	√		√	√	√
92.	<i>Pangasius pangasius</i> (Hamilton)	√	√	√		
93.	<i>Pterigoplichthys anisitsi</i> (Johnathan Armbruster)			√	√	
94.	<i>Rita rita</i> (Hamilton)	√	√	√	√	√
95.	<i>Sisor raddophorus</i> (Hamilton)	√	√	√		√
96.	<i>Silonia silondia</i> (Hamilton)	√	√	√		√
97.	<i>Sperata aor</i> (Hamilton)	√	√	√	√	√
98.	<i>Sperata seenghala</i> (Sykes)	√	√	√	√	√
99.	<i>Wallago attu</i> (Schneider)	√	√	√	√	√
H.	Synbranchiformes					
100.	<i>Macroglyptus aral</i> (Bloch & Schneider)			√	√	
101.	<i>Macroglyptus pancalus</i> (Hamilton)	√	√	√	√	√
102.	<i>Mastacembelus armatus</i> (Lacepede)	√	√	√	√	√
103.	<i>Monopterus albus</i> (Zuiew)			√		
104.	<i>Monopterusuchia</i> (Hamilton)		√			
J.	Tetraodontiformes					
105.	<i>Leiodon cutcutia</i> (Hamilton)	√	√	√	√	√
106.	<i>Tetraodon fluviatilis</i> (Hamilton- Buchanan)			√		
Total		47	50	81	77	63

Setipinna sp., *Puntius* sp. and *Salmophasia bacaila* were abundantly available in the stretch.

Exotic Fish Species

Five exotic fish species - *Cyprinus carpio*, *Hypophthalmichthys nobilis*, *Pterigoplichthys anisitsi*, *Oreochromis mossambicus*, and *Panna microdon* - were recorded from the Ganges during the study.

PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER

A definite seasonal variation in physico-chemical characteristics of the river water was observed. The range, mean and standard deviation of pH varied from (7.4-8.4, 8.15±2.9), dissolved oxygen (4.5-8.5, 6.9 ±2.36) mg/l, biochemical oxygen demand (1.1-2.9, 2.05 ±1.2) mg/l, total dissolved solids

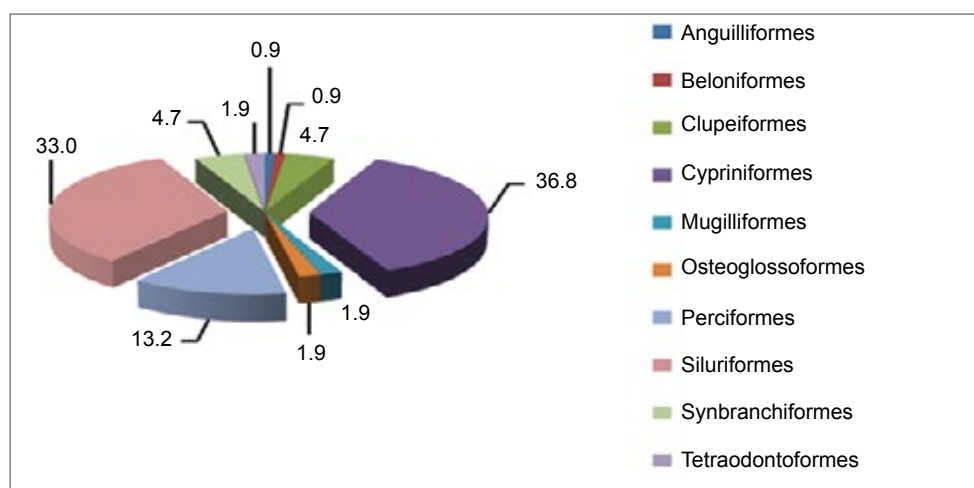


Figure 2: Temporal variation in fish diversity (Order wise) in middle-lower stretch of the River Ganges during December 2007-May 2009

(144-227, 214.5 ± 54.5) mg/l, air temperature (14-35, 21.5 ± 9.5)°C and water temperature (15-30, 24.5 ± 8.12)°C, Conductivity (356-465, 410 ± 77) μ S/cm), Turbidity (6-280, 143 ± 193) NTU and velocity (0.3-1.9, 0.22 ± 1.1) m/sec. The physico-chemical characteristics of Ganges water has been depicted in Table-III. The physico-chemical characteristics of Ganges water were found to be suitable for the fish fauna and fish diversity in the stretch.

DISCUSSION

Hundred and six fish species were recorded during the study indicating a rich ichthyofaunal diversity in the stretch. In the present survey, 100 species belonging to 71 genera, 29 families and 10 orders were recorded at Patna.

In the previous study at Patna (1993-95), 106 species were recorded (Hassan 1999). Out of 106, 19 species - *Aplocheilichthys panchax*, *Badis badis*, *Channa gachua*, *Channa channa*, *Danio dangila*, *Eristichthys pusillus*, *Gonialosa modestus*, *Garra lamta*, *Gagata gagata*, *Hara jerdoni*, *Hypophthalmichthys sephen*, *Hyporhamphus limbatus*, *Johnius gangeticus*, *Labeo pangusia*, *Rasbora daniconius*, *Raiamas bola*, *Tor tor*, *Trichogaster lalia*, *T. sota* - recorded in 1993-95, could not be encountered in the current study of 2007-2009. whereas 13 additional fish species, *Amblypharyngodon gora*,

Amblyceps mangois, *Anguilla bengalensis*, *Barilius bendelisis*, *Cyprinus carpio*, *Glyptothorax botia*, *G. cavia*, *Hypophthalmichthys nobilis*, *Nangra punctata*, *Oreochromis mossambicus*, *Pangio pangia*, *Panna microdon* and *Pterigoplichthys anistsi* which were not recorded in previous survey (1993-95), from the Ganges at Patna, were recorded in the recent study (Table 1).

A new exotic species *Pterigoplichthys anistsi*, a South American species of sailfin fish, hitherto not recorded from the Indian subcontinent, was recorded during this study from the Ganges in 2008-09. This is an aquarium fish and probably was released into the river by aquarium traders. But collection of juvenile individual of this fish from the river indicates that the fish might have started breeding in the river (Sinha et.al. 2010).

Five exotic fish species - *Cyprinus carpio*, *Hypophthalmichthys nobilis*, *Pterigoplichthys anistsi*, *Oreochromis mossambicus*, and *Panna microdon* - were recorded from the Ganges during the study. During the earlier study in 1993-95, no exotic fish species was recorded (Hassan 1999). The diverse river system in India harbour one of the richest fish germ plasma resources in the world and as many as 272 species (Hora 1929) have so far been recorded from River Ganges basin.

Table 3: Water quality at different sampling sites in middle-lower stretch of the River Ganges during December 2007-May 2009

Parameters	Sampling Sites									
	Patna		Munger		Bhagalpur		Kahalgaon		Rajmahal	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
pH	7.4 - 8.4	7.9± 0.5	8.1 - 8.4	7.74± 2.8	8.0 - 8.3	8.02±0.29	8.0 - 8.3	8.15±2.95	8.0 - 8.3	8.15± 2.7
Air temp. (°C)	14 – 35	24.5± 14.8	11–32	21.5± 9.5	15 - 30	22.5±7.5	16 – 32	24±8.72	12-34	23± 9.3
Water temp. (°C)	11-30	20.5± 3.4	16 – 31.5	23.5± 8.6	15 – 29.5	22±7.0	18.5 - 30	24±8.12	16 – 30	22± 8.2
DO (mg/l)	4.5 - 8.5	6.5± 2.8	5.4 - 7.9	6.64± 2.2	5.2 - 8.5	6.85±1.62	5.5 - 8.2	6.94±2.36	5.0 - 8.4	6.8± 2.3
Conductivity (µS/cm)	356 – 465	410 ± 77	372 – 467	421±149	382 - 422	402±20	367 - 474	411 ± 149	368 -469	419 ± 139
Turbidity (NTU)	7.0 – 85	46± 55.2	6.0 – 280	143± 193	4.0 - 165	84.5±80.5	4.0 - 223	114±80.1	3.0 – 214	109±78
TDS (mg/l)	176 – 253	214.5± 54.4	175 – 248	212± 51	155 -249	202± 47	161 - 246	204±69.3	144 -227	186±66
BOD (mg/l)	1.1 – 2.9	2± 1.2	1.2 – 2.9	2.05±1.2	1.2 – 1.7	1.45± 0.35	1.1 – 2.1	1.6±0.7	1.1 – 2.1	1.6± 0.7
Velocity (m/s)	0.3 – 1.9	0.22± 1.1	0.2 – 1.0	0.53± 0.2	0.3 – 1.4	0.52± 0.3	0.7 – 1.7	0.5±0.5	0.1 – 1.7	0.51 ±0.6
Depth (m)	1.1 – 7.2	3.7± 1.6	3.2 –13.9	9.5± 6.1	1.6– 26.3	9.5± 6.6	2.1 – 30	15.2± 9.0	3.3 -30.0	15.81± 8.8

Table 4: Order, family, genus and species recorded in the middle-lower stretch of the River Ganges

	Patna	Munger	Bhagalpur	Kahalgaon	Rajmahal	Total
Order	10	09	07	08	09	10
Families	30	20	16	15	19	30
Genus	71	49	37	32	51	73
Species	100	68	47	40	69	106

Talwar (1991) listed 375 species of fish from the entire Ganges. The National Bureau of Fish Genetic Resources (NBFGR) in its Annual Report (1996-97) has reported 382 species from Ganges river system out of which 111 are from Uttar Pradesh and Bihar.

In a recent NBFGR report (2008-09), 121 species of fishes were recorded. Jhingran and Ghosh (1978) reported 40 per cent of total catch in the winter months, November to February, in the lower stretches of Ganges i.e. Patna and downstream during pre-Farakka period.

In this study, the winter contribution was recorded to be only 11.8 per cent. This may be due to collapse of Hilsa fishery in post-Farakka period. It may be noted that in pre-Farakka period, Hilsa used to contribute a high per cent of catch during the winter season at Patna.

Conservation programme helps more sustainable fish productions and maintains fish diversity at the same time. Conserving diversity also improves the livelihood of fishers maintaining minimal viable populations of rare and endangered fish species.

Many fish species may provide important genetic material and also may serve as ecological indicators. Diversity reduces disease problems and encourages recovery from disturbance.

The physico-chemical characteristics of the river water fluctuate spatially and temporally. Latitude, altitude, degree of insulation, substrate composition, turbidity, ground or rainwater inflows, wind, and vegetation cover, season and size of the water body can all influence the temperature of water in rivers and floodplain lakes.

Zafar (1968) studied the seasonal variation of temperature and found that in the tropical water bodies there is direct correlation between the sunshine hours and water temperature. During the study, higher temperature was recorded in summer in the Ganges which corroborated the above observation. In fact, the temperature of the environment plays an important role in the sexual maturation and breeding of fishes. Warm or high temperature plays a primary role in stimulation and maturation of gonads in a number of fishes and also accelerates spermiation (Ahsan 1966).

The pH value is a very important parameter as far as water quality is concerned. According to Roule (1930) and Nees (1946) water with pH 7.0 to 8.0 is the most desirable for fish crops. Bilgrami et al. (1985) recorded low pH during rainy season and high in winter. Sinha (*Op. cit.*) also recorded high value of pH in winter and low in monsoon in Ganges water at Patna.

The pH of water is directly correlated with CO₂ released by the fauna, phytoplankton and microbes in night. The present finding of pH value indicates that the Ganges water between Patna and Rajmahal is suitable for aquatic life.

Among the chemical substances present in the waters, oxygen is the primary important factor as a regular metabolic process for both plants and animals community and also acts as an indicator

of water condition. The variation of D.O during the present investigation was observed to be between (4.5 – 8.5) mg/l which is well within the desirable limit for the fish fauna in the river. Tarzwell (1957) reported the minimum requirement of dissolved oxygen to be 3.0 mg/l for ichthyofauna whereas Ellis (1937) recommended a minimum value of 5 mg/l dissolved oxygen content in water for maintaining fish live in healthy conditions at 20°C.

Biochemical oxygen demand (BOD) measures the amount of oxygen consumed by micro-organisms during aerobic decomposition of organic pollutants. It is the only parameter that provides an indication of the amount of biodegradable organic materials in the stream receiving wastewater discharge (Young 1984). In the present investigation, the BOD value was found to be less than 3 mg/l which indicates fairly clean water of the river.

Higher the TDS and mineral content of the water, higher will be its conductivity; consequently, the electric current can flow freely through the water. Higher conductivity is an indication of eutrophication in water bodies (Radwan 1976). The best suitable range of TDS for the survival of fishes should be between 150-500 µS/cm and it should not exceed 1000 µS/cm.

Fine clay particles, silt and organic debris, and also high density of plankton contribute turbidity to the water. Low flow rate, high depth, hard rock bed with benthic vegetation result in low turbidity. High turbidity causes low production due to injurious “blanketing effect” on the phytoplankton (Welch 1952; Chakraborty et. al. 1959) and causes death of plankton. Turbidity also affects the fish diversity of the River Ganges. Besides, favourable physico-chemical characteristics of the Ganges water, major tributaries such as Ghaghara, Gandak, Kosi, Burhi Gandak, Son, Punpun etc, and the lateral connectivity of the rivers with floodplain wetlands, vast floodplains, very low gradient of 13000: 1, might be contributing to the ichthyofaunal diversity and abundance of the Ganges in the stretch under study.

However, rampant juvenile fishing in this stretch of the Ganges and its tributaries, especially during post-monsoon season using mosquito nets is badly affecting the fish and fish catch in the river. The Hilsa fishery in particular and other migratory species (both Anadromous and Catadromous) in general collapsed in this stretch after construction of Farakka Barrage in 1975. Also, a new threat of invasion of exotic fish species was recorded during the study.

With growing globalisation, this threat is likely to increase. Therefore, there is a serious need of special attention for the scientific and government authorities to control the exotic species in the rivers and streams. It may be mentioned that catch of Indian Major Carps are declining and that of exotic species is increasing at Allahabad in the last decade.

ACKNOWLEDGEMENT

I extend my thanks to Subhash Sahni, an expert fisherman of Patna, for helping me in this study.

I am also thankful to the Head, Department of Zoology, Patna University, Patna for providing me a well equipped laboratory that helped me to conduct proper research work.

Financial support during the study period by the NBFGR, Lucknow is also acknowledged.

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THEME

Plankton and Benthic Organisms

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Floodplains of the Brahmaputra River Basin - Globally Interesting Eco-tones with Rich Rotifer (*Rotifera: Eurotatoria*) Biodiversity

Bhushan Kumar Sharma and Sumita Sharma

Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University,
Shillong - 793022, Meghalaya, India
E-mail: profbksharma@gmail.com

ABSTRACT

Two hundred and twenty rotifer species (21 families and 46 genera) observed in our collections from the Brahmaputra floodplains of Assam reveal the richest diversity of the taxon recorded from any part of the Indian sub-region and one of the richest known globally.

These comprise ~40.0 per cent of the Oriental rotifer species. Bio-geographically, interesting taxa include five Australasian and 10 Oriental endemics; fourteen Palaeotropical, one Holarctic, two Arctic-temperate and twelve Eastern hemisphere species.

Lecane bulla diabolica is new to Assam. Lecanidae > Lepadellidae > Brachionidae > Trichocercidae are the speciose families and *Lecane* is species-rich genus. Our report of 171 species from Deepor Beel (a Ramsar site) assigns a globally rich rotifer ecosystem status to this important floodplain lake.

Our report of 131 species from Majuli, the largest river island, reflects rich micro-metazoan diversity of this fluvial floodplain. The diversity pattern of rotifers is predominantly tropical, and follows the moderate endemism model.

Key words: Composition, distribution, ecology, interesting species, richness, hot-spot

INTRODUCTION

Rotifera, a group of primary freshwater invertebrates, occur widely in inland aquatic habitats and play an important role in freshwater ecosystem functioning. The members of this phylum serve as indicators of water quality (Sladeczek 1983), test organisms in toxicology (Arnold et al. 2011), and fish-food in aquaculture (Lubzens 1987; Ogata and Kurokura 2011).

Taxonomic studies on the Indian Rotifera were initiated by Anderson (1889) while those from northeast India (NEI) and Assam began with *ad-hoc* lists by Patil (1978) and Sharma (1980), respectively. The studies on faunal diversity of the rotifers in certain floodplain lakes (*beels*) of the Brahmaputra river basin were, however, initiated by Sharma (2000) and Sharma and Sharma (2001).

Realising the biodiversity value of these eco-tones and other wetlands (*dobas or dubies*) of this river basin vis-à-vis rotifera diversity, Sharma 2005; Sharma and Sharma (2005, 2008) began an intensive survey from lower and upper Assam which continued till recently (Sharma and Sharma 2012a , 2013, 2014a).

Augmenting our earlier results, we present an inventory of 220 rotifer species observed from the Brahmaputra floodplains noting the salient features of species richness, ecosystem diversity, biogeography, distribution of interesting taxa, and nature and composition of the rotifer assemblage in these floodplains. We comment briefly on their ecology based on our limnological studies in selected *beels*.

MATERIAL AND METHODS

This study is based on the analysis of our plankton and semi-plankton samples collected (Figure 1), during 2010-2013, from floodplain lakes (*beels*) and small wetlands (*dobas or dubies*) of the Brahmaputra river basin from lower and upper Assam; the samples collected, during 2010-2012, from 20+ *beels* and 30+ *dobas or dubies* of Majuli River Island of upper Assam; critical evaluation of our published reports; and re-examination of our earlier collections (2005-2010).

The sampled biotopes often showed varied aquatic plants namely *Eichhornia crassipes*, *Hydrilla verticillata*, *Vallisneria spiralis*, *Utricularia flexuosa*, *Trapa natans*, *Lemna major*, *L. minor*, *Pistia striates*,

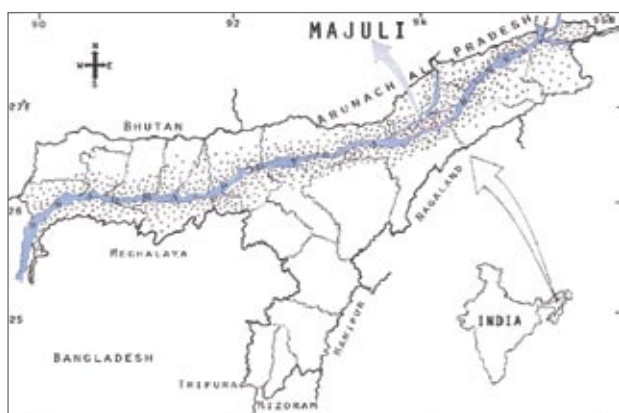


Figure 1: Map of Assam showing the sampled floodplains of the Brahmaputra river basin

Salvinia sp., *Nymphaea* spp., *Nymphoides* spp., *Najas graminca*, *Nelumbo mucifera*, *Potamogeton* spp., *Azolla pinnata*, *Euryale ferox*, *Sagittaria* spp, and *Cyperus* spp.

The collections were made from the littoral and semi-limnetic/ limnetic regions of different ecosystems by towing plankton net (# 50 µm) and were preserved in five per cent formalin. Individual samples were screened with a wild-stereoscopic binocular microscope, the different rotifers were isolated, mounted in polyvinyl alcohol-lactophenol mixture and were observed with a Leica DM 1000 image analyser fitted with drawing-tube.

The rotifer taxa were identified following Koste (1978); Koste and Shiel (1987, 1989, 1990); Shiel and Koste (1992); Segers (1995); De Smet (1995, 1997); Sharma (1983, 1987, 1998); Sharma and Sharma (1999, 2000) and Nogrady and Segers (2002). We followed Segers (2007) and Jersabek and Leitner (2013) for classification, nomenclature and biogeography.

RESULTS

We present a systematic list of 220 species of Rotifera, belonging to 46 genera and 21 families, observed from the floodplains of the Brahmaputra river basin:

Phylum : Rotifera Cuvier, 1817
Class : Eurotatoria De Ridder, 1957
Subclass : Monogononta Plate, 1889
Order : Ploima Hudson & Gosse, 1886

Family: Brachionidae

1. *Anuraeopsis coelata* (De Beauchamp 1932)
2. *A. fissa* (Gosse 1851)
3. *A. navicula* (Rousselet 1910)
4. *Brachionus ahlstromi* (Lindeman 1939)
Syn.: *B. caudatus* var. *personatus* (Ahlstrom 1940)
5. *Brachionus angularis* (Gosse 1851)
6. *B. bidentatus* (Anderson 1889)
7. *B. budapestinensis* (Daday 1885)
8. *B. calyciflorus* (Pallas 1766)

9. *B. caudatus* (Barrois and Daday 1894)
10. *B. dichotomus reductus* (Koste and Shiel 1980)
11. *B. diversicornis* (Daday 1883)
12. *B. donneri* (Brehm 1951)
13. *B. durgae* (Dhanapathi 1974)
14. *B. falcatus* (Zacharias 1898)
15. *B. forficula* (Wierzejski 1891)
16. *B. kostei* (Shiel 1983)
17. *B. mirabilis* (Daday 1897)
18. *B. quadridentatus* (Hermann 1783)
19. *B. rubens* (Ehrenberg 1838)
20. *Keratella cochlearis* (Gosse 1851)
21. *K. edmondsoni* (Ahlstrom 1943)
22. *K. javana* (Hauer 1937)
23. *K. lenzi* (Hauer 1953)
24. *K. procurva* (Thorpe 1891)
25. *K. quadrata* (O. F. Muller 1786)
26. *K. tecta* (Gosse 1851)
27. *K. tropica* (Apstein 1907)
28. *Platyias leloupi* (Gillard 1967)
29. *P. quadricornis* (Ehrenberg 1832)
30. *Platyonus patulus* (O.F. Muller 1786)
31. *P. patulus macracanthus* (Daday 1905)

Family: Epiphanidae

32. *Epiphanes brachionus brachionus* (Ehrenberg 1837)
33. *E. brachionus spinosa* (Rousselet 1901)
34. *E. senta* (O.F. Muller 1773)

Family: Euchlanidae

35. *Euchlanis dilatata* (Ehrenberg 1832)
36. *E. incisa* (Carlin 1939)
37. *E. meneta* (Myers 1930)
38. *E. oropha* (Gosse 1887)
39. *E. triquetra* (Ehrenberg 1838)
40. *Dipleuchlanis ornate* (Segers 1993)
41. *D. propatula* (Gosse 1886)
42. *Tripleuchlanis plicata* (Levander 1894)
43. *Beauchampiella eudactylota* (Gosse 1886)

Family: Mytilinidae

44. *Lophocharis oxysternon* (Gosse 1851)
45. *L. salpina* (Ehrenberg 1834)
46. *Mytilina acanthophora* Hauer 1938
47. *M. bisulcata* (Lucks 1912)
48. *M. michelangellii* (Reid & Turner 1988)
49. *M. ventralis* (Ehrenberg 1830)
50. *M. ventralis brevispina* (Ehrenberg 1830)
51. *M. ventralis longidactyla* (Wulfert 1965)

Family: Trichotriidae

52. *Macrochaetus collinsi* (Gosse 1867)
53. *M. danneelae* (Koste and Shiel 1983)
54. *M. longipes* (Myers 1934)
55. *M. sericus* (Thorpe 1893)
56. *T. tetractis* (Ehrenberg 1830)
57. *Volga spinifera* (Western 1894)

Family: Lepadellidae

58. *Colurella adriatica* (Ehrenberg 1831)
59. *C. colurus* (Ehrenberg 1830)
60. *C. obtusa* (Gosse 1886)
61. *C. sanoamuangae* (Chittapun, Pholpunthin and Segers 1999)
62. *C. sulcata* (Stenroos 1898)
63. *C. uncinata* (O.F. Müller 1773)
64. *Lepadella acuminata* (Ehrenberg 1834)
65. *L. apsida* (Harring 1916)
66. *L. benjamini* (Harring 1916)
67. *L. bicornis* (Vasisht and Battish 1971)
68. *L. biloba* (Hauer 1938)
69. *L. cristata* (Rousselet 1893)
70. *L. costatoides* Segers 1992
71. *L. dactyliseta* (Stenroos 1898)
72. *L. discoidea* (Segers 1993)
73. *L. elongata* (Koste 1992)
74. *L. eurysterna* (Myers 1942)
75. *L. latusinus* (Hilgendorf 1889)
76. *L. lindau* (Koste 1981)
77. *L. minoruoides* (Koste and Robertson 1983)
78. *L. minuta* (Weber and Montet 1918)
79. *L. ovalis* (O. F. Müller 1786)
80. *L. patella* (O. F. Müller 1773)

81. *L. quinquecostata* (Lucks 1912)
82. *L. rhomboides* (Gosse 1886)
83. *L. rhomboidula* (Bryce 1890)
84. *L. triba* (Myers 1934)
85. *L. triptera* (Ehrenberg 1832)
86. *L. vandenbrandei* (Gillard 1952)
87. *L. (Heterolepadella) apsicora* (Myers 1934)
88. *L. (H.) ehrenbergi* (Perty 1850)
89. *L. (H.) heterostyla* (Murray 1913)
90. *L. (H.) heterodactyla* (Fadeev 1925)
91. *Squatinella lamellaris* (O. F. Müller 1786)

Family: Lecanidae

92. *L. acanthinula* (Hauer 1938)
93. *L. aculeata* (Jakubski 1912)
94. *L. arcua* (Harring 1914)
95. *L. aspasia* (Myers 1917)
96. *L. batillifer* (Murray 1913)
97. *L. bifurca* (Bryce 1892)
98. *L. blachei* Berzins 1973
99. *L. braumi* (Koste 1988)
100. *L. closteroerca* (Schmarda 1859)
101. *L. crepida* (Harring 1914)
102. *L. curvicornis* (Murray 1913)
103. *L. bulla bulla* (Gosse 1851)
104. *L. bulla diabolica* (Hauer 1936)
105. *L. decipiens* (Murray 1913)
106. *L. doryssa* (Harring 1914)
107. *L. elegans* (Harring 1914)
108. *L. elongata* (Harring and Myers 1926)
109. *L. flexilis* (Gosse 1886)
110. *L. furcata* (Murray 1913)
111. *L. glypta* (Harring and Myers 1926)
112. *L. hamata* (Stokes 1896)
113. *L. hastata* (Murray 1913)
114. *L. haliclysta* (Harring and Myers 1926)
115. *L. hornemanni* (Ehrenberg 1834)
116. *L. inermis* (Bryce 1892)
117. *L. inopinata* (Harring and Myers 1926)
118. *L. lateralis* (Sharma 1978)
119. *L. leontina* (Turner 1892)
120. *L. ludwigii* (Eckstein 1883)
121. *L. luna* (O.F. Müller 1776)
122. *L. lunaris* (Ehrenberg 1982)

123. *L. monostyla* (Daday 1897)
124. *L. nana* (Murray 1913)
125. *L. nitida* (Murray 1913)
126. *L. niwati* (Segers, Kothetip and Sanoamuang 2004)
127. *L. obtusa* (Murray 1913)
128. *L. ohioensis* (Herrick 1885)
129. *L. papuana* (Murray 1913)
130. *L. paxiana* (Hauer 1940)
131. *L. pertica* (Harring and Myers 1926)
132. *L. ploenensis* (Voigt 1902)
133. *L. pusilla* (Harring 1914)
134. *L. pyriformis* (Daday 1905)
135. *L. quadridentata* (Ehrenberg 1830)
136. *L. rhenana* (Hauer 1929)
137. *L. rhytida* (Harring and Myers 1926)
138. *L. rugosa* (Harring 1914)
139. *L. ruttneri* (Hauer 1938)
140. *L. signifera* (Jennings 1896)
141. *L. simonneae* (Segers 1993)
142. *L. sola* (Hauer 1936)
143. *L. solfatara* (Harring and Myers 1926)
144. *L. stenroosi* (Meissner 1908)
145. *L. styrax* (Harring and Myers 1926)
146. *L. superaculeata* (Sanoamuang and Segers 1997)
147. *L. sympoda* (Hauer 1929)
148. *L. tensuiseta* (Harring 1914)
149. *L. thienemanni* (Hauer 1938)
150. *L. undulata* (Hauer 1938)
151. *L. unguitata* (Fadeev 1925)
152. *L. unguata* (Gosse 1887)

Family: Notommatidae

153. *Cephalodella forficata* (Ehrenberg, 1832)
154. *C. forficula* (Ehrenberg 1830)
155. *C. gibba* (Ehrenberg 1830)
156. *C. mucronata* (Myers 1924)
157. *C. ventripes* (Dixon-Nuttall 1901)
158. *Monommata longiseta* (O.F. Müller 1786)
159. *M. maculata* (Harring and Myers 1930)
160. *Notommata pachyura* (Gosse 1886)
161. *N. spinata* (Koste and Shiel 1991)
162. *Taphrocampa selenura* (Gosse 1887)

Family: Scaridiidae

163. *Scaridium longicaudum* (O.F. Müller 1786)

Family: Gastropodidae

164. *Ascomorpha saltans* (Bartsch 1870)
165. *A. ovalis* (Bergendal 1892)

Family: Trichocercidae

166. *Trichocerca abilioi* (Segers and Sharma, 1993)
167. *T. bidens* (Lucks 1912)
168. *T. bicristata* (Gosse 1887)
169. *T. capucina* (Wierzejski and Zacharias 1893)
170. *T. cylindrica* (Imhof 1891)
171. *T. elongata* (Gosse 1886)
172. *T. flagellata* (Hauer 1938)
173. *T. iernis* (Gosse 1887)
174. *T. insignis* (Herrick 1885)
175. *T. kostei* (Segers 1993)
176. *T. longiseta* (Schränk 1802)
177. *T. porcellus* (Gosse 1881)
178. *T. pusilla* (Jennings 1903)
179. *T. rattus* (O.F. Müller 1776)
180. *T. ruttneri* Donner 1953
181. *T. scipio* (Gosse 1886)
182. *T. similis* (Wierzejski 1893)
183. *T. sulcata* (Jennings 1894)
184. *T. tenuior* (Hudson and Gosse 1886)
185. *T. tigris* (O.F. Müller 1786)
186. *T. voluta* (Murray 1913)
187. *T. weberi* (Jennings 1903)

Family: Asplanchnidae

188. *Asplanchna brightwelli* (Gosse 1850)
189. *A. priodonta* (Gosse 1850)

Family: Synchaetidae

190. *Synchaeta oblonga* (Ehrenberg 1832)
191. *Pleosoma lenticulare* (Herrick 1885)
192. *Polyarthra euryptera* (Wierzejski 1891)
193. *P. vulgaris* (Carlin 1943)

Family: Dicranophoridae

194. *Dicranophoroides caudatus* (Ehrenberg 1834)

195. *Dicranophorus forcipatus* (O.F. Müller 1786)

Order: Flosculariaceae**Family: Floscularidae-5/4**

196. *Floscularia ringens* (Linnaeus 1758)
197. *Lacinularia flosculosa* (O.F. Müller 1773)
198. *Limnias ceratophylli* (Schränk 1803)
199. *Sinantherina socialis* (Linne 1758)
200. *S. spinosa* (Thorpe 1893)

Family: Conochilidae

201. *Conochilus unicornis* (Rousselet 1892)

Family: Hexarthridae

202. *Hexarthra intermedia* (Wiszniewski 1929)
203. *H. mira* (Hudson 1871)

Family: Testudinellidae

204. *Testudinella brevicaudata* (Yamamoto 1951)
205. *T. emarginula* (Stenroos 1898)
206. *T. greeni* (Koste 1981)
207. *T. parva parva* (Ternetz 1892)
208. *T. parva bidentata* (Ternetz 1892)
209. *T. parva semiparva* (Hauer 1938)
210. *T. patina* (Hermann 1783)
211. *T. tridentata* (Smirnov 1931)
212. *Pompholyx sulcata* (Hudson 1885)

Family: Trochosphaeridae

213. *Horaella brehmi* (Donner 1949)
214. *Filinia brachiata* (Rousselet 1901)
215. *F. camasecla* (Myers 1938)
216. *F. longiseta* (Ehrenberg 1834)
217. *F. opoliensis* (Zacharias 1898)
218. *F. pejeri* (Hutchinson 1964)
219. *F. saltator* (Gosse 1886)
220. *F. terminalis* (Plate 1886)
221. *Trochosphaera aequatorialis* Semper, 1872

Order: Collothecaceae**Family: Collothecidae**

222. *Collotheca ornata* (Ehrenberg 1832)

Sub-class: Digononta

Order: Bdelloidea

Family: Philodinidae

- 223. *Philodina citrina* (Ehrenberg 1832)
- 224. *Rotaria macroceros* (Gosse 1851)
- 225. *R. neptunia* (Ehrenberg 1830)
- 226. *R. neptunoida* (Harring 1913)
- 227. *R. rotatoria* (Pallas 1766)

Our collections revealed 220 species including five Australasian and 10 Oriental endemics, 14 Palaetropical, one Holarctic, two arctic-temperate and 12 Eastern hemisphere species. The Oriental *Lecane bulla diabolica* (Figure 2) is a new record from Assam based on our recent samples from Deepor Beel; *Lecane niwati* (Figure 3), *L. rhytida* (Figure 4) and *L. undulata* (Figure 5), recent additions to the Indian Rotifera, were recorded from Majuli (Sharma and Sharma 2014b); and *Lepadella vandenbrandei* (Figure 6), yet another new record from India, was recorded from Majuli (Sharma 2014). *Mytilina michelangellii* (Figure 7) and *Lecane rhenana* (Figure 8) are new records from India. *Euchlanis meneta* (Figure 9) and Wolga *spinifera* (Figure 10), observed in our collections from Deepor Beel (Sharma and Sharma unpublished), are new records to NEI.

Brachionus angularis, *B. quadridentatus*, *Keratella cochlearis*, *K. tropica*, *Plationus patulus*, *Mytilina ventralis*, *Trichotria tetractis*, *L. ovalis*, *L. bulla*, *L. closteroerca*, *L. curvicornis*, *L. leontina*, *L. papuana*, *L. lunaris*, *L. unguata*, *Trichocerca similis*, *T. rattus*, *Asplanchna priodonta*, *Polyarthra vulgaris* and *Testudinella patina* exhibit common occurrence. *Brachionus dichotomus reductus*, *B. kostei*, *Keratella edmondsoni*, *K. javana*, *Dipleuchlanis ornata*, *Macrochaetus danneelae*, *Colurella sanoamuangae*, *Lepadella heterodactyla*, *L. lindaui*, *L. minoruoides*, *L. minuta*, *L. triba*, *L. bifurca*, *L. braumi*, *L. glypta*, *L. rugosa*, *L. ruttneri*, *L. scutata*, *L. solfatara*, *L. sola*, *L. superaculeata*, *Pleosoma lenticulare*, *Taphrocampa annulosa*, *Trichocerca bicristata*, *T. kostei*, *T. insignis*, *Filinia brachiata*, *F. saltator*, *Testudinella brevicaudata*, *T. greeni*, *T. tridentata*, *Horaella brehmi* and *Trochosphaera aequatorialis* are rare species. *Ascomorpha*, *Epiphanes*, *Horaella*, *Lophocharis*, *Pleosoma*, *Squatinella*, *Synchaeta*, *Taphrocampa*, *Trochosphaera* and *Notommata* are rare genera while *Pompholyx* is rare in the beels of upper Assam. Four Eurotatoria families namely Lecanidae > Lepadellidae > Brachionidae > Trichocercidae included 146 species while *Lecane* > *Lepadella* > *Trichocerca* > *Brachionus* are species-rich genera (125 species). One hundred



Figure 2: *Lecane bulla diabolica* (Hauer)

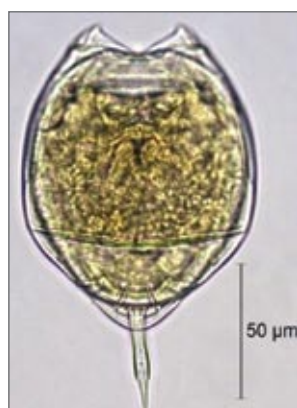


Figure 3: *Lecane niwati*
Segers, Kothetip &
Sanoamuang



Figure 4: *Lecane rhytida*
Harring & Myers



Figure 5: *Lecane undulata*
Hauer

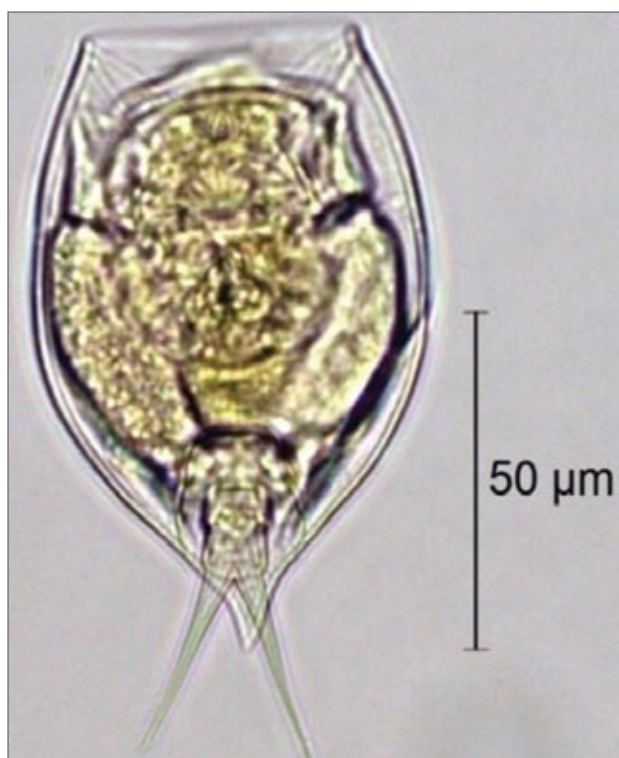


Figure 6: *Lepadella vandenbrandei* Gillard



Figure 7: *Mytilina michelangellii* Reid & Turner

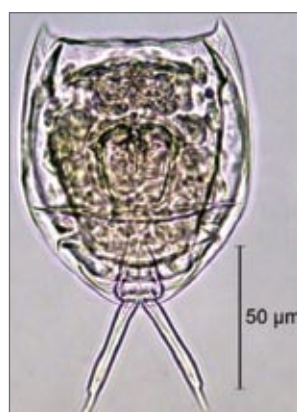


Figure 8: *Lecane rhenana*
Hauer

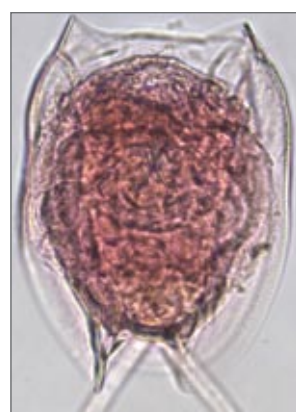


Figure 9: *Euchlanis meneta*
Myers

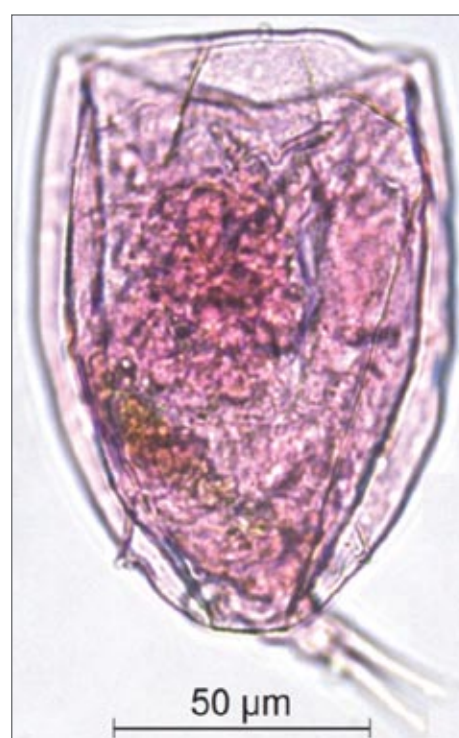


Figure 10: *Wolga spinifera* (Western)

and seventy species are observed from Deepor Beel (a Ramsar site) and 131 species are examined from the floodplains of Majuli, the largest river island.

DISCUSSION

Species Richness and Ecosystem Diversity

Our collections from the floodplains of the Brahmaputra river basin reveal one of the richest diversity (220 species) of Phylum Rotifera known from these ecotones globally. These comprise ~40.0

per cent, ~54.0 per cent and ~11.0 per cent of the species known from the Oriental region, India and the world, respectively.

Amongst 67 genera and 25 families of Eurotatoria recorded from inland waters of India, 46 genera and 21 families are represented in our collections. The species-rich nature and higher diversity (genera and families) value show diverse rotifera assemblage in the Brahmaputra floodplains.

This salient feature is supported by our report of 131 species belonging to 33 genera and 17 families (Sharma 2014) from Majuli — the largest river island and a fluvial floodplain of the Brahmaputra basin.

The speciose rotifer assemblage of the Brahmaputra floodplains reflects their environmental heterogeneity and habitat diversity and thus, concurs with the reports from the floodplains of Argentina (Jose de Paggi 1993), South America (Bonecker et al. 1998) and Australia (Shiel et al. 1998).

Our results affirm the hypothesis of Segers et al. (1993) on the rich rotifer diversity of (sub) tropical floodplain lakes. The overall richness (220 species) observed by us is comparable with 207 and 218 species reported from the floodplains of Africa (Segers et al. 1993) and South America (Bonecker et al. 1998), respectively, while it is marginally lower than 252 species known from Australian floodplains (Shiel et al. 1998).

The rotifer richness from the Brahmaputra floodplains is distinctly high than the reports of 110 species (Arora and Mehra 2003) from the backwaters of the river Yamuna at Delhi; 48 species from 37 *beels* (Sarma 2000) and 64 species from 12 *beels* of the Pobitora Wildlife Sanctuary (Sharma 2006) of Assam; and 27 species from two floodplain lakes of Kashmir (Khan 1987) and 38 species from four ox-bow lakes and nine floodplain lakes of South-eastern West Bengal (Khan 2003). The present report, incidentally, represent the total tally of rotifera known from Assam state and is, in turn, higher than reports of 148 species from West Bengal (Sharma 1998) and 177 species from Tamil Nadu (Sharma and Sharma 2009).

Sharma and Sharma (2012a, 2013) indicated Deepor Beel, an important floodplain lake of the Brahmaputra basin, to be the richest rotifer habitat (154 species) of Asia. Our recent collections raised total richness (S) of this “hot-spot” (B. K. Sharma, unpublished) to 171 species which is distinctly more than 120 species (Sharma 2009a) recorded from Loktak Lake (another Ramsar site).

The updated S value from Deepor Beel concurs with the report by Dumont and Segers (1996) for “All Taxa Biological Inventories (ATBI)” for rotifers of lakes in tropical and subtropical regions (S=123–210). The rotifer richness in Deepor Beel is higher than the records from various global floodplains i.e., 114 species (Jose de Paggi 2001) from the Rio Pilcomayo National park (a Ramsar site), Argentina; 124 species (Oguta lake) and 136 species (Iyi-Efi lake) in the Niger delta (Segers et al. 1993); 130 species from Lake Guarana, Brazil (Bonecker et al. 1994); 106 taxa from Thale-Noi Lake, a Ramsar site in Thailand (Segers and Pholpunthin 1997); 104 species from Laguna Bufeos, Bolivia (Segers et al. 1998).

Our values of S for certain other individual beels of the Brahmaputra basin i.e., 85 species from Ghorajan beel (Sharma and Sharma 2012b) of lower Assam and S = 69-93 species from different beels of Assam (Sharma and Sharma 2008) are somewhat lower than ATBI reported by Dumont and Segers (1996) due to lack of intensive surveys of these sites.

The former is, however, higher than 71 and 75 species observed from Utra and Waithou pats respectively of Manipur (Sharma 2011), while the later range is marginally wider than S = 62-73 species known from 15 pats of Manipur (Sharma 2009b).

INTERESTING ELEMENTS AND DISTRIBUTION

Various bio-geographically interesting elements (14.5 per cent of total S) observed by us include:

Australasian elements: *Brachionus dichotomus reductus*, *B. kostei*, *Macrochaetus danneelae*, *Lecane batillifer* and *Notommata spinata*;

Oriental species: *Brachionus donneri*, *Keratella edmondsoni*, *Colurella sanoamuangae*, *Lecane acanthinula*, *L. blachei*, *L. bulla diabolica*, *L. niwati*, *L. superaculeata*, *L. solfatara* and *Filinia camasecla*;

Palaeotropical species: *Keratella javana*, *Dipleuchlanis ornata*, *Lepadella bicornis*, *L. discoidea*, *L. minoruoides*, *L. vandenbrandei*, *Lecane braumi*, *L. lateralis*, *L. simonneae*, *L. unguitata*,

Trichocerca abilioi, *T. kostei*, *Testudinella greeni* and *T. brevicaudata*;

Others: these include Arctic-Temperate; *Lecane scutata*; Nearctic-Palaeartic; *Lecane elongata* and *L. rugosa*.

The Australasian elements recorded from the Brahmaputra basin impart distinct bio-geography value to Assam rotifers in particular as well as an interesting affinity with the faunas of Southeast Asia and Australia. This salient aspect endorses the remarks of Sharma (2005) and Sharma and Sharma (2008, 2012a, 2014a). *Lecane batillifer* and *Brachionus dichotomus reductus*, *B. kostei* and *Notommata spinata* are restricted to NEI with last two species known only from the Brahmaputra floodplains.

The occurrence of *reductus* vicariant of *B. dichotomus* in NEI lends support to hypothesis on a possible Australian origin of this taxon (Segers 2001) with recent expansion of these populations to Southeast Asia and India. *Macrochaetus danneelae* is reported from Australia and Thailand while its report from the floodplains of Assam (Sharma 2005) is the only confirmed record from India.

The occurrence of 10 Oriental endemics is a distinctive feature to the Brahmaputra rotifera in particular. Our new report of the rare Oriental taxon *Lecane bulla diabolica* from Assam deserves special record. Originally described from Tamil Nadu (Hauer 1936) and believed to be an Indian endemic, this lecanid is not known elsewhere from India except for its recent record from Manipur state of NEI (Sharma and Sharma 2014b).

Besides, the only non-illustrated Oriental record of this taxon is from Thailand (Segers and Savatnalinton 2010). *Lecane niwati* is reported (Sharma and Sharma 2014b) from the Brahmaputra floodplains and Manipur (NEI). *Colurella sanoamuangae* and *Lecane superaculeata* were described from Thailand and *Lecane solfatara* was described from Indonesia; these interesting species are known from India

only from the floodplains of the Brahmaputra basin. *Keratella edmondsoni*, described from Tamil Nadu, is reported from Rajasthan, Orissa and Assam while its distributional range now extends to North East Thailand.

Lecane blachei is known in Cambodia and Thailand while its Indian reports are limited to Assam and West Bengal. *Lecane acanthinula* shows disjunct distribution in India with reports from Southern and North-Eastern regions while *Filinia camasecla* is recorded from Assam and Tripura states of NEI. *Brachionus donneri*, described from Tamil Nadu, is known in NEI (Assam, Meghalaya, Manipur, and Tripura) and West Bengal. Sharma and Sharma (2005) believed this brachionid to be a Pantropical species while Segers (2007) treated it as an Oriental element.

Of the palaeotropical elements, *Keratella javana*, *Euchlanis semicarinata*, *Trichocerca abilioi*, *Testudinella brevicaudata* are known only from NEI; *Dipleuchlanis ornata*, *Lepadella vandenbrandei*, *Testudinella greeni* are observed from the Brahmaputra floodplains; and *Lepadella bicornis*, *L. discoidea*, *Lecane braumi*, *L. lateralis*, *L. simonneae*, *L. unguitata* and *Trichocerca kostei* exhibit disjunct distribution in India. The Arctic-temperate *Lecane scutata* is known from NEI and West Bengal from Eastern India.

The Nearctic-Palaeartic *Lecane elongata* is recorded from Assam floodplains and Yamuna backwaters, Delhi while *L. rugosa* is known from Brahmaputra basin and West Bengal. The tropical-latitude populations of these cold-water taxa may represent glacial relicts as hypothesized by Segers (1996). The occurrence of certain members of these categories in NEI is also attributed to extension of the Himalayan mountain ranges and to unique location of the region in the Indo-Chinese subdivision as hypothesised by Sharma and Sharma (1997).

Twelve species namely *Brachionus diversicornis*, *B. forficula*, *Dipleuchlanis ornata*, *Keratella javana*,

Lecane braumi, *L. lateralis*, *L. simonneae*, *L. unguitata*, *Lepadella discoidea*, *L. vandenbrandei*, *T. brevicaudata*, *Testudinella greeni* are characterised as “Eastern hemispheric” elements following Segers (2001) and Savatnalinton and Segers (2005).

In addition, *Anuraeopsis navicula*, *Brachionus donneri*, *Lophocharis salpina*, *Mytilina acanthophora*, *M. bisulcata*, *Lepadella costatoides*, *L. dactyliseta*, *L. heterodactyla*, *L. lindau*, *L. bifurca*, *L. doryssa*, *L. glypta*, *L. haliclysta*, *L. rugosa*, *Taphrocampa annulosa*, *Trichocerca bicristata*, *T. flagellata*, *Pleosoma lenticulare*, *Filinia brachiata*, *F. camascela*, *F. pejleri*, *F. saltator*, *Testudinella parva* and *Horaella brehmi* are examples of local distributional importance.

NATURE AND COMPOSITION

The cosmopolitan species form major component (61.9 per cent) of the rotifer assemblage of the Brahmaputra floodplains while Pantropical (15.9 per cent) > Tropicopolitan (11.4 per cent) species are well represented. Four Eurotatoria families namely Lecanidae (49 species) > Brachionidae (27 species) > Lepadellidae (26 species) > Trichocercidae (11 species) comprise a major fraction (64.2 per cent) of overall rotifer richness documented from the Brahmaputra basin.

Their biodiversity value broadly concurs with the reports from the floodplains of South America (Jose de Paggi 1993, 2001; Bonecker et al. 1994, 1998; Segers et al. 1998), Africa (Segers et al. 1993), Thailand (Sanoamuang 1998) as well as Indian Rotifera (Sharma 1996) and the Oriental fauna (Segers 2008). Besides, Notommatidae > Testudinellidae = Euchlanidae > Trochosphaeridae > Trichotriidae, together, form a valuable component (18.7 per cent).

A majority of these families, except Brachionidae, include predominantly littoral-periphytic taxa (Segers 2001). The relative paucity of planktonic elements is attributed to the lack of definite pelagic habitats (De Manuel 1994) in the floodplain wetlands, shallow nature and the growth of aquatic macrophytes.

Segers (2001) stressed the role of thermophiles in the rotifer fauna of Southeast Asia with significance of *Lecane* and to a lesser degree of *Brachionus*. The importance of these “tropic-centered” genera is evident in the rotifera of the floodplain of the Brahmaputra basin with *Lecane* (60 species) representing 27.3 per cent of the total richness.

The lecanid dominance compares well with the reports from floodplains of Africa (Segers et al. 1993, 1998), Thailand (Sanoamuang 1998) and Argentina (Jose de Paggi 2001) as well as with its richness in the rotifer fauna of NEI (Sharma and Sharma 2014a, 2014b). *Brachionus* includes 16 species in the Brahmaputra floodplains with only fewer common eurytopic species while the rest showed limited occurrence. Our results also show importance of *Lepadella* (20 species) and *Trichocerca* (11 species). Thus, the four monogonont genera: *Lecane* > *Lepadella* > *Brachionus* > *Trichocerca* comprised the bulk of the reported richness (94 species, 53.4 per cent) concurrent with the composition of the rotifer fauna of NEI (Sharma and Sharma 2005, 2014a).

The significance of “tropic-centered” *Lecane* and *Brachionus* and occurrence of several Pantropical and Cosmotropical species impart a general ‘tropical character’ to the rotifer fauna of the Brahmaputra floodplains. This generalisation is conformity with the composition of the tropical faunas from different parts of the globe (Green 1972; Pejler 1977; Fernando 1980; De Ridder, 1981; Dussart et al. 1984; Segers 1996, 2001, 2008). These remarks are supported by low richness of “temperate-centered” *Keratella* and scarcity of speciose “cold-water” genera *Cephalodella* and *Synchaeta*.

The lack of “temperate-centered” *Notholca* is noteworthy as its species are reported to drift with the Himalayan Rivers to lower latitudes of northwest India (Arora and Mehra 2003).

The rotifer communities are characterised by the occurrence of a number of small-sized taxa of *Colurella*, *Lecane*, *Lepadella* and *Trichocerca* in

particular. The salient feature of the rotifer community structure may be assigned to conditions of low concentrations of food, and predation by fish and invertebrates as suggested by Papinski (1990) and Baumgartner et al. (1997) respectively. However, the detailed observations are required to confirm these findings.

Interestingly, our observations demonstrate a frequent occurrence of non-planktonic taxa in open waters of several sampled beels. The establishment of both planktonic and non-planktonic taxa in the beels with marginal vegetation suggested the occupation of different niches as hypothesized by Bonecker et al. (1998).

To sum up, the rich and diverse rotifer assemblage of the Brahmaputra floodplains is of special biodiversity value; Deepor Beel is the globally important “hot-spot” for the taxon; and high rotifer diversity in floodplains of Majuli is noteworthy. Our report of various globally interesting rotifer elements imparts distinctive character and biogeography importance to these floodplains.

The diversity pattern of rotifers is predominantly tropical, and followed the moderate endemism model. The predominance of non-planktonic littoral-periphytic species and occurrence of several small-sized species is interesting. The present collections are biased towards planktonic and semi-planktonic taxa and, hence, our conservative estimate of occurrence of > 300 rotifer species with specific sampling of the periphytic, sessile, colonial and benthic communities of these ecotones deserves biodiversity and biogeography interest.

ACKNOWLEDGEMENTS

One of the authors (BKS) is thankful to the Ministry of Environment and Forests (Government of India) for sanctioning a research project No. 22018-09/2010-CS (Tax) under its AICOPTAX program under which the present study is undertaken.

Thanks are due to the Head, Department of Zoology, NEHU, Shillong for laboratory facilities and Messer's M. Hatimuria, T. Pou, N Noroh and J. D. Mali for help in field collections on various occasions.

We are thankful to IUCN, India office, New Delhi for sponsoring our participation in the International Symposium and to the organisers to facilitate this presentation.

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Unraveling Chromophytic Phytoplankton Assemblages from Indian Sundarbans Mangrove Wetlands Based on *rbcL* Clone Library and Sequencing Approach

Brajogopal Samanta and Punyasloke Bhadury

Integrative Taxonomy and Microbial Ecology Research Group, Department of Biological Sciences,
Indian Institute of Science Education and Research, Kolkata,
Mohanpur - 741246, West Bengal, India
E-mail: pbhadury@iiserkol.ac.in, pbhadury@gmail.com

ABSTRACT

The Sundarbans represent the world largest contiguous mangrove wetlands located at north-west of the Bay of Bengal, encompasses over 102 islands with a network of innumerable rivers, rivulets, and creeks. This vast deltaic region is formed at the estuarine phase of the Ganges-Brahmaputra and Meghna river system across India and Bangladesh.

Phytoplankton is the important constituent of aquatic primary production in Sundarbans wetlands. The phylogeny and diversity based on the amplification and sequencing of *rbcL*, the large sub-unit encoding the key enzyme RuBisCO was investigated coupled with traditional microscopy for improved understanding of the community structure and temporal trends of chromophytic phytoplankton assemblages in the Indian part of Sundarbans.

Diatoms (Bacillariophyceae) were by far the most frequently detected group in clone libraries as also based on microscopy, consistent with their importance as a major bloom-forming group. Other major chromophytic algal groups including Cryptophyceae, Haptophyceae, Pelagophyceae, Eustigmatophyceae and Raphidophyceae which are important component of the assemblages were detected for the first time from Sundarbans based on *rbcL* approach, but not using microscopy.

Many of the sequences from Sundarbans *rbcL* clone libraries showed identity with key bloom forming diatom genus such as *Thalassiosira* Cleve and also confirmed by microscopic observations. Principal coordinates analysis showed temporal pattern of OTUs distribution across the study area as also confirmed by other statistical approaches. This study applied molecular and microscopic tools to delineate chromophytic phytoplankton assemblages in Indian part of Sundarbans wetland ecosystem.

Key words: Chromophytic phytoplankton, microscopy, *rbcL*, phylogeny, Sundarbans

INTRODUCTION

Wetland is a boundary ecosystem at the edge of a body of water and land which is characterised by the presence of sluggishly moving or standing water

saturating soil either permanently or seasonally. Wetlands can be broadly classified into swamp, marsh, bog, and fen depending upon the soil quality and vegetation type.

Sundarbans is a tidally influenced swamp mangrove wetland situated at the estuarine phase of river Ganges, Brahmaputra, and Meghna. It is the single largest area of swamp mangrove wetland globally, with a dense tidal mangrove forest of approximately 6,050 square kilometres shared between India (2,000 square kilometres in West Bengal state) and Bangladesh (4,050 square kilometres).

In mangrove ecosystems such as Sundarbans, phytoplankton communities, in particular diatoms are key contributors of aquatic primary production and their diversity is strongly influenced by nutrient outwelling from the mangrove forest (Biswas et al. 2010; Aziz et al. 2012). To date, members belonging to Bacillariophyceae, Chrysophyceae, and Xanthophyceae have been only detected as chromophytic phytoplankton from Indian and Bangladesh parts of Sundarbans, in addition to green algae and photosynthetic prokaryotes (e.g. Manna et al. 2010; Aziz et al. 2012).

Photosynthetic carbon fixation in phytoplankton is mediated by ribulose-1, 5-bisphosphate carboxylase/ oxygenase (RuBisCO) enzyme via Calvin-Benson-Bassham (CBB) reductive pentose phosphate pathway (Watson and Tabita 1997). Chromophytic phytoplankton possesses form ID RuBisCO. Moreover, plastid encoded *rbcL* gene (large sub-unit of RuBisCO) has conserved and variable domains which can be used for studying diversity and molecular phylogeny of phytoplankton assemblages (e.g. Watson and Tabita 1997). Molecular techniques in conjunction with traditional microscopy can provide a better understanding of community structure for lesser known biological groups including phytoplankton (Joo et al. 2010). Information on chromophytic algal groups other than Bacillariophyceae and some members of Chrysophyceae in Indian part of Sundarbans mangrove wetland are sparse. Therefore, the detection of unexplored diversity of chromophytic phytoplankton in Sundarbans warrant further investigation towards better understanding of their role in ecosystem functioning.

The main objective of this study was to assess chromophytic phytoplankton assemblages and diversity in Indian part of Sundarbans based on functional gene sequencing (*rbcL*) approach in conjunction with traditional microscopy.

MATERIALS AND METHODS

The study was undertaken across four sampling stations in Sagar Island of the Indian part of Sundarbans wetland (Figure 1). Details about the sampling stations are available from Bhattacharjee et al (2013). Surface water samples were collected in early summer (April, 2010), spring (March, 2011) and across two stations (Stn1 and Stn2) in winter (December, 2010). For water collection from the study area and subsequent steps including biomass concentration, standard protocol was adopted (Bhattacharjee et al. 2013).

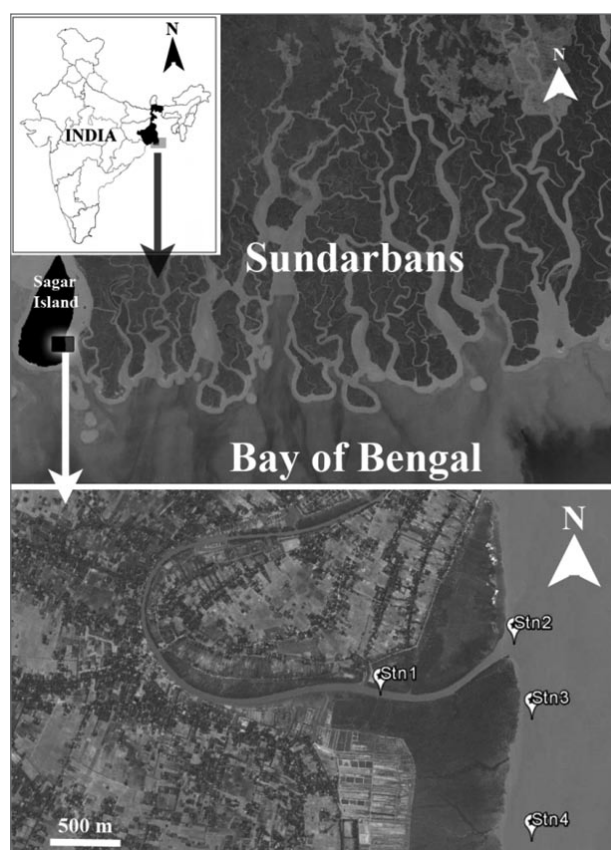


Figure 1: Map showing study areas, Stn1 (21°40'44.4"N; 88°08'49.5"E) and Stn2 (21°40'59.3"N; 88°09'13.1"E) in Chemaguri creek and Stn3 (21°40' 40.6"N; 88°09'19.2"E) and Stn4 (21°40'09.8"N; 88°09'21.2"E) in Mooriganga estuary. Map was adopted from Google Earth (<https://earth.google.com/>).
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Total environmental DNA was extracted from each sterivex based on published protocol (Boström et al. 2004). The form ID *rbcl* gene fragment (554 bp) was amplified from environmental DNA in triplicates using previously published chromophyte specific *rbcl* primers (Wawrik et al. 2002). Subsequent steps including cloning and sequencing were undertaken based on published protocol (e.g. Bhattacharjee et al. 2013). The clone libraries and number of *rbcl* clones are detailed in Table 1.

Generated DNA sequences were checked and subsequent steps including alignment in Clustal

Table 1: Details of *rbcl* clones sequenced from each library of April 2010, December 2010, and March 2011

Clone library	Number of <i>rbcl</i> clones
Stn1_Apr10	57
Stn2_Apr10	54
Stn3_Apr10	50
Stn4_Apr10	47
Stn1_Dec10	50
Stn2_Dec10	54
Stn1_Mar11	54
Stn2_Mar11	50
Stn3_Mar11	50
Stn4_Mar11	53
Total	519

Omega Platform (e.g. Bhattacharjee et al. 2013). A maximum-likelihood (ML) tree based on JTT model was constructed based on the amino acid alignment consisting of 519 *rbcl* clones (184 deduced amino acids) generated from this study and 118 reference *rbcl* sequences of cultured and uncultured photosynthetic eukaryotes from databases (Guindon and Gascuel 2003).

The accession numbers of *rbcl* sequences used as part of this study are from KF035830-KF035881 and KF536109-KF536581. Microscopic identification of eukaryotic phytoplankton was undertaken following the protocol of Bhattacharjee et al (2013).

For taxonomic delineation, *rbcl* clones at the amino acid level were grouped into operational taxonomic units (OTUs) using DOTUR (three per cent cut off) (Schloss and Handelsman 2005). Jackknife Environment Clustering was performed using normalised weighted UniFrac metric in UniFrac for comparative analysis of chromophytic phytoplankton assemblages (Lozupone and Knight 2005). UniFrac significance test was also applied to determine contribution of unique branch length from each library in the phylogenetic tree. Principal Coordinates Analysis (PCA) was performed to determine how sampling stations are separated in different dimension based on type ID *rbcl* gene heterogeneity.

RESULTS

In total, 519 *rbcl* clones were sequenced from April 2010, December 2010, and March 2011 clone libraries (Table 1). Six chromophytic phytoplankton groups namely, Bacillariophyceae, Cryptophyceae, Haptophyceae, Pelagophyceae, Eustigmatophyceae, and Rhaphidophyceae were detected in varying proportion across the libraries (Figure 2, Table 2).

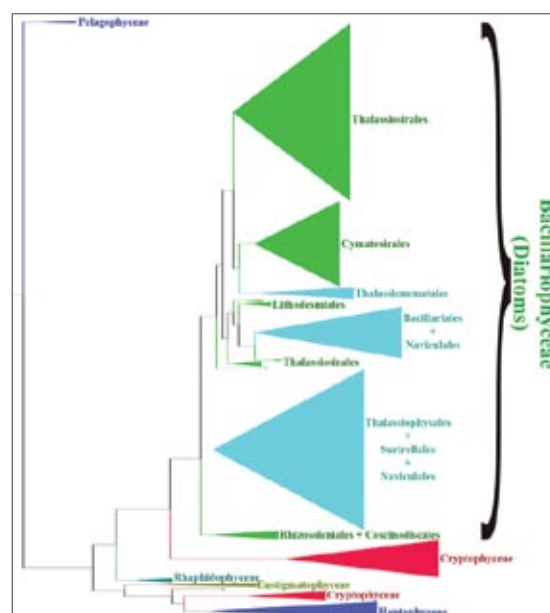


Figure 2: Consensus tree obtained from maximum likelihood analysis using JTT as a substitution model of a deduced 184 amino acid long alignment of 637 *rbcl* sequences including 519 sequences generated in this study showing major classes and orders of chromophytic phytoplankton. © Punyasloke Bhaduri

Table 2: The distribution pattern of OTUs across all the ten *rbcl* clone libraries. A total 103 OTUs were recovered from pooled *rbcl* clone libraries. Sequences were grouped into OTUs using 3 per cent cut off at the amino acid level. '√' indicates presence while '–' indicates absence of OTUs

Class	Bacillariophyceae																			
Order	Thalassiosirales (Centric)																			
OTUs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Stn1_Apr10	√	√	√	–	√	√	√	√	√	–	–	–	–	–	–	–	–	–	–	–
Stn2_Apr10	√	√	√	–	–	–	–	–	–	√	√	√	√	–	–	–	–	–	–	–
Stn3_Apr10	√	√	√	–	–	–	–	√	–	–	–	–	–	√	√	–	–	–	–	–
Stn4_Apr10	√	√	√	–	√	–	–	–	–	–	–	–	–	–	–	√	√	–	–	–
Stn1_Dec10	√	–	√	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stn2_Dec10	√	√	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	√	√	–
Stn1_Mar11	√	–	–	–	–	–	–	–	–	√	–	–	–	√	–	–	–	–	–	–
Stn2_Mar11	√	√	–	–	–	–	–	–	–	√	–	–	–	–	–	–	–	–	–	–
Stn3_Mar11	√	√	–	–	–	–	–	–	–	–	–	–	–	√	–	–	–	–	–	√
Stn4_Mar11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Class	Bacillariophyceae																			
Order	Cymatosirales (centric)										Lithodesmiales (Centric)								Coscinodiscales (Centric)	
OTUs	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Stn1_Apr10	√	√	–	–	–	–	–	–	–	–	–	√	√	–	–	–	–	–	–	–
Stn2_Apr10	√	√	–	–	–	–	–	–	–	–	–	–	–	√	√	√	–	–	–	–
Stn3_Apr10	–	√	√	√	–	–	–	–	–	–	–	√	√	–	–	–	–	√	√	–
Stn4_Apr10	–	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stn1_Dec10	√	√	–	–	–	√	–	–	–	–	–	–	–	√	–	–	√	–	–	–
Stn2_Dec10	√	√	–	–	√	–	–	–	–	–	–	–	–	√	√	–	–	–	–	–
Stn1_Mar11	√	√	–	√	√	–	–	–	–	–	–	–	–	–	–	√	–	–	–	–
Stn2_Mar11	√	√	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stn3_Mar11	√	√	–	–	–	√	√	√	√	√	√	–	–	–	–	–	–	–	–	–
Stn4_Mar11	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	√

Class	Bacillariophyceae																			
Order	Rhizosoleniales (Centric)			Thalassiosirales (Pennate)																
OTUs	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Stn1_Apr10	–	–	–	√	√	√	√	√	√	√	–	–	–	–	–	–	–	–	–	–
Stn2_Apr10	√	–	–	√	–	–	–	–	–	–	–	√	–	–	–	–	–	–	–	–
Stn3_Apr10	√	√	–	√	√	√	√	–	√	–	–	√	√	√	√	–	–	–	–	–
Stn4_Apr10	–	–	–	√	√	–	–	–	–	–	–	–	–	–	√	√	√	–	–	–
Stn1_Dec10	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–	√	√	–	–
Stn2_Dec10	√	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stn1_Mar11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	√	–
Stn2_Mar11	–	–	–	–	–	–	–	–	–	–	–	–	–	√	–	–	–	–	–	–
Stn3_Mar11	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	√
Stn4_Mar11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Class	Bacillariophyceae																	
Order	Bacillariales (Pennate)									Naviculales (Pennate)								
OTUs	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Stn1_Apr10	√	√	–	–	–	–	–	–	√	√	–	–	–	–	–	–	–	–
Stn2_Apr10	–	–	√	√	√	–	–	–	√	–	–	–	–	–	–	–	–	–
Stn3_Apr10	√	–	–	–	√	–	–	–	–	–	√	–	–	–	–	–	–	–
Stn4_Apr10	–	–	–	–	–	–	–	–	√	–	–	–	–	–	–	–	–	–
Stn1_Dec10	–	–	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–
Stn2_Dec10	√	√	–	–	–	–	–	–	–	–	–	√	√	√	√	–	–	–
Stn1_Mar11	√	–	√	–	–	–	–	–	–	–	–	–	√	–	–	√	√	√
Stn2_Mar11	–	–	–	–	–	–	–	√	–	–	–	–	√	–	–	–	–	√
Stn3_Mar11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	√
Stn4_Mar11	–	–	–	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–

Class	Bacillariophyceae								Cryptophyceae							
Order	Surirellales (Pennate)			Thalassionemales (Pennate)												
OTUs	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Stn1_Apr10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stn2_Apr10	√	–	–	–	–	–	–	–	–	√	–	–	–	–	–	–
Stn3_Apr10	–	–	–	√	–	–	–	–	–	–	–	–	–	–	–	–
Stn4_Apr10	–	–	–	–	–	–	–	–	–	√	√	√	–	–	–	–
Stn1_Dec10	√	–	–	–	–	–	–	–	–	–	√	–	√	–	–	–
Stn2_Dec10	√	–	–	√	√	–	–	–	–	–	√	–	√	√	√	–
Stn1_Mar11	√	√	–	–	√	√	–	–	–	√	√	–	√	√	√	√
Stn2_Mar11	√	–	–	–	–	–	√	–	√	–	–	–	–	–	–	–
Stn3_Mar11	√	√	–	–	–	–	–	–	–	–	–	–	–	√	–	√
Stn4_Mar11	√	√	√	–	–	–	–	√	–	–	–	–	–	–	–	–

Class	Eustigmatophyceae	Raphidophyceae	Haptophyceae			
OTUs	98	99	100	101	102	103
Stn1_Apr10	–	–	–	–	–	–
Stn2_Apr10	–	–	√	√	–	–
Stn3_Apr10	–	–	–	–	–	–
Stn4_Apr10	–	–	–	–	–	–
Stn1_Dec10	–	–	–	√	–	–
Stn2_Dec10	√	–	–	–	√	√
Stn1_Mar11	–	–	–	–	–	–
Stn2_Mar11	–	–	–	–	–	–
Stn3_Mar11	–	√	–	–	–	–
Stn4_Mar11	–	–	–	–	–	–

In total, 103 OTUs were detected from pooled *rbcL* clone libraries (Table 2). Eighty eight OTUs belonged to 10 orders under Bacillariophyceae (Table 2). Among 10 orders, five orders belonged to centric diatoms namely, Thalassiosirales Glezer and Makarova, Cymatosirales Round and Crawford,

Lithodesmiales Round and Crawford, Coscinodiscales Round and Crawford, and Rhizosoleniales Silva whereas remaining five orders belonged to pennate diatoms and represented by Thalassiosiphysales Mann, Bacillariales Hendey, Naviculales Bessey, Surirellales Mann, and Thalassionematales Round.

Highest number of OTUs were represented by order Thalassiosirales (20 OTUs), followed by Thalassiophysales (17 OTUs). Many *rbcL* sequences under Thalassiosirales showed significant identity with *rbcL* sequences of cultured species of *Thalassiosira* including, *T. nodulolineata* (hendey) Hasle and Fryxell and *T. nordenskiöldii* Cleve.

Remaining 15 OTUs were represented by five classes namely, Cryptophyceae, Haptophyceae, Pelagophyceae, Eustigmatophyceae, and Raphidophyceae (Table 2). Out of 15 non-diatom OTUs, eight and four OTUs belonged to classes Cryptophyceae and Haptophyceae respectively while the remaining three OTUs, one each, belonged to Pelagophyceae, Eustigmatophyceae, and Raphidophyceae.

Additionally, based on microscopy, some of the chromophytic phytoplankton was also identified to taxon level. Compared to *rbcL* clone libraries, only Bacillariophyceae was detected based on microscopy. In total, 23 genera represented by 14 orders under Bacillariophyceae were detected (Table 3). Among 14 orders of Bacillariophyceae, eight orders belonged to centric diatoms namely Thalassiosirales, Lithodesmiales, Coscinodiscales, Rhizosoleniales, Melosirales Crawford, Triceratiales Round and Crawford, Climacospheniales Round, and Chaetocerotales Round and Crawford while pennate diatoms were represented by six orders namely: Thalassiophysales, Bacillariales, Naviculales, Surirellales, Thalassionematales, Cymbellales Mann, and Fragilariales Silva.

Table 3: Generic composition of eukaryotic chromophytic phytoplankton based on microscopy from the study sites; '√' indicates presence while '-' indicates absence of the genera

Order	Thalassiosirales (Centric)		Coscinodiscales (Centric)		Lithodesmiales (centric)	Melosirales (Centric)	Triceratiales (centric)
Genera	<i>Thalassiosira</i>	<i>Cyclotella</i>	<i>Coscinodiscus</i>	<i>Actinocyclus</i>	<i>Ditylum</i>	<i>Melosira</i>	<i>Triceratium</i>
Stn1_Apr10	–	–	√	–	–	–	√
Stn2_Apr10	√	–	√	–	–	–	–
Stn3_Apr10	√	–	√	–	–	–	√
Stn4_Apr10	√	–	√	–	–	–	√
Stn1_Dec10	–	–	√	√	√	–	–
Stn2_Dec10	√	–	√	√	√	–	–
Stn1_Mar11	√	√	√	–	–	–	–
Stn2_Mar11	–	–	√	–	–	√	–
Stn3_Mar11	√	–	√	–	–	–	–
Stn4_Mar11	–	–	√	–	–	–	–

Order	Rhizosoleniales (Centric)	Climacopheniales (Centric)	Chaetocerotales (Centric)	Thalassionematales (Pennate)		Surirellales (Pennate)
Genera	<i>Rhizosolenia</i>	<i>Climacophenia</i>	<i>Chaetoceros</i>	<i>Thalassionema</i>	<i>Thalassiothrix</i>	<i>Surirella</i>
Stn1_Apr10	–	–	–	√	–	–
Stn2_Apr10	–	–	–	–	–	–
Stn3_Apr10	–	–	–	√	–	–
Stn4_Apr10	√	–	–	√	–	–
Stn1_Dec10	–	–	√	–	–	–
Stn2_Dec10	–	–	–	√	–	–
Stn1_Mar11	–	–	–	–	√	–
Stn2_Mar11	–	–	–	–	√	–
Stn3_Mar11	–	–	–	√	√	√
Stn4_Mar11	–	√	–	–	√	–

Order	Thalassiophysales (Pennate)	Bacillariales (Pennate)	Fragilariales (Pennate)	Cymbellales (Pennate)	Naviculales (Pennate)		
Genera	<i>Amphora</i>	<i>Cylindrotheca</i>	<i>Fragilaria</i>	<i>Cymbella</i>	<i>Navicula</i>	<i>Nitzschia</i>	<i>Pinnularia</i>
Stn1_Apr10	–	–	–	√	√	–	–
Stn2_Apr10	–	–	√	–	√	√	–
Stn3_Apr10	–	–	–	–	√	–	–
Stn4_Apr10	–	–	–	–	√	–	–
Stn1_Dec10	–	–	–	–	√	–	–
Stn2_Dec10	–	–	–	–	–	–	–
Stn1_Mar11	–	√	–	–	√	√	–
Stn2_Mar11	√	–	–	–	√	–	–
Stn3_Mar11	√	√	–	–	–	√	√
Stn4_Mar11	–	–	–	–	√	–	√

Order	Naviculales (Pennate)		
Genera	<i>Pleurosigma</i>	<i>Gyrosigma</i>	<i>Amphiprora</i>
Stn1_Apr10	–	–	–
Stn2_Apr10	–	–	–
Stn3_Apr10	√	–	–
Stn4_Apr10	–	–	–
Stn1_Dec10	–	–	–
Stn2_Dec10	√	–	–
Stn1_Mar11	√	–	–
Stn2_Mar11	√	√	–
Stn3_Mar11	√	–	√
Stn4_Mar11	√	–	–

Phytoplankton cells belonging to the genus *Thalassiosira* and *Coscinodiscus* Ehrenberg were encountered in overwhelming number. Some frequently occurring diatom species were represented by *Coscinodiscus radiatus* Ehrenberg, *Thalassiosira punctigera* (Castracane) Hasle, *T. weissflogii* (Grunow) G. Fryxell and Hasle, *T. sundarbana* Samanta and Bhadury, *Chaetoceros affinis* Lauder, *Surirella gemma* Ehrenberg, *Ditylum brightwelli* West, *Amphora coffeaeformis* (Agardh) Kützing, *Cyclotella stylorum* Brightwell, and *Cylindrotheca closterium* (Ehrenb.) Reimann and Lewin.

Jackknifing biodiversity conservation and economic development in five tropical forest landscapes of *rbcL* sequences from 10 clone libraries were performed to assess how number and evenness of *rbcL* sequences in different clone libraries affected UPGMA clustering results.

The results showed that Stn1_Apr10, Stn3_Apr10, Stn4_Apr10, and Stn1_Dec10 formed a cluster, whereas, Stn1_Mar11, Stn2_Mar11, Stn3_Mar11, and Stn2_Dec10 formed another cluster in UPGMA tree (Figure 3).

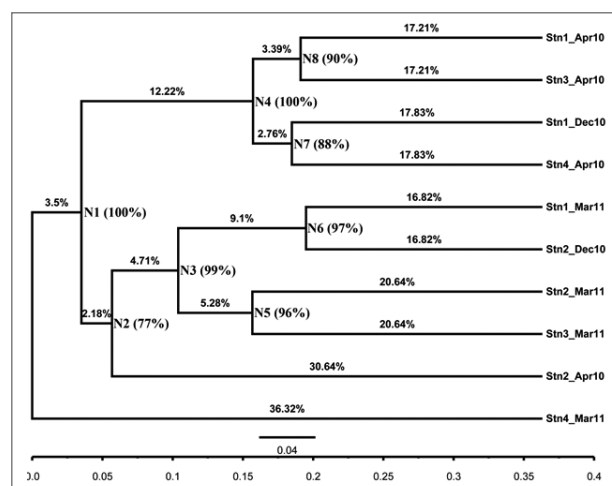


Figure 3: UPGMA cluster of ten *rbcL* clone libraries. The nodes recovered in the UPGMA tree are labelled as N1-8. Jackknife value of each node is indicated in bracket next to the node name. Branch lengths are indicated above each branch in percentage. The scale bar shows the distance between clusters in UniFrac units. © Punyasloke Bhaduri

Stn2_Apr10 and Stn4_Mar11 were separated from the above clusters in UPGMA tree and showed deep branching. All the nodes in the UPGMA tree were also supported by jackknife values (> 75 per cent) (Figure 3). For example, Stn1_Apr10, Stn3_Apr10, Stn4_Apr10 and Stn1_Dec10 clustered together 100 per cent of the time, whereas Stn1_Mar11, Stn2_Mar11, Stn3_Mar11 and Stn2_Dec10 clustered together 99 per cent of the time.

On the other hand, Stn1_Mar11 library has highest amount of unique branch length (P value = 0.04) with respect to other clone libraries in the phylogenetic tree (Table 4).

Table 4: Environmental distance P values from 10 clone libraries based on the unique branch length. The lowest P value indicates highest amount of branch length in particular *rbcl* clone library with respect to the others

Environmental Distance P Value (s)	
Clone libraries	P value
Stn1_Apr10	0.71
Stn2_Apr10	0.16
Stn3_Apr10	0.13
Stn4_Apr10	0.90
Stn1_Dec10	0.94
Stn2_Dec10	0.12
Stn1_Mar11	0.04
Stn2_Mar11	0.73
Stn3_Mar11	0.23
Stn4_Mar11	1.00

In principal coordinates analysis (PCA), the first two components (P1 = 39.2 per cent and P2 = 20.4 per cent) explained approximately 60 per cent of total variations (Figure 4 and Table 5). The first component axis clearly separated the clone libraries of April 2010 from the clone libraries of March 2011 except Stn2_Apr10 (Figure 4 and Table 5).

Table 5: Factor coordinates (P1 and P2) of the *rbcl* clone libraries, based on correlations with factors considered for PCA

PC vector number	P1	P2
Stn1_Apr10	0.390736	0.054649
Stn2_Apr10	-0.03853	-0.10793
Stn3_Apr10	0.335204	0.072328
Stn4_Apr10	0.299054	-0.12674
Stn1_Dec10	0.195648	-0.08445
Stn2_Dec10	-0.27779	-0.21346
Stn1_Mar11	-0.27779	-0.16736
Stn2_Mar11	-0.2773	-0.00763
Stn3_Mar11	-0.26805	0.099086
Stn4_Mar11	-0.13526	0.48151
Eigvals	0.688487	0.358366
per cent variation explained	39.22032	20.41465

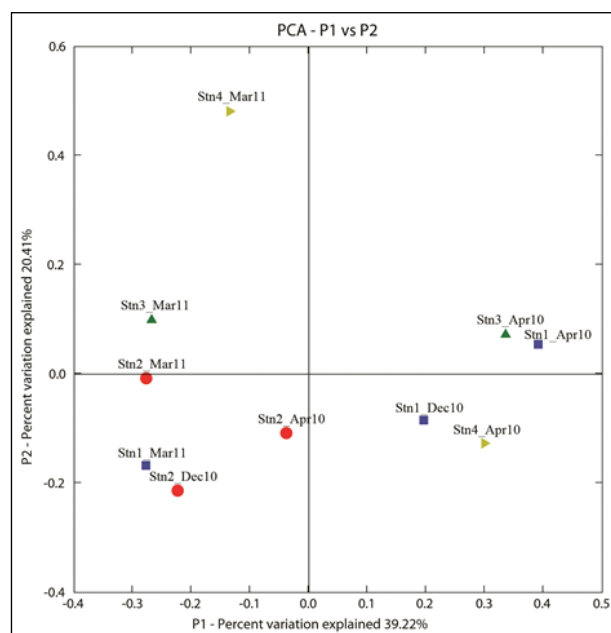


Figure 4: UPGMA cluster of ten *rbcl* clone libraries. The nodes recovered in the UPGMA tree are labelled as N1-8. Jackknife value of each node is indicated in bracket next to the node name. Branch lengths are indicated above each branch in percentage. The scale bar shows the distance between clusters in UniFrac units. © Punyasloke Bhaduri

On the other hand, first component axis also separated the two stations of December 2010 from each other, where Stn1_Dec10 and Stn2_Dec10 had positive and negative loading factor value respectively.

DISCUSSION

This study was undertaken to gain an understanding about chromophytic phytoplankton assemblages from study sites of Indian Sundarbans wetland. Based on the integrative taxonomy approach involving form ID *rbcl* phylogeny and microscopy, it was found that the study area is overwhelmingly dominated by diatoms. However, the *rbcl* phylogeny approach provided us with a better idea of the composition of chromophytic phytoplankton assemblages compared to microscopy. For example, six classes of major chromophytic phytoplankton were detected in clone libraries compared to microscopic observation (only one) (Figure 2, Table 2 and 3).

It is important to note that water samples collected for microscopic identification were concentrated using 10µm mesh size plankton net. As a result

chromophytic phytoplankton lesser than 10µm size in bulk assemblages may have been missed out. This result was reflected in *rbcL* clone libraries because environmental DNA was extracted from two liters water sample representing fifty per cent (1L) water concentrated in 10µm mesh size plankton net and fifty percent (1L) of natural water.

For example, we detected nano-planktonic Haptophyceae, Eustigmatophyceae, and Pelagophyceae such as OTUs but they were not encountered in microscopic observation. Thus the use of plankton net should be based on the type of ecosystem targeted as part of a study. The OTUs belonging to Cryptophyceae and Raphidophyceae were detected in clone libraries but they were missed out in microscopic observation although most of them are >10µm in size.

The identification of cells belonging to Cryptophyceae and Raphidophyceae are very difficult in environmental samples because they undergo rapid structural deformation during preservation as also observed in previous studies (Bowers et al. 2006).

To gain a better understanding of chromophytic phytoplankton assemblages from the study area, OTUs retrieved from pooled *rbcL* clone libraries was complemented with genera identified using microscopy. In *rbcL* clone libraries, Bacillariophyceae such as OTUs were distributed among 10 orders. Generic representative of all the 10 orders detected in clone libraries were also identified based on microscopy except for the order Cymatosirales.

Eleven OTUs belonging to the order Cymatosirales were detected exclusively in clone libraries and most importantly some of the Cymatosirales such as *rbcL* sequences showed 100 per cent identity with a nanoplanktonic centric diatom *Minutocellus polymorphus* Hargraves and Guillard at the amino acid level. But *Minutocellus* was not detected based on microscopy since these small-sized cells might have been missed out while passing through the plankton net. Bloom forming phytoplankton genus

such as *Thalassiosira* was detected using *rbcL* and microscopy indicating congruency between the two methods.

On the other hand, phytoplankton taxa representing four orders under Bacillariophyceae were detected exclusively based on microscopy. These orders were Melosirales, Triceratiales, Cymbellales, and Fragilariiales. The possible reason behind the under-estimation of these orders in clone libraries could be due to their low relative cell abundance in natural assemblages. Previous study based on microscopy also showed that *Thalassiosira punctigera*, *Nitzschia longissima* Brebisson, and *Navicula rhombica* Gregory was the dominant species of diatoms across our study area (Bhattacharjee et al. 2013).

The temporal variations of OTUs distribution across the *rbcL* clone libraries were quite prominent based on Jackknife Environment Clustering. Jackknifing the UPGMA tree revealed that chromophytic phytoplankton assemblages of April 2010 differed from March 2011 except for two libraries (Stn2_Apr10 and Stn4_Mar11). Stn4_Mar11 was separated from the March 2011 cluster because bulk of the eukaryotic chromophytic assemblages was heavily dominated by pennate diatoms like OTUs. For example, all the three OTUs under the order Surirellales were detected from this clone library.

It is interesting to note that chromophytic phytoplankton assemblages of Stn1_Dec10 were very similar to April 2010, whereas Stn2_Dec10 chromophytic phytoplankton populations were very similar to March 2011 in UPGMA tree. Clustering of the stations in the PCA plot also showed similar temporal pattern of OTUs distribution across the study area as observed in UPGMA tree. Since the study area is diurnally influenced by tidal action and the sampling stations are differing spatially only about one kilometer from each other, therefore, it is most likely that chromophytic phytoplankton assemblages were similar to a certain extent across all the stations at a particular time point.

Previous studies have shown that Bacillariophyceae is an important contributor to primary production in the Sundarbans. But in the present study, detection of chromophytic phytoplankton other than Bacillariophyceae based on *rbcl* gene sequencing approach indicate that other small-sized (nano and pico) chromophytic phytoplankton may be important in this wetland. Further study of these minor groups of chromophytic phytoplankton will elucidate their contribution in the aquatic food chain of a swamp mangrove water column.

Overall the present study suggests that integrated approach using gene sequencing and microscopy can provide us with an improved understanding of chromophytic phytoplankton assemblages and associated diversity from aquatic environments such as mangrove wetlands.

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Species Richness of Freshwater Diatoms and Fish in the Mountain Chains of the Indian Subcontinent: Examining the Spatial Scales, Area-Richness Model and the Role of Historical Factors

Prakash Nautiyal¹, Rachna Nautiyal², Jyoti Verma³ and Asha Agarwal⁴

¹Aquatic Biodiversity Unit, Department of Zoology & Biotechnology,

HNB Garhwal University (A Central University), Srinagar - 246174, India

²Department of Zoology, Govt. PG College, Dakpatthar, Vikasnagar, Dehradun - 248125, India

³Department of Zoology, University of Allahabad, Allahabad - 211002, India

⁴Department of Zoology, S. S. S. Girls College, Bhopal, India

¹Email: lotic.biodiversity@gmail.com

ABSTRACT

The species richness of the diatom and fish were examined at a variety of spatial scales in the light of the models of richness and the role of historical factors in shaping richness in major mountain chains (eco-regions) of the subcontinent.

The richness of diatoms in the Himalayas and the Highlands of Central India (CHL) increased from locality to river (locality 77 per cent, 88 per cent of river scale, respectively) and eco-region scale. Fish richness of a locality formed only 20 per cent of river scale, but increased from river to the eco-region scale in the West Himalayas.

Comparably, the richness is higher at locality scale in CHL and Western Ghats (WG). Within the Himalayas, the Eastern part was richest compared with the Central (Nepal) and the West Himalayas. The area-richness and species-discharge models explain an increase in the richness of diatom from locality to river/ basin scale, from a stream to a river and the eco-region in lesser Himalayas, but not in the Doon valley with far-less area.

However, the species-discharge model does not explain the decline in the richness of diatoms and fish from headwaters to mouth despite increase in discharge in CHL ecoregion. Area-richness model is unable to explain disparity in richness within Himalaya (East, Central, and West) and among Himalayas, Western Ghats and CHL.

The Himalayan orogeny, the volcanic past and glaciations of the peninsular India have shaped the richness patterns of the diatom flora and fish fauna in subcontinent. The habitats that harbour diatoms and fish are under threat from the ambitious hydropower development in the Himalayas, exemplified by the Putitor Mahseer, while the Khudree and other Mahseer species in WG. The proposed Ken-Betwa link will threaten the Tor Mahseer habitat in CHL.

Keywords: Fish, diatom, species richness, Himalaya, Central Highland

INTRODUCTION

The freshwater biodiversity distribution differs from that of the marine systems because freshwater habitats are relatively discontinuous, and the species do not disperse easily across the land barriers that separate river drainages into discrete units. The loss of biodiversity in an ecosystem has important implications, including diminished resistance and resilience to disturbance, system simplification, and loss of ecological integrity (WRI et al. 1992).

The distribution comes from the inaccessibility of the particular area to the species. There are numerous instances of disjunctive distributions i.e. closely related species living in widely separated areas of a continent. The fragmentation of biota is largely due to physical changes in environment as a consequence of continental drift, climatic changes that contract and fragment the areas of habitat favorable for species (Hickman et al. 1991).

Geologically, the peninsula and extra-peninsula (the Himalayas) constitute the Indian subcontinent. Geographically, India has three distinct landforms: the mountains, plains and plateau. The highlands of the peninsula are highly varied as they consist of the plateau and small mountain chains. Historically, the Himalayas became part of the subcontinent in recent times that further influenced climate of the subcontinent during glaciations (Wadia 1983).

The connection of Himalayas with the ancient peninsula has influenced the freshwater biodiversity of extra-peninsula, because it was a new landmass with mountain character because of steep gradient and eroding rivers.

In the mountain waters the algae among the producers while fish among consumers at various trophic levels constitute the major components of freshwater biodiversity in the Indian subcontinent. Among the producers, the siliceous diatoms have been considered here as they account for a major part of the benthic microflora, both qualitatively and quantitatively (Nautiyal et al. 1997).

The present contribution, however, discusses freshwater biodiversity (diatoms, fish) with respect to the species richness in the Indian subcontinent at different spatial scales, examines the area-richness models and the historical reasons for the present state of diversity. Further, large tracts of fish habitats are being fragmented at rapid pace, primarily due to the ambitious hydropower development. This has threatened much of the biodiversity hampering the functions of the producers and thereby affecting the consumers at primary, secondary and tertiary levels, well exemplified by the iconic Mahseer. The situation will be far critical if climate change is also considered.

In the Himalayas, Gangetic drainage consists of the rivers and streams of varying dimensions. There are large rivers such as the Alaknanda and Bhagirathi and smaller like Mandakini and Pindar that have glaciers at their source while a large number of Ist and IInd order streams fed by snow close to the snowline and fed by springs away from the snowline towards the foothills. The species richness of diatoms pertains to a locality (Srinagar) along the glacier River Alaknanda at an altitude of 500-550 m asl. The Alaknanda-Ganges river stretch considered for richness studies extended within the mountain zone from 1000 m asl (Chamoli) to 280 m asl (Ajeetpur near Haridwar) described in Nautiyal and Nautiyal (1999 a); Nautiyal et al. (2004a).

The Nagni Gad towards the foothills was examined for a locality of a springfed stream and for the total stream as well by sampling at four stations along its course of ca. 150 km (N1, 2200 m asl; N2 1400 m asl; N3 1200 m asl; N4 375 m asl). The Mandakini basin of the Alaknanda river system was considered for the richness at basin scale (Nautiyal et al., 2004 b).

The Doon Valley that contains two basins, the Asan joining the Yamuna and Song joining the Ganges was considered for the valley scale (for details see Nautiyal et al., 2013). The pooled information was used for the eco-region scale.

The CHL rivers investigated for diatoms include the springfed Betwa, Ken, Paisuni, Tons and the Damodar. These rivers were sampled at four-five stations along their course. Paisuni was the smallest ca. 100 kilometres in length. The details of locations are described in Nautiyal and Nautiyal (1999 b) for Damodar, Nautiyal and Verma (2009) for other CHL rivers and Agarwal (2009) for Betwa.

Fish richness studies in the Himalayas and CHL are based on secondary literature from the same rivers in each eco-region, even though it may not be same locality because fish have vast mobility. Additionally, secondary literature on Western Ghats ecoregion has been included to compare richness levels.

MATERIALS AND METHODS

The diatom samples were obtained by scraping surface of solid substrate from an area of 3x3 centimetres with the help of razor and brush and thereafter, preserved in four per cent formaldehyde solution. Permanent mounts were prepared in Naphrax after acid and peroxide treatment of these samples and examined at x1500 by Olympus Trinocular Research Microscope.

Diatoms were identified to species according to standard literature (Krammer 2002, 2003; Krammer and Lange Bertalot 1986-1991, 1999, 2004; Hustedt and Jensen 1985; Sims 1984, Lange-Bertalot 1999, 2001, 2002, 2005, Gandhi 1998; and Sarode and Kamat 1984). Total number of species was recorded for each sample at locality, river or basin scale.

The information on species richness of fish has been derived from secondary sources; Jammu and Kashmir (Nath 1986), Himachal Pradesh (Johal et al. 2002), Uttarakhand (Singh et al. 1987; Hussain and Tilak 1995), Nepal (Shrestha 1995, 1999), Central India (Malviya 1961; Grover and Gupta 1977; Kulshrestha 2005) and Western Ghats (Easa and Shaji 1997; Dahanukar et al. 2004). Other lists of fish fauna from these regions are described in Nautiyal and Singh (2009).

RESULTS

Richness at Locality, River, Basin and Eco-region Scales in the Indian Subcontinent

Diatoms: The locality of the glacier fed Alaknanda yielded 193 taxa; the locality of a springfed stream yielded 100-112 taxa across its course. However, the richness increased relatively from origin to mouth. The river Alaknanda-Ganges yielded 251 taxa while the Nagni Gad 130 taxa. The Mandakini basin yielded 200 taxa (18 locations sampled seasonally) while the Doon valley consisting two small basins yielded 354 taxa (30 stations sampled monthly for two years except monsoon months of July and August).

This difference may be attributable to the sampling protocol, but it is to be noted that the number of sampling stations increased only because they were available compared with Mandakini basins where habitats were repeated with higher frequency. Monthly sampling in the Mandakini basin may have yielded few more taxa but certainly not 100 more species. The Gangetic drainage (in West Himalaya ecoregion) that includes all above thus, harbours 634 taxa compared with 457 taxa recorded earlier (Nautiyal et al. 2004 b). Kant and Vohra (1999) recorded 266 taxa from Jammu and Kashmir. Gosh and Gaur (1991) reported 134 taxa from the Northeast.

Among the rivers of the central highlands, the richness declined from origin to mouth in the Ken (K1 182, K2 178, K3 159 and K4 151), River Paisuni (P1 171, P2 183 and P3 170), Tons (T1 177, T2 186, T3 157 and T4 156) and the Betwa (B1 122, B2 122, B3 115, B4 115, B5 110). However, total flora amounted to 202-211 taxa in each river, while 429 taxa in the ecoregion. Recently Karthick et al. (2013) listed 205 common taxa from the Western Ghats.

Fish: In case of fish, 12 taxa occurred at locality scale in mid stretches while 20 in the lower stretch close to the foothills, 42 taxa in the Alaknanda, 56 taxa in the Ganges, 138 taxa in the Uttarakhand, 95 taxa in the Himachal Pradesh while only 42 taxa in

Kashmir (Nath 1986) out of 107 species recorded from Jammu and Kashmir (Nautiyal and Singh 2009). The fish species richness for Himalayan segments are 174, 180 and 270 in the West Himalayas (Indus to Sutlej 560 kilometres, Sutlej to Kali 320 kilometres), Central-Nepal Himalayas (Kali to Tista 800 kilometres) and East Himalayas (725 kilometres Tista to Brahmaputra), respectively. The richness of higher taxa (genera, family, order) increases from West (76-24-9) to East Himalayas (109-35-12). Thus, 346 fish species occur in the Himalayas (India+Nepal), 174 in the CHL and 270 species in the Western Ghats.

DISCUSSION

The loss of biodiversity in ecosystems has important implications, diminished resistance and resilience to disturbance, system simplification and loss of ecological integrity. Critical to preventing losses biodiversity is an understanding of patterns in biodiversity at a variety of spatial scales.

The fascination for numbers is justified, as species-rich locations can be valuable laboratories for investigating processes that control speciation or shape the evolution of fishes. Therefore, great emphasis and interest has been placed on localities with, say, 200+ species in a given lake. 100 species in a single stream reach or 50-60 species associated in a patch of underwater structure, such as a boulder in the African rift lakes (Matthews 1998).

The magnitude of richness varied with scale. The richness of diatoms in the Himalayas and CHL increased from locality to river scale. The locality accounted for 77 per cent of the river scale in the Himalayas and 88 per cent in the CHL. Further, the locality amounted to only 30 per cent of the eco-region scale while the river accounted for 40 per cent of the eco-region. Notably, the Doon Valley harbours slightly over half the share (56 per cent) of the eco-region.

Similar pattern can be expected from the hotspot Western Ghats ecoregion also which too is a

montane region. This indicates presence of more diverse habitats within an eco-region and the need to examine diatom richness from all possible habitats.

In case of fish, the species richness is low for a lesser Himalayas location, as locality formed 29 per cent of river scale. This appears to be low, because the locality lies in the upper middle stretch. In the foothills where more species occur (56 taxa) in a locality the share increases to 88 per cent of basin fauna (64 taxa) and river Ganges (Devprayag to Haridwar) accounts for 41 per cent fauna of the ecoregion. A small Doon Valley river (Asan <50 km length) harbours 30 per cent of the Gangetic drainage (West Himalayan eco-region) scale.

Compared to the Himalayas, richness is higher at locality scale in the central highlands as well as Western Ghats (WG). Johal et al. (2002) reported three to 14 species from nine locations spread across Himachal Pradesh (each habitat was repeatedly sampled over two kilometers stretch). Khanna et al. (1998) reported 28 species from the river Ganges at Rishikesh.

Khanna and Badola (1990) had earlier recorded 44 species from the Ganges and its two tributaries between Lakshman Jhula (upstream Rishikesh town) and Kangri village (across the river Ganges at Hardwar town).

At river scale, the fish fauna is richer in the Western Ghats (River Chalakudy 71 species from 50 genera 27 families) than the central highlands (River Betwa 63 species from 45 genera 20 families) and the Himalayas (Alaknanda 64 species, 23 genera 10 families) (Raghavan et al. 2008; Lakra et al. 2010; Singh et al. 1987).

The richness of WG is evident from the following comparisons; 59 and 50 species in the Kabani and Chaliyar river systems of the Nilgiri Biosphere (Easa and Shaji 1997), 33 fish species in the River Kosi in eastern part of Nepal 35 species in the River Kali Gandaki draining the central part of Nepal and 22

species for the River Bagmati (Shrestha 1999). This was evident at other scales also; 92 species of 24 families from the five rivers in the Kerala part (1455 km²) of the Nilgiri Biosphere Reserve (Easa and Shaji 1997) compared with 49 species in the Rajaji National Park - 831.5 square kilometres (Hussain and Tilak 1995).

Examination of richness data shows that the estimate of taxonomic richness from locality scale in certain parts of the Himalayas has not exceeded 200 taxa. However, even larger areas have not yielded more taxa such as the Mandakini basin in the present study, the adjoining Kumaun (Jüttner and Cox 2001), Nepal (Ormerod et al. 1994; Jüttner et al. 1996; Rothfritz et al. 1997), Eastern Himalayas (Rout and Gaur 1994) and even the Alps (Cantonati et al. 2001). This was observed in the CHL rivers too.

The estimate for a river, however, exceeded 200 in the Alaknanda but not for the Nagni Gad. It just exceeded 200 taxa in each Vindhya river (202 to 211 taxa). However, if the river lengths are examined, 251 taxa have been reported from 216.4 km long Alaknanda-Ganges (Nautiyal et al. 2004 b) compared to 202 to 211 taxa only from ca. 300 km long Ken or Tons. The estimates from not only one station but also one river were high in the Himalayas, than in the Vindhya. It is notable that Paisuni with much shorter length (sampled length ca. 42 Km) was quite rich by that measure (Paisuni three stations within ca. 40 kilometres, 202 taxa compared with Nagni four stations ca. 150 kilometres., 130 taxa). This would happen as any one locality contains very high share of the river or basin flora.

Species-Area Relationship

Apparently, it appears from the above account that richness increases with increasing area of study, familiarly known as species richness-area relationship (Begon 1990). Recently, Bhatt et al. (2012) propounded a species-discharge model to explain elevational gradients in fish diversity in the Himalayas. They stated that higher water discharge could also be considered a surrogate measure of

higher area resulting in greater habitat diversity in the rivers. In that sense, species area theory could accordingly be modified in the case of aquatic ecosystems as species water discharge theory.

Although the information for diatom flora at species level is inadequate across the highlands of the subcontinent, an increase in the richness of diatom from locality to river/ basin scale and from a stream (130 taxa) to a river (251 taxa) and the eco-region (634 taxa) scale can be explained by area-richness model only in general sense as there appears to be an increase.

However, in true sense this is happening only at spatial scale and not at longitudinal scale, as a locality contains around 80 per cent of the flora and very few species are being added. Hence, the increase is not in simple linear fashion because it is increasing with the increase in the basin area as more and more aquatic habitats are added in the basin and hence, the eco-region. This is true for the mountain terrain in Himalayas but fails to explain the high richness levels in the Doon valley with far-less area implying that the increase is un-proportionate.

The great variety of aquatic habitats accounts for high richness in the valley, a different terrain from regular undulating mountain terrain. This suggests that if some other variables, that can increase diatom richness, also occur in the area/basin, and then increase in area is not the only factor.

In CHL, the area-richness model also explains slight increase in richness from a locality to a river and moderate increase at basin and reasonable increase at eco-region scale. However, it fails to explain the longitudinal patterns of richness increase from one locality to other because the richness declined from headwater to mouth zone locality. Lack of substrate heterogeneity in the mouth zone is an important factor that causes decline in richness from headwater to mouth in all CHL rivers. This again demonstrates that a factor other than area is important for the richness levels of diatoms.

Though the richness of diatoms and fish increase with number of samples, locations and rivers and hence, the area, their richness in the Himalayas is not proportionate to its area, because the Himalayas (531,250 square kilometres) is over four times of the area of Western Ghats (160,000 square kilometres) and six times the area of Central Highlands (103,600 square kilometres).

As per the species richness-area relationship (Begon 1990), more area of Himalayas should mean more species. Thus, CHL with least area had least numbers of species and the Indian Himalayas Region (IHR) and WG with more area had more species. However, the richness in H, or IHR and WG was not proportionate to their area (Nautiyal and Singh 2009).

Within the Himalayas, West Himalayas was the largest segment (>331,000 square kilometres) but Central (Nepal) Himalayas (147,181 square kilometres) were richer followed by East Himalayas (180,000 square kilometres). Thus, the area-richness model is unable to explain why the Himalayan eco-regions do not contain richness proportionate to their area.

An array of factors is known to influence biodiversity (Botkin and Keller 2000). The cause of low proportion of richness can be attributed to harsh environment in the Himalayas, especially the large area under perennial snow. The locations closer to snow line comprise harsh habitat due to steepness and extremely cold waters. The locations sampled in the headwaters may hence, be low in taxonomic richness and taxa diversity.

Richness increases with reduction in harshness. Further, the Himalayan streams/ rivers have poor electrolyte content and nutrients occur in traces (Badoni et al. 1997; Cantonati et al. 2001), especially the headwaters. Nutrients leach out from the rocks and agriculture fields in the basin in the middle and lower sections and substrate becomes heterogeneous creating more habitats

and microhabitats than the headwaters resulting in increased richness as observed in the Alaknanda. The CHL and WG region have moderate climate and gentle slope and hence, are not harsh.

Nautiyal et al. (2004 b) have compared diatom taxa richness with respect to the number of sampled sites in the Himalayas and other European mountains such as Tatra and Alps, and found the Gangetic drainage in the West Himalayas was richer than central (Nepal) Himalayas and the mountains in the northern hemisphere. There is greater richness especially at the generic level in the northern hemisphere towards the poles.

Area-richness also fails to explain low richness in the large Himalayas (346) compared with the Western Ghats (270 taxa) and why the Central Highlands despite similar dimensions of WG has much lower richness. Lack of proportionate richness can be attributed to the view that the recently deglaciated high altitude locations in the Alps or in the Himalayas have not been geologically stable in contrast to the mountain chains in Central and South India.

In the Himalayas, the orogeny continues in addition to the climatic extremes due to cooling (Pant et al. 2006). Disproportionate richness may be secondary and not be primary for historical reasons discussed by Mani (1974).

Historical Factors and the Present State of Richness in the Himalayas

The development of freshwater biodiversity and the present state of its richness in the Himalayas cannot be seen in isolation because past ice-ages and resulting oscillations in the climate must have caused extinctions and exchanges among the drainages of the peninsula and Himalayas.

The presence of common elements among the major constituents of freshwater biodiversity (the algae, and fish) despite differences in the antiquity of peninsula and extra-peninsula supports the above opinion. The endemics in the peninsula are attributed to speciation

during Pleistocene (Silas 1952). Similarly, the Snow Trout (sub-family Schizothoracinae, *Schizothorax* spp.) present in the Himalayas and sub-Himalayan regions of Indian sub-continent, Afghanistan, Kazakhstan, China and Myanmar got isolated in the Kashmir region by land upheavals and evolved into a large number of indigenous species many of which are now regarded as endemic in the Kashmir valley (Das and Subla 1970). This provides sufficient evidence for the role of isolation in speciation.

Mani (1974) comments: "Compared to peninsula, the Himalayas is extremely rich in relatively very young and phylogenetically highly plastic forms of more recent and more highly evolved Asiatic groups, with a corresponding poverty of the ancient Gondwana elements". The mountain building process in the tertiaries and their proximity to the Assam gateway opened up opportunities for the colonisation by Chinese and Malayan teleostean elements of the Oriental region.

The geo-chronology since Palaeozoic is important for fish while that during Mesozoic and Cenozoic is important for the diatoms, as the first physical remains of diatoms are from the Jurassic, and well-preserved, diverse floras are available from the Lower Cretaceous, which diversified in Cenozoic till Eocene (Sims et al. 2006). The major historical events were: a) **Separation of Indian subcontinent from Gondwanaland** in early Cretaceous b) **Lava flows in peninsular India from Cretaceous to Eocene**, one in Rajmahal area during Cretaceous period covering an area of 3,97,000 square kilometres and second in Maharashtra area (from Kathiawar to Nagpur and from Malawi to Dharma) during Eocene period covering an area of 5,18,000 square kilometres buried the earlier landforms and topography.

The prolonged denudation of basaltic surface by fluvial process resulted into the development of hills, ridges, valleys and plains c) **The Himalayan orogeny**: The folding and uplift of the Himalayas started during the mid-Miocene period (16 m. yr.

to 11.6 m. yr.) and continued in phases up to the Pleistocene period (<http://www.britannica.com/EBchecked/topic/38479/Asia/48118/Paleozoic-events-in-the-continental-nuclei>). (i) Himadri or Greater Himalayas during Oligocene (25-40 million years ago), (ii) Himanchal or Lesser Himalayas during mid-Miocene (14 million years ago), and (iii) Siwalik or Outer Himalayas during post-Pliocene (750,000 years ago) periods-by the folding of the Tethys sediments

There were substantial climate changes in this duration that possibly affected the richness levels. At the Cretaceous-Tertiary (K-T) boundary (c. 65 Ma), a drop in global temperature by as much as 5°C (Frakes 1986) was associated with a sudden drop in eustatic sea levels and the loss of many epicontinental seas (Sims et al. 2006).

Throughout the Cenozoic, changes in temperature have caused major flooding events and recessions (Pickering 2003). Commencing at 37 Ma (late Eocene), there was a transition from generally warm climate warm of Mesozoic and early Cenozoic to an Oligocene climate with continental ice-sheets and/ or glaciers reaching sea level (Miller et al. 1991). By the late Miocene to Pliocene (c. 23-5 Ma), permanent Antarctic ice-sheets had been established, accompanied by strong cooling (Barron and Baldauf 1995). During max glacial advance, the ice-sheet covered entire Peninsular India north of the Krishna valley (latitude 15°N) and extended into sea beyond the Vindhyan and Aravalli ranges that at the time were forming the northern coastline of Peninsular India (Hambrey and Harland 2011).

Peninsular Drainages

Three axes of the Archaean drainage are known from the Peninsula. The uplift of the Vindhyan ranges led to the origin of various consequent streams and readjustment was noticed in the existing drainage systems (<http://www.preservearticles.com/2012013022220/short-essay-on-the-peninsular-block.html>).

Today, along the northern border of the Peninsula, the Chambal and Betwa flow into the Jumna (Yamuna); the Son rises from the Amarkantak plateau and flows south of the Kaimur range and joins the Ganges near Patna. This northerly drainage from the Peninsula was, during the Mesozoic and the early Tertiary period, very prominent and contributed much sediment to the northerly sea (Krishnan, 1949). The Cratonic Rivers are believed to have provided the basin's axial drainage for prolonged periods. The cratonic rivers may have contributed more sediment to the River Ganges and the Bay of Bengal than has generally been supposed (Sinha et al. 2009; <http://home.iitk.ac.in/~rsinha/PDF's/2009cratonGSA.pdf>). Thus, the Vindhyan rivers existed much before the Himalayan uplift.

Colonisation of Himalayan Rivers by Peninsular Elements of Diatom Flora and Fish Fauna

Generally, the warm climate of the Cretaceous, Palaeocene and early Eocene suggests that the elements similar to those in the rivers of peninsular India colonised the paleo-Ganges river system. The formation of permanent Antarctic ice-sheets and subsequent cooling possibly led to the spread of some elements that can colonise ice-cold waters into the uplifted Himalayas where glaciers were formed.

During maximum glacial advance the ice-sheet covered entire peninsular India north of the Krishna valley (latitude 15°N) and extended into sea beyond the Vindhyan and Aravalli ranges that at the time were forming the northern coastline of Peninsular India [Earth's Pre-Pleistocene Glacial Record Hambrey and Harland 2011], allowing the cold-loving forms to extend their range well into the Indian peninsula.

The global changes in climate are correlated with a decline in many old genera and families of diatoms and the appearance of many new ones, adapting to the new environments, both on land and in the seas. After the end of glaciations, genera and species adapted to warm climate, in the peninsula, spread into the Himalayan foreland and probably invaded further up which accounts for the share of similarity among these eco-regions.

Unlike diatoms that have various modes of dispersal, the freshwater fishes are inescapably confined to their own particular drainage systems and can migrate from one isolated stream basin to the next only through the slow physiographical change of the land itself (stream capture, etc.). Throughout the world the migrations of fresh-water fishes over extensive continental areas have generally been excessively slower than those of almost any creature that can creep, crawl, walk, or fly, however closely that creature may have been bound by its ecological tolerances. This is exceptionally well illustrated by Central America, where the interpenetration of North and South American faunas has proceeded in many groups practically to the limit of climatic tolerance, but where no truly neotropical (South American) freshwater fish has gotten farther north than Texas or New Mexico, and none truly nearctic (North American) farther south than Nicaragua (Myers 1938).

The bio-geography of fish fauna in the now Indian subcontinent¹ can be traced back to *200 million years before present (the Triassic period)* when a mixture of chondrosteian fishes (now represented by paddlefish, sturgeon), early neopterygian fishes (represented by *Amia* and gars), lungfishes and crossopterygians prevailed in the *Pangea* and were dominant even after the *Pangea* split, until the Cretaceous period. There are big gaps in knowledge. Did the ancient non-ostariophysian fish stock of *Pangea* exist in Peninsular India after the separation of India from Gondwanaland 105 million years

¹On the separation of India from Gondwanaland 105 million years before present (during Early to Mid-Cretaceous period) the modern groups of fish Ostariophysi (minnows, catfishes etc.) began to develop; 75-60 million years before present (Late-Cretaceous period) following Africa, Eurasian contact - ostariophysian fishes enter Laurasia and swamp the earlier non-ostariophysian stock. In *Paleocene* the Cyprinids evolved in North Africa or Europe. These and catfishes radiated through Laurasia and most of Africa. Cyprinidae, Catostomidae, and Percidae evolved and radiated. 50-45 million years before present (Eocene) Oriental region becomes separated from rest of Asia as Himalayas rise. In late Eocene subfamilies of Cyprinidae develop, and Cobitidae (loaches), and Siluridae, and many ostariophysian families with limited modern distributions. Large radiation of freshwater dispersants in Oriental region, which subsequently entered India. 2.5 million to 10,000 years B.P.-Pleistocene Glaciation freshwater dispersant fish in Indonesia - islands were once the uplands of a large river system during a glaciation period. Lack of western US fauna and Europe is partly due to lack of refuges for fish to escape glaciation (<http://www-personal.umich.edu/~pwebb/NRE422-BIO440/lec08.html>).

before present (early to mid-Cretaceous) and until Cretaceous and possibly till the Himalayan orogeny; did the modern groups of fish Ostariophysi develop before separation, if not, what happened during the period India was adrift; did it develop during or after Himalayas were uplifted?

Amidst all this, the periods of high richness of fish fauna in the peninsula must have been before the Cretaceous-Eocene lava flows compared to the glaciations that well extended to north of the River Krishna in the subcontinent.

The present levels of richness discussed above, have developed only after the end of the glaciations. Endemism in the WG and East Himalayas suggests that there has been sufficient time for fish speciation. Moser et al. (1998) stressed that speciation requires long period of stable conditions. In case of the diatoms, Strel'nikova (1990) estimated that in every million years, 1.6 diatom genera were created in the period from the Upper Cretaceous to the end of the Oligocene.

Theriot (1992) showed that new diatom species can evolve in as little as 4000 years and so it is reasonable to assume that there would be plenty of time for adaptation and speciation during flooding episodes, when presumably salinity levels varied from marine to brackish to freshwater, with creation also of hypersaline environments in arid zones.

Threats to Species Richness

The Government of India (GOI) aims to construct 292 dams throughout the Indian Himalayas in 28 of 32 major river valleys (90 per cent run-of-the-river dams), leading to one dam for every 32 kilometres of river channel. Proposed locations of dams correlate with zones of species richness for angiosperms, birds, fishes, and butterflies. In the Indian Himalayas, subtropical and temperate forests are most vulnerable to species losses driven by land-use changes, yet 88 per cent of proposed dams are located in these ecosystems (Grumbine and Pandit 2013).

This is perceived as a threat to habitats of all dimensions, and hence, to all trophic levels that are a part of food-webs in the river ecosystems of the subcontinent. The subcontinent is witnessing degradation of native fish stocks because of water pollution, flow modification, destruction of habitats, proposed river links and exotics (Atkore and Sivakumar 2011; Jena and Gopalakrishnan 2012; Nautiyal 2013; Nautiyal et al. 2013; Pinder and Raghavan 2013).

CONCLUSIONS

1. In Himalayas and CHL, the richness of diatoms at local scale is very high (77 per cent) and there is a gradual increase as the area of investigation grows larger. Total richness at eco-region scale was 634 taxa in the Gangetic drainage.
2. In CHL, the richness of diatoms declines from source to mouth at locality scale. Total richness amounted to 429 taxa in CHL. As investigation area increases the richness is expected increase. The rate of species accumulation in CHL needs to be compared with Himalayas. The species discharge model cannot be applied to diatoms.
3. In respect of river or the eco region scale the fish species richness is low at locality scale (ca. 30 per cent), increases modestly at river scale. Localities in upper and middle sections of mountain rivers have low richness (42 taxa) than in the foothill sections. Further, the increase from basin (138 taxa) to ecoregion scale (174) is not high as much of the ecoregion (HP, J & K) remains unaccounted in this study.
4. Among regions of the Himalayas, the fish richness was 270 taxa in East Himalayas, 180 taxa in Central Himalayas and 174 taxa in West Himalayas. This difference in the richness despite similar lengths and least area of the East Himalayas does not find much support from the area-richness model.
5. The species discharge model explains longitudinal increase in fish richness, but fails

to explain richness increase as more and more rivers of a basin and as basins of ecoregion are added.

6. The area richness model is not able to explain the current fish richness levels; low in many times larger Himalayas (346 taxa) in contrast to the Central Highlands (174 taxa) and the Western Ghats (270 taxa) that are much smaller in dimension.
7. It augurs that the parts of the Himalayas with harsh climate and terrain support low richness. The EH has high richness as terrain becomes milder and rainfall becomes very high. This also explains why WG also has high richness and CHL has least richness due to prevailing semi-arid climate despite mild terrain and extensive plateau topography.
8. The present levels of richness are attributable to the historical factors, especially geochronology; lava flows in the peninsular India, the Himalayan orogeny, glaciations. The fish fauna has been more affected as they have been around since Cambrian while diatoms are said to have originated in Mesozoic. Since the rates of evolution will vary for diatoms and fish, faster in former and slower in latter, the present richness levels appear to be secondary influenced by both lava flows and ice-ages.

ACKNOWLEDGEMENTS

I thank Prof. R. K. Sinha for extending the invitation for the International Symposium. I also thank the anonymous reviewers for valuable suggestions to improve this manuscript.

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Diatom Communities in Freshwater Ecosystems of the Doon Valley

Rachna Nautiyal

Zoology Department, Government P.G. College,
Dakpathar, Vikasnagar - 248125, Dehradun, Uttarakhand, India
E-mail: rachnanauiyal@ymail.com

ABSTRACT

Doon valley is surrounded by the lesser Himalaya and Siwalik mountain ranges in Uttarakhand where the Song and Asan river systems drain each half of this valley into the Ganges and Yamuna, respectively and henceforth, treated as the Ganges drainage (GD) and Yamuna drainage (YD). Epilithic and epiphytic diatom communities were examined from a variety of ecosystems at 30 stations.

Diatom flora consisted of 358 taxa, 291 from YD and 256 taxa from GD ecosystems. YD was species rich owing to more site-specific taxa at greater number of locations than in GD. In YD *Achnanthes linearis* occurred as the dominant/ sub-dominant taxa along with *Synedra ulna*, *Cocconeis placentula*, *Achnanthes minutissima*, *Nitzschia palea*, *Cymbella sinuata*, *Gomphonema parvulum* and *Achnanthes orientalis*.

The dominants also prevail in some GD localities. Along with *Achnanthes linearis* as dominant taxa, *Achnanthes catenatum*, *Encyonema leei*, *Achnanthes gondwana* and *Achnanthes conspicua* were observed as co-dominant in the GD only. Variety of dominants in GD compared to YD shows more diverse communities in the former.

Diatoms exhibited four categories of associations. Shannon diversity patterns differed in YD and GD. Principal Component Analysis shows that some sites of Yamuna river basin were similar to the Ganges river basin. Further, Canonical Correspondence Analysis explained that pH, DO, total alkalinity and hardness accounted for variations in community structure in YD and GD.

Keywords: Positive and negative diatom associations, twinspan, indicator species

INTRODUCTION

Diatom communities are excellent indicators of modified environment (Lobo et al. 1985; Ghosh and Gaur 1991; Whitton and Rott 1996; Nautiyal et al. 1996; Finney et al. 2000). Studies around the world stress the importance of investigating the relationship between environmental conditions and diatom species in different geographical regions in order to enhance the use of diatoms in regional monitoring programs (Van de Vijver and Beyens 1999), especially in temperate regions (Potapova

and Charles 2003; Bennion et al. 2004; Soininen et al. 2004).

The environmental forces shape community structure and determine which and how many species occur together, which species are common and which are rare and the interactions among them. A considerable number of studies using diatoms have been conducted in aquatic systems. The community structure at smaller and larger spatial scale can also be used to assess the influence of

human interference and land use (Vaultonburg and Pederson 1994).

In the light of these facts, the study has been aimed to record communities in the Doon Valley that contains diverse habitats much different from the regular mountain terrain in the adjoining lesser Himalaya.

STUDY AREA

The Doon Valley lies between the foothill tracts of the River Ganges (30°7'0"N, 78°19'E) and River Yamuna (30°19'N, 77°7'E) and is bound by the high mountains of the lesser Himalaya and Sivalik. Thus, the tributaries of the Ganges drain (GD) northeastern half of the valley and the tributaries of the Yamuna drain (YD) the northwestern half of the valley.

The area of the valley is 1800 square kilometres. In order to comprehend sampling one to six stations were selected in each grids of 15 x 15 kilometres. (District Planning Map Series, DEHRADUN, 1996, Survey of India, Government of India). Thirty sampling stations in the Yamuna and Ganges drainages were selected, based on the accessibility and maximum representation of the different habitats in Doon valley. These stations lie in the grids 6B, 6C, 7C, 7D, 8D, 8E, 9E (Figure 1).

Fourteen sampling stations were seasonal and 16 sites were perennial. Seasonal sites were sampled

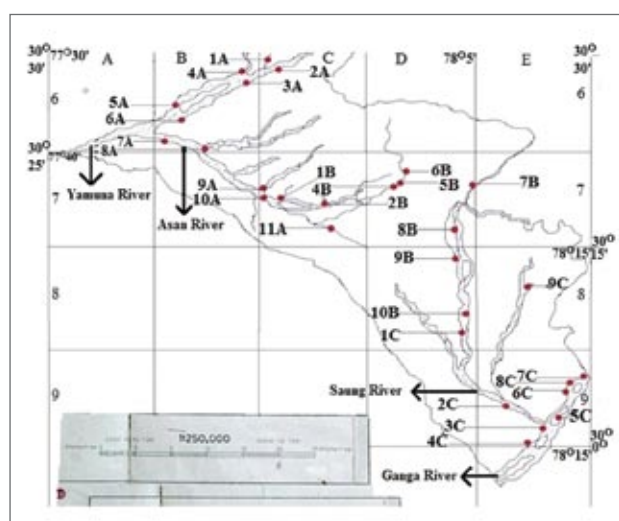


Figure 1: Sampling locations of various ecosystems of Yamuna and Ganga drainages in Doon Valley

after every two to three months and perennial sites were sampled at regular monthly intervals. All sampling sites are categorised into 1st, 2nd and 3rd order streams (Table 1).

Abbreviations Used in Text

S. N.	Parameter	Abbreviation
1.	Current Velocity	CV
2.	Dissolved Oxygen	DO
3.	Hydrogen Ion Concentration	pH
4.	Phosphate	PO ₄
5.	Silicate	Si
6.	Water Temperature	WT
7.	Total Alkalinity	TA
8.	Total Hardness	TH
Diatom Taxa		
1.	Achnanthes	Ac.
2.	Achnanthes lanceolata	Ac. l.
3.	Achnanthes exigua	Ac. e.
4.	Achnanthes exigua var. heterovalvata	Ac. e. var. h.
5.	Amphipleura	Ap.
6.	Amphora	Am.
7.	Anomoeoneis	An.
8.	Caloneis	Ca.
9.	Cocconeis	Co.
10.	Cocconeis placentula	Co. pl.
11.	Cocconeis placentula var. euglypta	Co. pl. var. eu.
12.	Cyclotella	Cy.
13.	Cymatopleura	Cm.
14.	Cymbella	C.
15.	Cymbella excisa	C. e.
16.	Diatoma	D.
17.	Diatoma vulgaris	D. v.
18.	Diploneis	Di.
19.	Encynema	En.
20.	Encynopsis	Ec.
21.	Epithemia	Ep.
22.	Eunotia	E.
23.	Fragilaria	F.
24.	Frustulia	Fr.
25.	Gomphonema	G.
26.	Hantzschia	H.
27.	Hantzschia amphioxys	H. a.
28.	Navicula	N.
29.	Navicula constans var. symmetrica	N. c. var. sy

S. N.	Parameter	Abbreviation
30.	Navicula geoppertiana	N. ge.
31.	Navicula minuscula	N. m.
32.	Navicula viridula	N. v.
33.	Navicula viridula var. rostellata	N. v. var. r.
34.	Neidium	Ne.
35.	Nitzschia	Nt.
36.	Pinnularia	P.
37.	Rhopalodia	R.
38.	Sellaphora	Se.
39.	Stauroneis	St.
40.	Synedra	S.
41.	Synedra inaequalis	S. in.

In the Doon valley, the major wet period (monsoon 80 per cent rainfall) extends from June to September followed by a dry period till December. Winter rainfall during December to February constituted the second wet period. The summer constituted this dry period (October – December) with occasional showers of local rain.

The main vegetation in the Doon valley comprised of the broad-leaved trees in the foothills eg. *Shorea robusta*, *Toona hexandra*, *Ficus racemosa*, *Terminalia alata* etc. (Rawat et al. 2001). The substratum consists of boulders, stones, cobbles and pebbles in different combinations all along the valley. Silt occurs in patches only.

MATERIALS AND METHODS

Small-sized boulders (usually four-five in numbers), slightly larger than the hand were picked from the riffles zone of the channel, in apparently different flows such as stones above and below gushing waters, swift flow and slow flow conditions. Sampling was performed across the width of the stream at the depth of 15-50 centimetres.

The sample was replicated within five metres. An area of 3 x 3 square centimetres was marked using a sharp-edged razor. The area was scratched with a brush of fine metallic bristles in order to dislodge diatoms from crevices and minute cavities on the boulder surface. The razor was then used to scrap

the periphyton from the marked area. Samples were preserved in four per cent formaldehyde solution. Reimer (1962) method adopted earlier (Nautiyal and Nautiyal 1999, 2002) was followed to process the samples for light microscopy.

Cleaning was accomplished with the help of H₂O₂. The treated samples were washed repeatedly to remove traces of acid. The permanent mounts were prepared in Naphrax and examined using a Trinocular NIKON microscope (x10 with PLANAPO x100 oil immersion objective to identify under bright field microscope using appropriate filters and phase-contrast condenser.

Since, temperate like conditions prevail in the Himalayan region, there is a striking resemblance to the European flora. Identifications were made according to Hustedt and Jensen (1985) and Krammer and Bertalot (1986). The nomenclature adopted by Sims (1996) has been followed. Sarode and Kamat (1984) was used to identify the Oriental species, if any. The permanent mounts have been adequately stored at Department of Zoology, Government Post Graduate College, Dakpathar, Dehradun where the work was undertaken.

The physical and chemical analysis of water sample was performed at the sampling sites using standard methods and techniques (APHA 2005). Two replicates were obtained for each parameter, the result was integrated and the minimum-maximum values and mean $\pm$ SE was recorded. The physical and chemical parameters were water temperature, current velocity, pH, dissolved Oxygen, total hardness, total alkalinity, silicate and phosphate.

Community structure was determined on the basis of counts (250-400 valves) from each of the better three slides prepared from the samples of each zone across the width of the channel and the replication thereafter. Species with >10 per cent abundance were categorised as dominants, co- and sub-dominants.

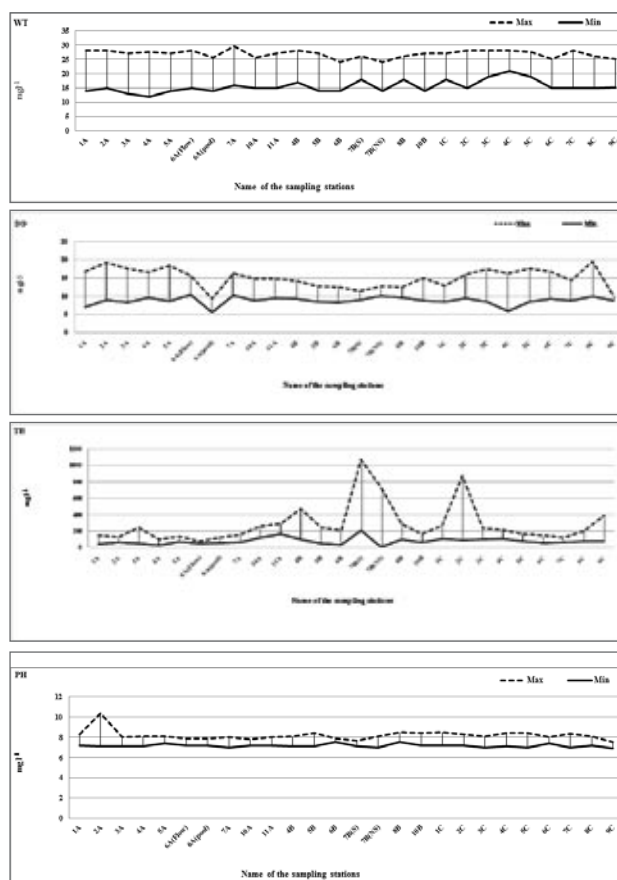
RESULTS

Physico-chemical Characteristics

In Doon Valley, water temperature varied from 12.0-29.5 in the stream/ rivers of YD compared to 14-28 in GD. The current velocity (CV) was high (1.9 msec⁻¹ during September) in the Yamuna (2A) and was lower than 1 m sec⁻¹ at all the other stations of Doon Valley.

High pH (10.4 during November) occurred at 2A in the YD compared with other stations of YD where the variations were low at all the stations of GD. However, 6.9-8.5 occurred throughout the year, respectively (Figure 2). There was considerable variation in dissolved Oxygen in both eastern and western part of Yamuna drainage (5.5-19.4) and Ganges drainage (8.4-19.6), respectively.

Variations in dissolved Oxygen were low in central part of Doon in Ganges drainage locations, total hardness and hence total alkalinity was much low



a few more than 10 taxa occurred at four sites in YD while it occurred at only two locations in GD (Figure 3).

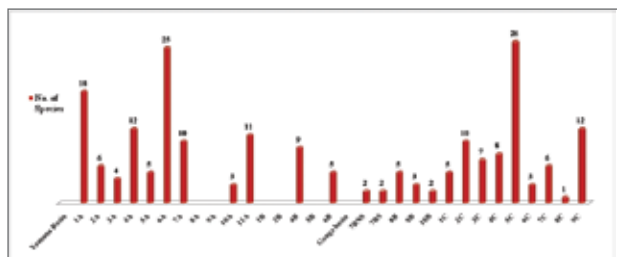


Figure 3: Site specific taxa of drainages in Doon Valley

COMMUNITIES: DOMINANCE PATTERN

Yamuna Drainage

In the YD (western Doons) *Ac. linearis* was consistently dominant especially during winters and occasionally during summer in some ecosystems (Table 2); Amlawa stream (1A), Yamuna River (2A), and Tons–Gucchupani (4B), In Burhi Tons (2B) ecosystems this taxa was dominant during post monsoon while during winters only in the ecosystem of Tons-Tapkeshwar (5B). *N. capitatoradiata* was dominant during summer in this ecosystem. The stream is shallow at latter two locations, of which 2B is entirely seasonal.

In certain ecosystems (3A, 10A) *Ac. linearis* also exhibits dominance with *Ac. minutissima* and *Ac.*

microcephala during different winter months. *Ac. minutissima* figured as dominant of the community during winter in the Yamuna (Dakpatthar and Asan barrage 4A, 5A). Some other taxa attain sporadic dominance at 5A such as *Synedra acus* and *Co. placentula* var. *euglypta*, similar sporadic dominance is shown by *C. subleptoceros* and *C. excisa* var. *procera* during summer at 4A.

Except for these locations, the consistent dominant taxa differed in other ecosystems; *C. subleptoceros* and *C. excisa* through winter to summer at 6A, *G. parvulum* and *C. excisa* in the Asan at Dharmawala (7A), *G. parvulum* sporadically during winter in the Asan at Selaqui (10A), *N. viridula* var. *rostellata* with *N. miniscula* var. *muralis* or *G. parvulum* in the Asan at Shimla bypass (11A), while *Co. placentula* var. *euglypta* and *Ni. palea* in the River Nalota near Malsi Deer Park (6B).

Asan Barrage (6A), a famous wetland and Ramsar Site is recorded with different dominance pattern throughout the year. During winters, *A. microcephala* as dominant taxa showed their presence with *N. capitatoradiata* as co dominant and with *A. biosolettiana*, *A. minutissima*, *C. subleptoceros*, *C. perparva* and *C. hustedtii* as sub-dominant taxa while during summer months, *C. excisa*, *C. subleptoceros* and *A. linearis* showed the co-dominance. Monsoon

Table 1: Description of sampling stations in various grids of Doon Valley

Grid No.	Sampling stations (Station code)	Altitude (Range) m asl	Details/Habitat/ stream order
Yamuna Drainage			
Grid 6C	1A, 2A	460	River/forest and less disturbed tributary/ 3rd order
Grid 6B	3A, 4A, 5A, 6A, 7A, 8A	440-460	River, wetland/ disturbed, less disturbed/ 1st-4th order
Grid 7C	9A, 10A, 11A, 1B, 2B	500-640	River/ disturbed/1st-2nd order
Grid 7D	4B, 5B, 6B	660-750	River, Stream, Sulphur Spring/highly disturbed/ 1st-2nd order
Ganga Drainage			
Grid 7D	7BS, 7BNS, 8B	690-710	River, Stream/highly disturbed/ 1st-3rd order
Grid 8D	9B, 10B, 1C	500-600	River/canal, stream/highly disturbed/ 2nd-3rd order
Grid 8E	9C	900	Spring/ undisturbed/ 1st order
Grid 9E	2C,3C,4C,5C,6C,7C,8C	330-353w	River, forest stream/Densely populated river stretch/1st-4th order

months are prevalent with the *A. microcephala* and *C. excisa* var. *angusta*.

At Asan River, Dharmawala (7A), *C. excisa* and *G. parvulum* are observed as the most dominant taxa throughout the winter and summer months and *Achnanthes microcephala*, *Achnanthes minutissima*, *Navicula capitatoradiata* and *Navicula viridula* var. *viridula* as the sub-dominant taxa during summer months. In post-monsoon months such as October, *Cymbella excisa* along with *Gomphonema affine* var. *affine* and *Synedra ulna* were found in dominant forms.

The sampling stations 8A, 9A and 1B are seasonal drains in Doon Valley and are open for sampling only during monsoon. Further, no water is available in summer and winter months. Rarely any diatom is present during monsoon; hence, community structure for diatoms is not recorded in these drains.

At Asan, Selaqui (10A) during winter, *G. parvulum* is observed as dominant taxa with sub-dominant forms such as *Ac. biasolettiana*, *Ac. catenatum*, *Ac. microcephala*, *C. pervarians* & *Ni. frustulum* while summer and monsoon months did not show any dominance. Post monsoon months, September and October are observed as *S. ulna* and *Ac. linearis* as the dominant taxa along with the *Ac. catenatum*, *S. ulna* var. *aequalis* and *Ac. microcephala*, respectively.

Asan at Simla bypass (11A) showed Diatom taxa *G. parvulum* and *N. viridula* var. *rostellata* as the dominant forms at all seasons throughout the year along with the *Ni. palea*, *N. viridula* var. *linearis* during winter, summer and with *N. minuscula* var. *muralis* only during summer, respectively. Post monsoon months such as September and October showed few sub-dominant taxa also e.g. *Ni. palea* and *N. minuscula* var. *muralis* also.

Burhi Tons at Premnagar (2B) showed *Ac. linearis* and *Ac. microcephala* as co-dominant taxa along with the *G. parvulum* and *Co. placentula* as the sub-

dominant taxa during post monsoon months i.e. September and October only.

Guchchupani, Garhi Cant (4B), *Ac. linearis* was found as most dominant taxa throughout the year while *C. excisa*, *D. vulgare* var. *producta*, *D. elongatum* var. *tenuis* and *Ac. microcephala* was found as a sub-dominant taxa during winter only and *Co. pediculus* and *Ac. catenatum* during summer only. River Tons at Tapkeshwar (5B) is recorded with *C. excise* and *Ac. linearis* as the most dominant taxa during winter while *N. capitatoradiata*, followed by *Ac. linearis*, *Co. pediculus* as sub-dominant taxa during summer. For the month of October, *Ac. linearis* with *C. excisa* and *G. parvulum* form the community structure.

At Nalotanadi, Malsi Deer Park (6B), *Co. placentula* var. *euglypta* is found dominant during winter followed by a number of diatoms in sub-dominant form eg. *En. minutum*, *Ac. minutissima* and *Co. pediculus* while *Co. placentula* var. *euglypta* as a most dominant taxa during summer and *Ni. palea* along with *G. parvulum* and *Ac. biosolettiana* is recorded for community structure.

GANGES DRAINAGE

In the Ganges drainage (eastern Doons), many diatoms occurred as dominants in the community throughout the basin. *Ac. minutissima* with *Co. placentula* var. *euglypta*, *Co. pediculus* in Song distributary (4C), *Ac. linearis* in the Ganges at Triveni Ghat (6C), at Laxman Jhoola (7C) and at Ram Jhoola (8C) with different sub-dominants (*Ni. palea* at 6C, *Ac. conspicua* at 7C, *En. leei* at 8C), respectively.

Other dominant forms are *Ac. orientalis* in Non Sulphur part of Baldi stream (Sahastradhara), *Ac. catenatum* in Sulphur stream (7B), combination of *Ac. biasolettiana*, *Ac. linearis*, *Ac. microcephala* in the Baldi stream at Maldevta (8B), *S. ulna* periodically only in Dulhaniya Nadi (9B), *S. palea* in stream Shyampur Khadri before Nepali farm (5C) and with variety of other taxa from the spring

at Bhogpur (9C), *Co. pediculus* in the Song River (10B) and in the midstretch of Song at Doiwala (at 1C), with assortment of taxa (*N. cryptotenella*, *G. parvulum*, *Ac. minutissima*) at former, *Co. placentula*

var. *euglypta*, *St. anceps*, *N. viridula* var. *rostellata* and others in Tawa stream (2C) while *Co. placentula* var. *euglypta*, *C. pediculus* and many others in the lower section of the Song (3C, Table 3).

Table 2: Community structure (percentage-wise) at different stations of the Yamuna drainage in Doon Valley

Sites	Name of the Taxa	Months																	
		S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
1A	<i>Co. pediculus</i>																		22
	<i>Co. pl.</i>														48				
	<i>Co. pl. var. euglypta</i>						12												
	<i>Ac. kryophilla</i>			17															
	<i>Ac. l. var. rostrata</i>														19				
	<i>Ac. linearis</i>		15		43	79	38		87								14		52
	<i>Ac. minutissima</i>	48		11															
	<i>Ac. sp.</i>		28																
	<i>N. capitatoradiata</i>										41						10		
	<i>C. excisa var. procera</i>				11														
	<i>C. sinuata</i>			14															
	<i>En. minutum</i>				14														
	<i>Nt. palea</i>	15			2														
2A	<i>D. vulgare</i>																16		
	<i>S. ulna</i>	45																	
	<i>S. in. var. jumensis</i>								10										
	<i>Co. pediculus</i>								12		12				38				
	<i>Ac. biasoletiana</i>		19																
	<i>Ac. linearis</i>		12	65			61		45		20				20		18		
	<i>Ac. microcephala</i>		21		43														
	<i>Ac. minutissima</i>		14				12												
	<i>N. capitatoradiata</i>														12				
	<i>Am. montana</i>																		23
	<i>C. e.</i>																13		
	<i>C. metzeltinii</i>																19		
	<i>G. parvulum</i>																		14
	<i>Nt. microcephala</i>																		27
3A	<i>Co. pediculus</i>																15		
	<i>Co. pl.</i>														22				
	<i>Ac. catenatum</i>																20		
	<i>Ac. linearis</i>		35														15		24
	<i>Ac. microcephala</i>				15												11		29
	<i>Ac. minutissima</i>		27		52														
	<i>N. capitatoradiata</i>														22				
	<i>C. turgidula</i>		13																
4A	<i>Ac. exigua</i>				11														
	<i>Ac. linearis</i>														13		10		13
	<i>Ac. microcephala</i>					11											16		
	<i>Ac. minutissima</i>			37	37	26													
	<i>N. phyllepta</i>					34													
	<i>C. e.</i>										16								
	<i>C. e. var. angusta</i>																14		
	<i>C. e. var. procera</i>														18				
	<i>C. hustedtii</i>																		13
	<i>C. subleptoceros</i>										19								
	<i>C. tumida</i>	14	25	12	19												14		

Sites	Name of the Taxa	Months																	
	<i>C. turgidula</i>	37	18																
	<i>Nt. palea</i>	17																	
5A	<i>D. v. var. producta</i>							11											
	<i>S. acus</i>																	52	
	<i>S. ulna</i>							13											
	<i>Co. pediculus</i>								11								22		
	<i>Co. pl. var. eu.</i>																55		
	<i>Ac. catenatum</i>			26															
Sites	Name of the Taxa	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
	<i>Ac. linearis</i>																		28
	<i>Ac. microcephala</i>		33		27				10						12				
	<i>Ac. minutissima</i>		40	56	26			36											
	<i>C. e.</i>								15										
	<i>C. e. var. angusta</i>														11				
	<i>C. microcephala</i>				13														
	<i>C. subleptoceros</i>										12								
6A	<i>Co. pediculus</i>																		11
	<i>Ac. biasoletiana</i>			14															
	<i>Ac. catenatum</i>					12													
	<i>Ac. linearis</i>								13									19	
	<i>Ac. microcephala</i>				14										16				
	<i>Ac. minutissima</i>				11	57													
	<i>N. capitatoradiata</i>			43															
	<i>C. e.</i>										18							23	19
	<i>C. e. var. angusta</i>														10				10
	<i>C. hustedtii</i>				11														
	<i>C. perparva</i>				11	10											12		
	<i>C. subleptoceros</i>				12	44			13		12								
	<i>Go. parvulum</i>			43															
7A	<i>S. ulna</i>														18				
	<i>Co. pl.</i>										15								
	<i>Ac. biasoletiana</i>			11															
	<i>Ac. e. var. h.</i>		18																
	<i>Ac. l. var. rostrata</i>		25																
	<i>Ac. microcephala</i>				15														15
	<i>Ac. minutissima</i>				35														
	<i>N. capitatoradiata</i>					13			12										
	<i>N. ge. var. ge.</i>																		18
	<i>N. schroeterii</i>																		20
	<i>N. v. var. viridula</i>					11													
	<i>C. e.</i>					73	35		70						36				
	<i>G. affine var. affine</i>														18				
	<i>G. parvulum</i>			39					12		30						22		
	<i>Nt. palea</i>		13																
10A	<i>S. ulna</i>	36																	
	<i>S. ulna var. aequalis</i>	15																	
	<i>Ac. biasoletiana</i>			18															
	<i>Ac. catenatum</i>		26														22		
	<i>Ac. linearis</i>		26												40		16		
	<i>Ac. microcephala</i>														11		22		13
	<i>Ac. minutissima</i>		22																
	<i>C. pervarians</i>																		20
	<i>C. vulgate var. vulgate</i>	17																	
	<i>En. minutum</i>																		20
	<i>G. parvulum</i>			44															
	<i>Nt. frustulum</i>			10															

Sites	Name of the Taxa	Months															
11A	<i>Nt. palea</i>	11															
	<i>S. ulna</i>					11											
	<i>Co. pl. var. eu.</i>					12		22									
	<i>Ac. minutissima</i>				24												
	<i>N. cryptotenella</i>													10			
	<i>N. m. var. muralis</i>	27					12	39									
	<i>N. veneta</i>									11							
	<i>N. v. var. r.</i>		27			10				21		13		47		46	28
	<i>N. v. var. linearis</i>					36											
	<i>C. hustedtii</i>				12												
	<i>C. subleptoceros</i>				15												
	<i>G. parvulum</i>	17				36	18	29	18			38		20		14	17
	<i>Nt. clausii</i>											20					
	<i>Nt. palea</i>	23	24			10		42		37							
2B	<i>Co. pl.</i>													15			
	<i>Ac. biasoletiana</i>	14															
	<i>Ac. linearis</i>	24												18			
	<i>Ac. microcephala</i>	21															
	<i>C. excisa</i>													10			
	<i>G. parvulum</i>													15			
	<i>Nt. palea</i>	18															
	<i>D. elongatum var. tenuis</i>					11											
	<i>D. v. var. producta</i>					14											
	<i>Co. pediculus</i>									49							
4B	<i>Co. pl.</i>													12			
	<i>Ac. catenatum</i>									17							
	<i>Ac. linearis</i>		35			17	57	57	68					17		22	64
	<i>Ac. microcephala</i>			35		21								18		14	
	<i>Ac. orientalis</i>		40														
	<i>C. e.</i>			12	14				11							10	13
	<i>C. e. var. Angusta</i>			11		35											
	<i>En. minutum</i>															25	
	<i>Nt. fonticola</i>				34												
	<i>Nt. romana</i>				30												
	<i>D. vulgare</i>							12									
	<i>Co. pediculus</i>							12	20								
	<i>Ac. linearis</i>								12					72		46	33
	<i>Ac. microcephala</i>			34													
	<i>N. capitatoradiata</i>					10		52	18								
	<i>C. e.</i>	58		17	14	51											
5B	<i>En. minutum</i>															28	13
	<i>G. parvulum</i>	15															
	<i>Nt. frustulum</i>				48												
	<i>Cy. meneghiniana</i>								15								
	<i>Co. pediculus</i>						12										
	<i>Co. pl. var. euglypta</i>					58		78									34
	<i>Ac. biasoletiana</i>	13															

Sites	Name of the Taxa	Months															
	<i>Ac. linearis</i>							13									
	<i>Ac. minutissima</i>						23										
	<i>Ac. sp.</i>	25		44													
	<i>C. subleptoceros</i>						26										
	<i>En. minutum</i>																53
	<i>G. parvulum</i>													11			
	<i>Nt. palea</i>	28		10										36			

This shows more diverse nature of the ecosystems in the GD compared with the YD. The dominants, the co-dominants and sub-dominants differed in each ecosystem and therefore, the community was entirely different in these ecosystems.

ASSOCIATIONS

Four categories of associations were evident (Table 4); species with no association viz. *Ac. linearis*, *S. ulna*, *C. excise* and *Ni. palea*, as they were present at all the stations throughout; species only with significant +ve associations (*D. vulgare* var *producta*, *Co. placentula* var *euglypta* and *Achnanthes normanii*); species with greater significant +ve associations and few negative associations (*D. elongatum* var. *tenuis* and *Ac. hauckiana*); species with few significant +ve and large –ve associations (*D. anceps*, *Ca. clevei*, *D. hiemale*, *F. intermedia*, *Ac. hungarica*, *S. ulna* var. *mediocontracta* and *E. sudetica*) and species only forming significant -ve associations were *An. vitrea*, *F. pinnata* in the Doon Valley.

The classification of ecosystems based on Shannon diversity reveals 7B (S) as outlier. The other unique

ecosystems that are outlier from 2nd major cluster were 2C (Tawa) and 9C (spring). The Shannon diversity of YD ecosystems 2A, 5A, 6A, 10B is similar to many GD ecosystems. Similarly, GD ecosystems 5C, 7B (NS), 11A ecosystems resemble the other YD ecosystems (Figure 4).

The associations also segregated the YD and GD, fewer associations in YD and large number of associations in the GD, which also points to more diverse communities in GD. Twinspan analysis for all the diatom community structure at all the 30 sampling stations revealed that most sites pertaining to same drainage are clustering together and showed related indicator diatom species for the particular cluster, e.g. clusters for sampling stations 2B, 8B and 10B has *C. orientalis* and 11A, 4C, 9B and 2C has *Achnanthes affinis* and 3A, 5A, 4B & 7C has *Amphora pediculus* as an indicator species, respectively.

Principal Component Analysis shows that most of the YD ecosystems account for the variation caused by first and second axis. The first axis, however, included River Ganges and the Tawa stream ecosystems,

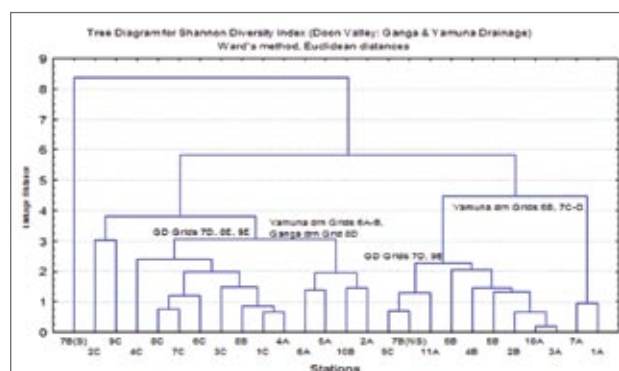


Figure 4: Cluster analysis - classification of sites based on Shannon diversity indices

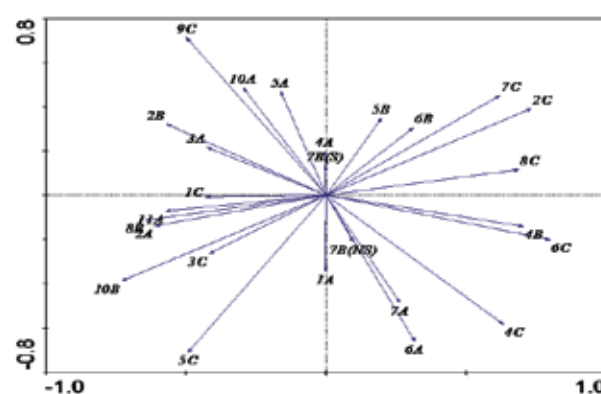


Figure 5: PCA to classify ecosystems of Doon Valley

Table 3: Community structure (percentage-wise) at different stations of the Ganga drainage in Doon Valley

Sites	Name of the Taxa	Months																	
		S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
7B (NS)	<i>S. amphicephala</i>		34																
	<i>Ac. catenatum</i>		13																
	<i>Ac. linearis</i>																16		
	<i>Ac. microcephala</i>																34		
	<i>Ac. minutissima</i>				32														
	<i>Ac. orientalis</i>						48												
	<i>N. cryptotenella</i>												36						
	<i>C. e.</i>		11			17											16		
	<i>C. subleptoceros</i>				11	28							36						
	<i>C. amphicephala</i>				15														
7B (S)	<i>Ac. catenatum</i>					47					94								
	<i>Ac. microcephala</i>					46													
	<i>N. ge. var. ge.</i>																72		
	<i>Co. pl. var. eu.</i>														10				
8B	<i>Ac. biasolettiana</i>	27	16												10				
	<i>Ac. linearis</i>	15					21										24	17	
	<i>Ac. microcephala</i>		18														21		
	<i>Ac. minutissima</i>	15	15																
	<i>N. v. var. r.</i>						14												
	<i>C. e.</i>														12				
	<i>C. microcephala</i>		14																
	<i>En. minutum</i>								20								13		
	<i>Nt. kutzingiana</i>								20										27
	<i>Nt. palea</i>	14	11				18												
9B	<i>S. ulna</i>														14				
	<i>N. confervacea</i>														12				
	<i>N. v. var. r.</i>														14				
	<i>G. parvulum</i>														10				
	<i>Co. pediculus</i>		32			67													
10B	<i>Co. pl. var. eu.</i>		13																
	<i>Ac. biasolettiana</i>								15						19				
	<i>Ac. microcephala</i>								12										
	<i>Ac. minutissima</i>	31																	
	<i>N. cryptotenella</i>														33		13		
	<i>N. schroeterii</i>												10						
	<i>N. subtilissima</i>	24																	
	<i>N. veneta</i>										45								
	<i>C. e. var. angusta</i>						65												
	<i>G. parvulum</i>								19						16		17		
	<i>Nt. hantzschiana</i>												42						
1C	<i>S. ulna</i>														16				
	<i>Co. pediculus</i>								30										10

Sites	Name of the Taxa	Months																	
	<i>Co. pl. var. eu.</i>																		26
	<i>N. capitatoradiata</i>							14											
	<i>Nt. frustulum</i>							12											
2C	<i>Co. pl. var. eu.</i>						97												
	<i>Ac. gondwana</i>			15															
	<i>Ac. inflata</i>			22															
	<i>Ac. l. var. rostrata</i>					10								14					
	<i>N. cincta</i>						11												
	<i>N. cryptotenella</i>					15													
	<i>N. ge. var. ge.</i>													19					
Sites	Name of the Taxa	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
	<i>N. v. var. r.</i>							12							19				
	<i>St. anceps</i>					21													
	<i>G. parvulum</i>																12		
	<i>Nt. palea</i>														16				
3C	<i>S. rumpens</i>										16								
	<i>Co. pediculus</i>							29									22		12
	<i>Co. pl.</i>																		13
	<i>Co. pl. var. eu.</i>										23								56
	<i>Ac. biasoletiana</i>								42										
	<i>Ac. l. var. rostrata</i>										23								
	<i>Ac. linearis</i>					38		14											
	<i>Ac. sp.</i>					37													
	<i>N. capitatoradiata</i>				16		16												
	<i>N. cryptotenella</i>				33														
	<i>N. ge. var. ge.</i>												13						
	<i>Am. montana</i>												37						
	<i>C. e.</i>							18											
	<i>C. tumida</i>		10																
	<i>C. turgidula</i>		20																
	<i>G. parvulum</i>	21							12								11		
	<i>H. a. forma capitata</i>												17						
	<i>Nt. palea</i>	32											21						
4C	<i>S. ulna</i>										19				11				
	<i>Co. pediculus</i>				17														
	<i>Co. pl. var. eu.</i>						17		11		22								
	<i>Ac. minutissima</i>						50												
	<i>N. capitatoradiata</i>				14														
	<i>N. cryptotenella</i>						36												
	<i>N. ge. var. ge.</i>			11		12													
	<i>N. v. var. viridula</i>														14				
	<i>N. sp.</i>																		15
	<i>C. e.</i>								11										
	<i>C. orientalis</i>								24										
	<i>C. tumida</i>			12													10		

Sites	Name of the Taxa	Months																	
	<i>En. minutum</i>																12		
	<i>Ec. leei</i>																		21
	<i>G. parvulum</i>			11	11				15								19	72	
	<i>N. frustulum</i>						11												
	<i>Nt. sp.</i>																	16	
5C	<i>S. ulna</i>													42					
	<i>Co. pl. var. eu.</i>								20										
	<i>Ac. l. var. rostrata</i>						15									11			
	<i>Ac. minutissima</i>				20														
	<i>N. cincta</i>				16														
	<i>N. cryptotenella</i>				13														15
	<i>N. ge. var. ge.</i>	15																	
	<i>N. v. var. r.</i>	22	21			26	24											13	
	<i>N. v. var. linearis</i>							29											
	<i>G. parvulum</i>									21		42		11					
	<i>Nt. palea</i>	29	49		12	17				46				14					15
6C	<i>Ac. linearis</i>			57	40														26
	<i>Ac. microcephala</i>				18														
	<i>Co. pl. var. eu.</i>					12													
	<i>C. e. var. angusta</i>													14					
	<i>Ac. minutissima</i>					26													
	<i>N. phyllepta</i>					18												11	
	<i>N. v. var. r.</i>													19		11			
Sites	Name of the Taxa	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
	<i>Am. pediculus</i>						13												
	<i>Nt. palea</i>														43				
7C	<i>Co. pl. var. eu.</i>						16	13										17	
	<i>Ac. conspicua</i>			29															
	<i>Ac. catenatum</i>																	13	
	<i>Ac. linearis</i>		12	38	38		44	52											
	<i>Ac. minutissima</i>		20		20	20													
	<i>En. leei</i>																	28	
	<i>N. v. var. r.</i>																		15
	<i>Nt. palea</i>																		14
8C	<i>Ac. biasoletiana</i>														13				
	<i>Ac. catenatum</i>																	93	16
	<i>Ac. linearis</i>			53	41										40		20		15
	<i>Ac. microcephala</i>				14	19											10		
	<i>Ac. minutissima</i>				21	13													
	<i>Ac. sp.</i>			11															
	<i>N. phyllepta</i>					11													19
	<i>C. e.</i>																		13
	<i>Ec. leei</i>																	23	
	<i>Nt. palea</i>														10				
9C	<i>S. ulna</i>							14											
	<i>Co. pediculus</i>							24											

Sites	Name of the Taxa	Months															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	<i>Ac. gondwana</i>		14	10												10	
	<i>Ac. lanceolata</i>							32				22					
	<i>Ac. l. var. rostrata</i>		21													40	
	<i>Ac. linearis</i>						12							30			
	<i>Ac. microcephala</i>												21				
	<i>Ac. minutissima</i>	36															
	<i>Ac. sps.</i>		28														
	<i>N. clementis</i>			21								28					
	<i>N. c. var. sy.</i>			16													
	<i>N. radiosa</i>														12		
	<i>N. schroeterii</i>						23										
	<i>C. excisa</i>											11					
	<i>C. tumida</i>												13				
	<i>En. minutum</i>							14									
	<i>Nt. palea</i>				95												
	<i>Fr. vulgare</i>			23											13		

while the 2nd axis contains a normal and a sulphur-spring. The third and fourth axis contains most of the GD ecosystems and a few YD ecosystems viz. the Amlawa and Asan (Figure 5).

Canonical Correspondence Analysis (CCA) exhibited greater role for pH, followed by dissolved Oxygen, current velocity, total alkalinity and total hardness across the YD and GD ecosystem. CCA clearly reveals the influence of CV on the ecosystems at 8B, 5B, 5C, 2A, all unobstructed free flowing streams and rivers.

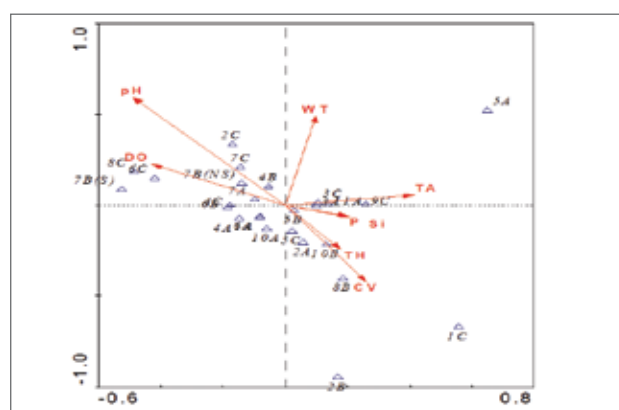


Figure 6: CCA showing the influence of environmental variables on various ecosystems of Doon Valley

The Ganges ecosystem, a similar flowing ecosystem, was, however, more influenced by DO. Few ecosystems especially 2C, 4B, 7C were influenced by pH, while 10B by TH and 1A, 3C, 9C by TA (Figure 6).

DISCUSSION

More flora in the YD compared to the GD were attributed primarily to high number of site specific taxa at two locations (Amlawa, Asan Barrage) in the YD in contrast to one location only in GD. The Asan barrage differs from other ecosystems as it consists of a variety of grass and periphytic substrate in contrast to hard stony substrate in other stream ecosystems.

Besides more than 10 site specific taxa occurred at four sites in YD while only at two locations in GD. It is for this reason that more taxa were exclusive to the YD (107) compared to GD (70) and YD has more flora than GD, which does not have such habitat.

In the YD *Ac. linearis* and *Ac. minutissima* with some other *Ac.* species prevailed as dominants in most of the ecosystems. These two taxa are known to be community dominants from wide variety of streams

and rivers in the mountain part of the Gangetic drainage (Nautiyal et al. 1996; Badoni et al. 1997; Nautiyal et al. 2005; Nautiyal and Mishra 2013).

Other consistent dominant taxa in ecosystems of YD were; *C. subleptoceros* and *C. excisa* at 6A, *G. parvulum* and *C. excise* in the Asan at 7A, *N. viridula* var. *rostellata* with *N. miniscula* var. *muralis* or *G. parvulum* in the Asan at 11A, while *Co. placentula* var. *euglypta* and *Ni. palea* in the Nalota nadi at 6B. Some of these taxa show sporadic (in any one month, usually winter or summer) dominance (*C. subleptoceros*, *C. excisa* var. *procera* and *G. parvulum*).

In the Ganges drainage (eastern Doon), *Achnanthes linearis* occurred as dominant in the community in the Ganges which is a larger glacierfed river than the Yamuna. It also occurred in combination with *Achnanthes biasoletiana* and *Achnanthes microcephala* in the Baldi stream at 8B. *Achnanthes minutissima* with *Cocconeis placentula* var. *euglypta*, *Cocconeis pediculus* figured only in the Song distributary (4C).

Other dominant forms that were different from YD were *Achnanthes orientalis* – non-sulphur stream 7B, *Achnanthes catenatum* Sulphur 7B, *Cocconeis pediculus* in the mid stretch of Song River at 10B and at 1C, with assortment of other taxa such as *Navicula cryptotenella*, at former while *Cocconeis placentula* var. *euglypta*, *Stauroneis anceps*, *Navicula viridula* var. *rostellata* in Tawa stream at 2C. Most of the taxa figure as dominants in the communities of ecosystems within GD, a pattern very different from YD. This shows more diverse nature of the ecosystems in the GD compared with the YD. Astrid et al. (2006) observed that in rivers draining into Golfo Dulce (Costa Rica) the epilithic diatom assemblages from the rainforest streams were very distinct from those found at open canopy sites.

The Shannon diversity of YD differs from GD. However, few ecosystems in YD had diversity similar to most GD ecosystems and vis-à-vis. The diversity

of sulphur spring a unique ecosystem, differed from other ecosystems of Doon Valley. An analysis of associations among the diatoms showed that diatom forming more significant +ve associations indicate those diatom species that are more tolerant forms. The diatom species showing more significant -ve associations are less tolerant forms and may be site specific diatoms. The associations also segregated the YD and GD which showed fewer associations in YD and large number of associations in the GD that also points to more diverse communities.

There were two clusters due to similar associations among the YD ecosystems. Those in western Doons (YD) were different from those in central Doon (YD in part, GD in part). This was true for eastern Doon (GD) ecosystems as some taxa exhibited no association viz. *Ac. linearis* that were found at all locations etc. Moreover, TWINSpan always produces a hierarchical structure, even if this structure is subtle or non-existent (Dufrene and Legendre, 1997). Soininen et al. (2004) recorded several ecologically meaningful groups that were explainable by several important gradients (levels of conductivity, water colour, total P, pH, and current regime), where TWINSpan revealed 11 river groupings forming three major categories by virtue of the associations.

For the present study, a total of 13 different ecosystems (flow, sunlight, terrain, depth, land use, human activity are the basis for different ecosystems) were recorded for all 30 sampling stations, each one with either one or more indicator species as the indicator species have a key role — they add ecological meaning to the clusters derived from data, and help to identify where to stop dividing clusters further into subsets (Dufrene and Legendre 1997).

Principal Component Analysis revealed that despite the strong individuality of YD and GD ecosystems, the abundance pattern resembled among few ecosystems in each of these drainages. CCA defined the role of pH, DO, CV and TA as the important environmental variables affecting the diatom community in the ecosystems (in order of

Table 4: Showing different +ve and –ve associations of diatom species in Doon Valley

Species Name	Associations	Name of the species in associations
<i>D. anceps</i>	+ve	<i>S. sps</i> , <i>Am. veneta</i> , <i>G. parvulum</i> , <i>N. cryptotenella</i> , <i>N. tripunctata</i> ,
	-ve	<i>D. hiemale</i> , <i>F. Intermedia</i> , <i>F. pinnata</i> <i>S. ulna</i> var. <i>mediocontracta</i> , <i>E. subetica</i> , <i>Ac. hungarica</i> , <i>Am aequalis</i> , <i>An. vitrea</i> , <i>Ca. clevei</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. o.</i> var. <i>minutissimum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. product</i> , <i>Cy. antique</i> , <i>Cy glomerata</i> , <i>Cy. meneghiniana</i> var. <i>unipunctata</i>
<i>D. elongatum</i> var. <i>tenuis</i>	+ve	<i>D. vulgare</i> var. <i>producta</i> , <i>S. inaequalis</i> var. <i>jumlensis</i> , <i>Cm. solea</i> , <i>C. amphicephala</i> , <i>C. laevis</i> , <i>C. novazeelandiana</i> , <i>C. perparva</i> , <i>C. subleptoceros</i> , <i>G. angustum</i> , <i>G. olivaceum</i> , <i>H. amphioxys</i> , <i>N. decussis</i> var. <i>decussis</i> , <i>N. radiosa</i> , <i>Nt. amphibia</i> , <i>Nt. denticula</i> , <i>Nt. dissipata</i> , <i>Nt. microcephala</i> , <i>Nt. sinuta</i> var. <i>tabellaria</i>
	-ve	<i>N. obusta</i>
<i>D. hiemale</i>	+ve	<i>Cy. meneghiniana</i> var. <i>unipunctata</i> , <i>Cy. glomerata</i> , <i>Cy. antiqua</i> , <i>St. producta</i> , <i>P. viridis</i> , <i>P. stomatophora</i> , <i>P. microstauron</i> , <i>P. maior</i> , <i>P. krockii</i> , <i>P. intermedia</i> , <i>P. hemiptera</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. esox</i> , <i>Nt. hungarica</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. coarctata</i> , <i>N. hitchcockii</i> , <i>N. tripunctata</i> var. <i>suecorum</i> , <i>N. suecorum</i> , <i>N. subtilissima</i> , <i>N. submolesta</i> , <i>N. storemii</i> , <i>N. reinhardtii</i> , <i>N. pseudokotschyi</i> , <i>N. kotschyi</i> , <i>N. hambergii</i> , <i>N. gregaria</i> , <i>N. gastrum</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. contenta</i> , <i>N. confervacea</i> , <i>N. cohnii</i> , <i>N. bacillum</i> , <i>N. angusta</i> , <i>H. capitata</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>Ep. sorex</i> , <i>Di. subovalis</i> , <i>Di. modica</i> , <i>C. stigmaphora</i> , <i>C. simonsenii</i> , <i>C. saxicola</i> , <i>C. cistula</i> , <i>Ca. stauroneiformis</i> , <i>An. vitrea</i> , <i>Ca. clevei</i> , <i>Am. veneta</i> , <i>Ac. hungarica</i> , <i>E. subetica</i> , <i>S. sps</i> , <i>S. ulna</i> var. <i>mediocontracta</i> , <i>F. pinnata</i> , <i>F. intermedia</i> .
	-ve	<i>Am. aequalis</i> , <i>G. parvulum</i> , <i>N. cryptotenella</i> , <i>N. exigua</i> , <i>St. phoenicenteron</i>
<i>D. vulgare</i>	+ve	<i>D. vulgare</i> var. <i>producta</i> , <i>S. inaequalis</i> var. <i>jumlensis</i> , <i>S. rumpens</i> , <i>A. biasoletiana</i> , <i>A. catenatum</i> , <i>Cm. solea</i> , <i>C. affinis</i> , <i>C. amphicephala</i> , <i>C. excisa</i> var. <i>procera</i> , <i>C. hustedtii</i> , <i>C. novazeelandiana</i> , <i>C. parva</i> , <i>C. perparva</i> , <i>C. silesiaca</i> , <i>C. subleptoceros</i> , <i>C. turgidula</i> var. <i>bengalensis</i> , <i>C. tropica</i> , <i>G. clevei</i> , <i>G. gracile</i> , <i>G. olivaceum</i> , <i>N. cryptocephala</i> , <i>N. mutica</i> var. <i>mutica</i> , <i>Nt. dravellensis</i> , <i>Nt. microcephala</i> , <i>Nt. sinuta</i> var. <i>tabellaria</i> , <i>Se. pupula</i> , <i>Se. parapupula</i>
	-ve	None
<i>D. vulgare</i> var. <i>producta</i>	+ve	<i>F. sps</i> , <i>S. inaequalis</i> var. <i>jumlensis</i> , <i>S. rumpens</i> , <i>Ac. l.</i> var. <i>rostrata</i> , <i>Co. pl.</i> var. <i>lineata</i> , <i>Cm. solea</i> , <i>C. amphicephala</i> , <i>C. excisa</i> var. <i>procera</i> , <i>C. hustedtii</i> , <i>C. kappii</i> , <i>C. novazeelandiana</i> , <i>C. sinuata</i> , <i>C. subleptoceros</i> , <i>C. turgidula</i> var. <i>bengalensis</i> , <i>C. tropica</i> , <i>G. angustum</i> , <i>G. bohemicum</i> , <i>G. minutum</i> , <i>G. olivaceum</i> , <i>H. amphioxys</i> , <i>N. phyllepta</i> , <i>Nt. dissipata</i> , <i>Nt. dravellensis</i> , <i>Nt. sinuta</i> var. <i>tabellaria</i>
	-ve	None
<i>F. capucina</i> var. <i>vaucheriae</i>	+ve	<i>S. rumpens</i> , <i>Cm. solea</i> , <i>C. leptoceros</i> , <i>C. metzeltinii</i> , <i>C. silesiaca</i> , <i>C. sinuata</i> , <i>C. turgidula</i> var. <i>venezolana</i> , <i>C. turgidula</i> var. <i>bengalensis</i> , <i>C. tropica</i> , <i>G. affine</i> var. <i>turris</i> , <i>G. clevei</i> , <i>G. clavatum</i> , <i>G. minutum</i> , <i>G. olivaceum</i> , <i>N. decussis</i> var. <i>decussis</i> , <i>N. microcephala</i> , <i>Se. pupula</i>
	-ve	None
<i>F. intermedia</i>	+ve	<i>G. parvulum</i>

Species Name	Associations	Name of the species in associations
	-ve	<i>F. pinnata</i> , <i>S. ulna</i> var. <i>mediocontracta</i> , <i>S. sps.</i> , <i>E. subetica</i> , <i>Ac. hungarica</i> , <i>Am. aequalis</i> , <i>Am. veneta</i> , <i>An. vitrea</i> , <i>Ca. clevei</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. cryptotenella</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>N. tripunctata</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>N. hungarica</i> , <i>N. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. product</i> , <i>Cy. antique</i> , <i>Cy. glomerata</i> , <i>Cy. meneghiniana</i> var. <i>unipunctata</i>
<i>F. pinnata</i>	+ve	<i>S. ulna</i> var. <i>mediocontracta</i> , <i>S. sps.</i> , <i>E. subetica</i> , <i>A. hungarica</i> , <i>Am. aequalis</i> , <i>Am. veneta</i> , <i>An. vitrea</i> , <i>Ca. clevei</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>G. parvulum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. cryptotenella</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>N. tripunctata</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. product</i> , <i>Cy. antiqua</i> , <i>Cy. glomerata</i> , <i>C. var. unipunctata</i>
	-ve	None
<i>S. ulna</i> var. <i>contracta</i>	+ve	<i>Co. pl. var. lineata</i> , <i>Ap. lindheimeri</i>
	-ve	None
<i>E. subetica</i>	+ve	<i>N. cryptotenella</i> , <i>P. Viridis</i>
	-ve	<i>Ac. hungarica</i> , <i>Am. aequalis</i> , <i>Am. veneta</i> , <i>An. vitrea</i> , <i>Ca. clevei</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>G. parvulum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>N. tripunctata</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>St. phoenicenteron</i> , <i>St. producta</i> , <i>Cy. antiqua</i> , <i>Cy. glomerata</i> , <i>Cy. meneghiniana</i> var. <i>unipunctata</i>
<i>Ac. hauckiana</i>	+ve	<i>Am. libyca</i> , <i>Am. normannii</i> , <i>Ca. silicula</i> , <i>N. expecta</i> , <i>N. pseudonglica</i> var. <i>pseudonglica</i> , <i>N. trivialis</i> , <i>Ne. ampliatus</i> , <i>Ne. binodeformis</i> , <i>R. gibba</i>
	-ve	<i>C. excisiformis</i> , <i>C. silesiaca</i>
<i>Ac. hungarica</i>	+ve	<i>Ca. clevei</i> , <i>G. parvulum</i> , <i>N. cryptotenella</i>
	-ve	<i>Am. aequalis</i> , <i>Am. veneta</i> , <i>An. vitrea</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>N. tripunctata</i> , <i>N. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. producta</i> , <i>Cy. antiqua</i> , <i>Cy. glomerata</i> , <i>C. meneghiniana</i> var. <i>unipunctata</i>

Species Name	Associations	Name of the species in associations
<i>Co. Pl. var. eu.</i>	+ve	<i>Am. montana</i> , <i>C. excisa</i> var. <i>angusta</i> , <i>C. perparva</i> , <i>C. subleptoceros</i> , <i>C. tumida</i> , <i>C. turgidula</i> , <i>En. minutum</i> , <i>Ec. leei</i> , <i>G. affine</i> var. <i>affine</i> , <i>G. minutum</i> , <i>G. olivaceum</i> , <i>N. capitatoradiata</i> , <i>N. cryptocephala</i> , <i>Nt. frustulum</i> , <i>Nt. linearis</i> , <i>Se. Parapupula</i>
	-ve	None
<i>An. vitrea</i>	+ve	None
	-ve	<i>Ca. clevei</i> , <i>Ca. stauroneiformis</i> , <i>C. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. frustulum</i> var. <i>subsalina</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. producta</i> , <i>Cy. antiqua</i> , <i>Cy. glomerata</i> , <i>Cy. meneghiniana</i> var. <i>unipunctata</i>
<i>Ca. clevei</i>	+ve	<i>Ca. molaris</i> , <i>G. parvulum</i> , <i>N. cryptotenella</i>
	-ve	<i>Ca. stauroneiformis</i> , <i>Ca. cistula</i> , <i>C. saxicola</i> , <i>C. simonsenii</i> , <i>C. stigmaphora</i> , <i>Di. modica</i> , <i>Di. subovalis</i> , <i>Ep. sorex</i> , <i>G. olivaceum</i> var. <i>minutissimum</i> , <i>H. capitata</i> , <i>N. angusta</i> , <i>N. bacillum</i> , <i>N. cohnii</i> , <i>N. confervacea</i> , <i>N. contenta</i> , <i>N. exigua</i> , <i>N. fossilis</i> var. <i>recordiata</i> , <i>N. gastrum</i> , <i>N. gregaria</i> , <i>N. hambergii</i> , <i>N. kotschyi</i> , <i>N. pseudokotschyi</i> , <i>N. reinhardtii</i> , <i>N. storemii</i> , <i>N. submolesta</i> , <i>N. subtilissima</i> , <i>N. suecorum</i> var. <i>suecorum</i> , <i>N. tripunctata</i> , <i>Ne. hitchcockii</i> , <i>Nt. coarctata</i> , <i>Nt. hungarica</i> , <i>Nt. protracta</i> , <i>P. esox</i> , <i>P. gibba</i> var. <i>mesogongyla</i> , <i>P. hemiptera</i> , <i>P. intermedia</i> , <i>P. krockii</i> , <i>P. maior</i> , <i>P. microstauron</i> , <i>P. viridis</i> , <i>St. phoenicenteron</i> , <i>St. producta</i> , <i>Cy. antiqua</i> , <i>Cy. glomerata</i> , <i>Cy. meneghiniana</i> var. <i>unipunctata</i>

decreasing importance). However, greater numbers of ecosystems were not influenced by any of these variables.

ACKNOWLEDGEMENTS

Sincere thanks to Department of Science and Technology, Government of India, New Delhi, due to financial support of Major Research Project, sanction no. SP/SO/PS-02/2004 entitled "Diatom Biodiversity of Doon Valley" and Department of Higher Education, Uttarakhand Government for providing the academic support.

The author is also indebted to Prof. Prakash Nautiyal, HNB Garhwal (Central) University, Srinagar Garhwal, Uttarakhand for his valuable remarks during preparation of manuscript.

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- The Doon valley map shows uniform grids (15 x 15 km) 6, 7, 8 and 9 (vertical numerals) and A, B, C, D, E (horizontal alphabets) within which location of 30 stations is indicated by red spots.

Biodiverse Assemblage of Cladocera (Crustacea: Branchiopoda) in the Floodplains of the Brahmaputra River Basin

Sumita Sharma and B. K. Sharma

Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University, Permanent Campus,
Shillong - 793022, Meghalaya, India
E-mail: profbksharma@gmail.com

ABSTRACT

The plankton and semi-plankton samples collected from the floodplain lakes (*Beels*) and other wetlands of the Brahmaputra basin reveal specious and diverse assemblage of Cladocera (74 species belonging to 41 genera). The examined species comprised a notable component (64.5 per cent) of the Indian Cladocera and signify biodiversity value as the richest diversity of the taxon known till date from any state/ part of India as well as of South and Southeast Asia.

This study is significant in the light of a conservative estimate of occurrence of up to 60-65 cladoceran species from tropical and subtropical parts of India. The reports of the Australasian *Disperalona caudata*; the Indo-Chinese *Alona cheni*, *A. kotovi* and *Sarsilatona fernandoi*; the Oriental *Celsinotum macronyx*, *Chydorus angustirostris*, *C. reticulatus*, *Diaphanosoma tropicum* and *Kurzia* (*Rostrokurzia*) *brevilabris*; and the Neotropical *Leydigopsis curvirostris* merit global biogeography importance.

Chydoridae is the most diverse family; *Chydorus* and *Diaphanosoma* are speciose genera; and the paucity of *Daphnia* spp. is characteristic. Deepor Beel is one of the richest Cladocera (58 species) “hot-spot”. 55 cladoceran species from the wetlands of Majuli island highlights its ecosystem diversity. The diversity pattern of Cladocera of the Brahmaputra floodplains is predominantly of “tropical” nature and its species-rich nature is hypothesised to habitat diversity and environmental heterogeneity of the sampled ecotones.

Key words: Cladocera, Brahmaputra river basin, distribution, heterogeneity, interesting species, tropical wetlands

INTRODUCTION

Cladocera, commonly termed as “Water Fleas”, form an integral link in aquatic food-webs and contribute significantly to biological productivity and energy flow in aquatic environs due to their rapid turnover rates. Taxonomic studies on Indian freshwater Cladocera were initiated by Baird (1860) while those from

northeast India (NEI) were initiated by Biswas (1964) after time lag of nearly one century. Initial reports on the diversity of these important fish-food organisms from Assam (Biswas 1980; Michael and Sharma 1988) were substantiated by our studies from the floodplain lakes (*beels*) of this state (Sharma and Sharma 2007, 2008, 2010, 2012a, 2014).

We now extend our efforts to provide a comprehensive account of the faunal diversity of Cladocera of the floodplains of the Brahmaputra river basin and incidentally of Assam state based on extensive collections during 2010-13. An inventory of 74 Cladoceran species observed in our collections is presented with remarks on their composition, faunal diversity, biogeographically interesting elements and their distribution of various taxa.

MATERIALS AND METHODS

This study is based on analysis of our plankton and semi-plankton samples collected, during 2010-2013, from floodplain lakes (*Beels*) and small wetlands (*dobas* or *dubies*) of the Brahmaputra river basin of lower and upper Assam (Figure 1); the samples collected, during 2010-2012, from 20+ *Beels* and 30+ *dobas* or *dubies* of Majuli River Island of upper Assam; critical evaluation of our published reports; and re-examination of our earlier collections (2005-2010) from this state.

The sampled biotopes often showed varied aquatic plants namely *Eichhornia crassipes*, *Hydrilla verticillata*, *Vallisneria spiralis*, *Utricularia flexuosa*, *Trapa natans*, *Lemna major*, *L. minor*, *Pistia striates*, *Salvinia* sp., *Nymphaea* spp., *Nymphoides* spp., *Najas graminca*, *Nelumbo mucifera*, *Potamogeton* spp., *Azolla pinnata*, *Euryale ferox*, *Sagittaria* spp., and *Cyperus* spp..

The collections were made from the littoral and semi-limnetic/ limnetic regions of different ecosystems by towing plankton net (mesh size 50 µm) and preserved in five per cent formalin. All collections were screened individually with a wild-stereoscopic binocular microscope; various cladocerans and their disarticulated appendages were mounted in polyvinyl alcohol-lactophenol mixture and then observed under a Leica DM 1000 image analyser fitted with drawing-tube.

The different species were identified following Smirnov (1971, 1976, 1992, 1996); Michael and

Sharma (1988); Korovchinsky (1992); Sharma and Sharma (1999); Orlova-Bienkowskaja (2001); Korinek (2002) along with some others.

RESULTS

During the study a total of 74 Cladocerans, belonging to 41 genera and 7 families were identified which are as follows:

Systematic list of the examined Cladocera

Super-class : Crustacea
Class : Branchiopoda
Super-order : Cladocera (*s. str.*)

Order: Ctenopoda

Family: Sididae

1. *Diaphanosoma excisum* (Sars 1885)
2. *D. dubium* (Manuilova 1964)
3. *D. sarsi* (Richard 1895)
4. *D. senegal* (Gauthier 1951)
5. *D. tropicum* (Korovchinsky 1998)
6. *D. volzi* (Stingelin 1805)
7. *Latonopsis australis* (Sars 1888)
8. *Pseudosida szalay* (Daday 1994)
9. *Sarsilatona fernandoi* (Rane 1983)
10. *Sida crystallina* (O. F. Muller 1776)

Order: Anomopoda

Family: Daphniidae

Subfamily: Daphniinae

11. *Ceriodaphnia cornuta* (Sars 1885)
12. *C. reticulata* (Jurine 1820)
13. *Daphnia lumholtzi* (Sars 1885)
14. *D. pulex* (Leydig 1860 emend. Scourfield 1942)
15. *Simocephalus*(*Echinocaudus*)*acutirostratus* (King 1853)
16. *S. (Echinocaudus) exspinosus* (De Geer, 1778)
17. *S. (Coronocephalus) serrulatus* (Koch 1841)
18. *S. (Simocephalus) mixtus* (Sars 1903)
19. *S. (Simocephalus) vetuloides* (Sars 1898)
20. *S. (Aquipiculus) heilongjiangensis* (Shi & Shi 1994)

Subfamily: Scapholeberinae

21. *Scapholeberis kingi* (Sars 1901)

Family: Bosminidae

22. *Bosmina (Bosmina) longirostris* (O. F. Muller 1776) s. lat
23. *B. (Bosmina) tripuræ* (Korinek et al 1999)
24. *Bosminopsis deitersi* (Richard 1895)

Family: Moinidae

25. *Moina micrura* (Kurz 1874)
26. *Moinodaphnia macleayi* (King 1853)

Family: Macrothricidae

27. *Macrothrix laticornis* (Fischer 1857)
28. *M. odiosa* (Gurney 1907)
29. *M. spinosa* (King 1853)
30. *M. triserialis* (Brady 1886)
31. *Guernella raphaelis* (Richard 1892)
32. *Grimaldina brazzai* (Richard 1892)
33. *Streblocerus serricaudatus* (Fischer 1849)

Family: Ilyocryptidae

34. *Ilyocryptus spinifer* (Herrick 1882)

Family: Chydoridae**Subfamily: Chydorinae**

35. *Alonella (Alonella) clathratula* (Sars 1886)
36. *A. (Alonella) excisa* (Fischer 1854)
37. *A. (Nanalonella) nana* (Baird 1850)
38. *Chydorus angustirostris* (Frey 1987)
39. *C. eurynotus* (Sars 1901 s.lat.)
40. *C. parvus* (Daday 1898)
41. *C. pubescens* (Sars 1901)
42. *C. reticulatus* (Daday 1898)
43. *C. sphaericus* (O. F. Muller 1776) s lato
44. *C. ventricosus* (Daday 1898)
45. *Dadaya macrops* (Daday 1898)
46. *Disperalona caudata* (Smirnov 1996)
47. *Dunhevedia crassa* (King 1853)
48. *D. serrata* (Daday 1898)
49. *Ephemeroporus barroisi* (Richard 1894)
50. *Pleuroxus (Picripleuroxus) laevis* (Sars 1862)
51. *P. (Picripleuroxus) similis* (Vavra 1900)
52. *Pseudochydorus globosus* (Baird 1843)

Subfamily: Aloninae

53. *Acroperus harpae* (Baird 1834)
54. *Alona affinis* (Leydig, 1860) s. lat
55. *A. cheni* (Sinev 1999)
56. *A. guttata guttata* (Sars 1862)
57. *A. guttata tuberculata* (Kurz 1875)
58. *A. kotovi* (Sinev 2012)
59. *Anthalona harti* (Van Damme, Sinev & Dumont 2011)
60. *Celsinotum macronyx* (Daday 1898)
61. *Coronatella anodonta* (Daday 1905)
62. *C. monacantha* (Sars 1901) s.lat.
63. *C. rectangula* (Sars 1862) s. lat.
64. *Camptocercus uncinatus* (Smirnov 1973)
65. *Euryalona orientalis* (Daday 1898)
66. *Graptoleberis testudinaria* (Fischer 1854)
67. *Karualona karua* (King 1853)
68. *Kurzia brevilabris* (Rajapaksa & Fernando 1986)
69. *K. latissima* (Kurz 1875)
70. *K. longirostris* (Daday 1898)
71. *Leberis diphanus* (King 1853)
72. *Leydigia acanthocercoides* (Fischer 1854)
73. *Leydigiopsis curvirostris* Sars 1901
74. *Notoalona globulosa* (Daday 1898)
75. *Oxyurella singalensis* (Daday 1898)

Disperalona caudata (Figure 2) is an Australasian species while *Alona cheni* (Figure 3), *A. kotovi*, (Figure 4) *Chydorus angustirostris* (Figure 5) and *Sarsilatona fernandoi* (Figure 6) are Indo-Chinese elements. In addition, the Oriental *Celsinotum macronyx* (Figure 7), *Chydorus reticulatus*, *Diaphanosoma tropicum* (Figure 8) and *Kurzia (Rostrokurzia) brevilabris* (Figure 9) were observed in our collections.

Chydoridae was the most species-rich family (40 species) with 22 and 18 species of Aloninae and Chydoridae, respectively. Daphniidae and Sididae were represented by 11 and 10 species, respectively and Macrothricidae included seven species. *Chydorus* and *Diaphanosoma* were speciose genera while paucity and restricted occurrence of *Daphnia* was characteristic.

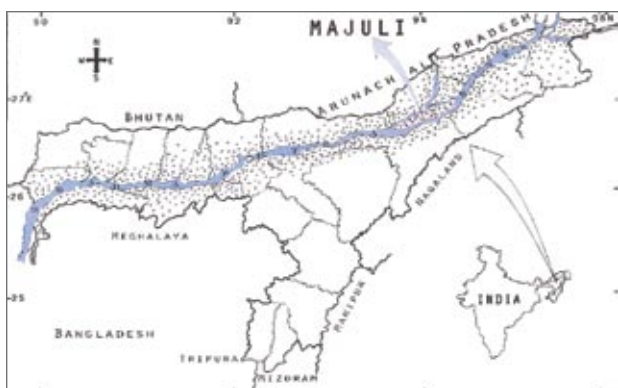


Figure 1: Map of Assam showing the sampled floodplains of the Brahmaputra river basin.

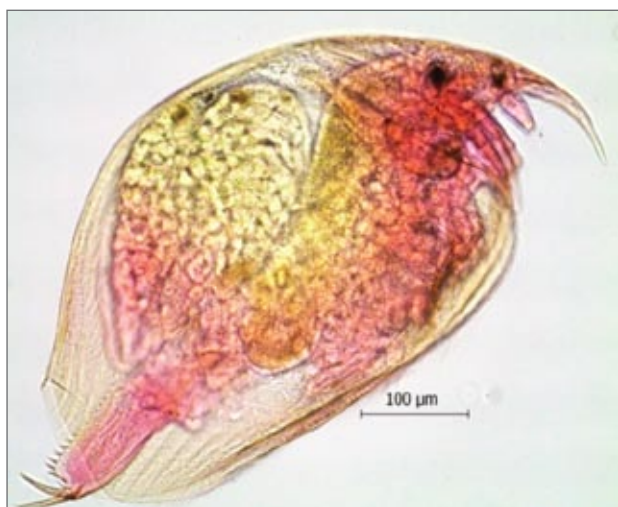


Figure 2: *Disperalona caudata* Smirnov, after Sharma & Sharma (2014)

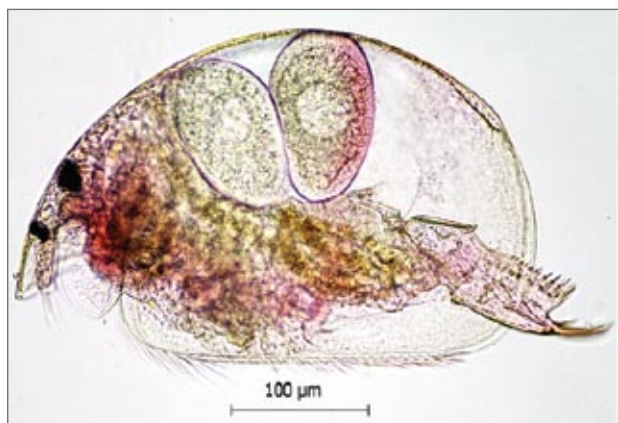


Figure 3: *Alona cheni* Sinev after Sharma & Sharma (2014)

Ceriodaphnia cornuta, *Diaphanosoma excisum*, *D. sarsi*, *Simocephalus mixtus*, *Macrothrix triserialis*, *Guernella raphaelis*, *Alonella excisa*, *C. sphaericus*, *Ephemeroporus barroisi*, *Alona cheni*, *Euryalona orientalis*, *Karualona karua*, *Kurzia longirostris*,

Notoalona globulosa and *Oxyurella singalensis* are common species. *Diaphanosoma tropica*, *D. volzi*, *Daphnia lumholtzi*, *D. pulex*, *Macrothrix odiosa*, *Grimaldina brazzai*, *Streblocerus serricaudatus*, *Alonella (Nanalonella) nana*, *Chydorus pubescens*, *Dunhevedia serrata*, *Pseudochydorus globosus*, *Alona kotovi*, *Graptoleberis testudinaria* and *Leydigiopsis curvirostris* showed their rare occurrence.

DISCUSSION

Seventy-four species of Cladocera collected from the floodplains of the Brahmaputra river basin of Assam state of NEI reveal highly diverse assemblage of the taxon, and their richest faunal diversity known till date from any state or part of India as well as from any particular region of South and Southeast Asia. The richness is of the biodiversity value as ~64.0 per cent of the known species of the Indian Cladocerans and also in the light of a conservative estimate of occurrence of up to 60-65 species from tropical and subtropical parts of India (Sharma and Michael 1987).

This study records high generic diversity of 41 genera amongst 47 genera known from India, while all the seven families of freshwater Cladocera known from the country are represented. Highly speciose and diverse Cladoceran assemblage is hypothesised to habitat diversity and environmental heterogeneity of the floodplains of the Brahmaputra basin. We attribute the rich diversity to the *cladocerologist effect* drawing our analogy to the *rotiferologist effect* advanced by Fontaneto et al. (2012).

The occurrence of all the documented species in the *Beels* of the Brahmaputra basin affirms our hypothesis on the sub (tropical) floodplain lakes as one of the globally rich aquatic environs for Cladoceran diversity. This salient feature reiterates our remarks (Sharma and Sharma 2013) on Deepor Beel (a Ramsar site and a biodiversity hot-spot) with its highest Cladoceran assemblage (58 species) known till date from any individual freshwater ecosystem of Asia.

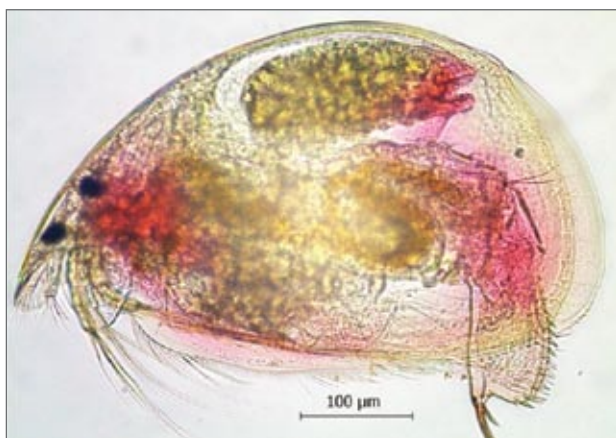


Figure 4: *Alona kotovi* Sinev after Sharma & Sharma (2014)

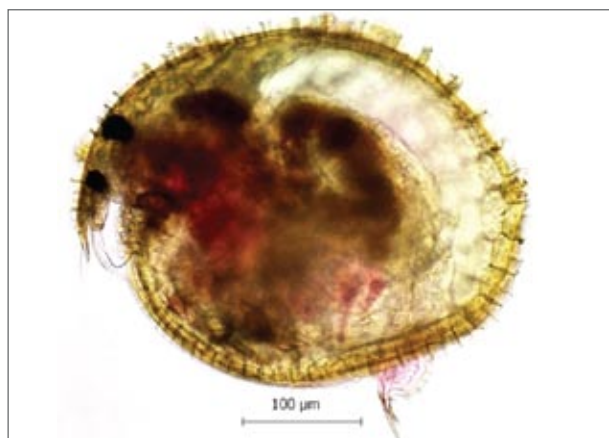


Figure 5: *Chydorus angustirostris* Frey after Sharma & Sharma (2014)



Figure 6: *Sarsilatona fernandoi* (Rane), after Sharma & Sharma 2013

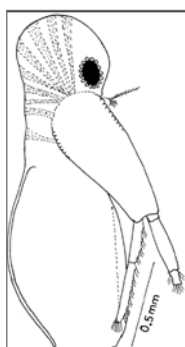


Figure 7: *Diaphanosoma tropicum* Korovchinsky, after Sharma & Sharma 2008

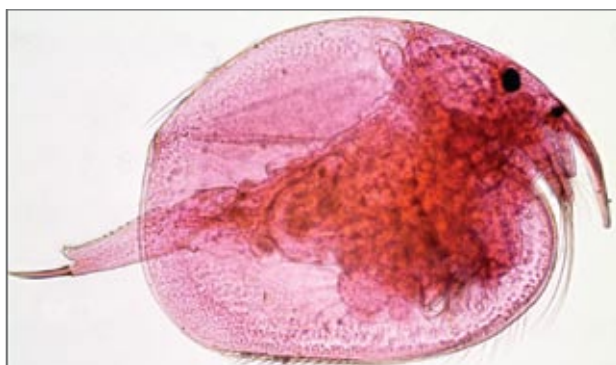


Figure 9: *Kurzia brevilabris* Rajapaksa & Fernando, Sharma & Sharma 2014

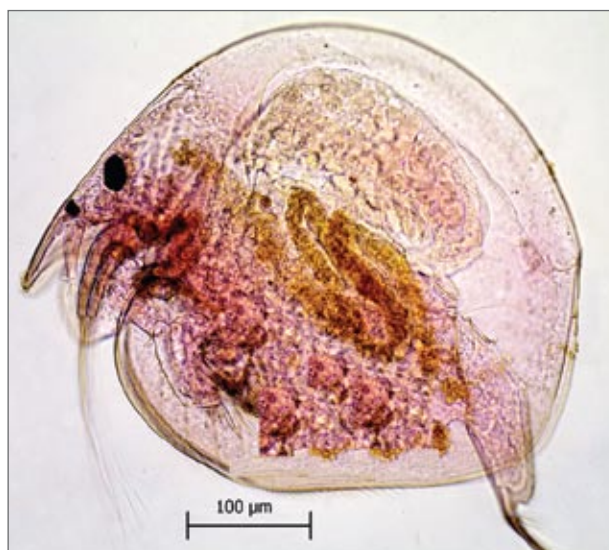


Figure 8: *Celsinotum macronyx* (Daday) after Sharma & Sharma 2013

Interestingly, the richness even exceeds the report of 51 species (Sharma and Sharma 2010) from Loktak Lake, Manipur, another Ramsar site. Further, our report of 55 species (Sharma and Sharma 2014) from wetlands of Majuli (the largest river island) highlights ecosystem diversity of the floodplains of the Brahmaputra basin.

Incidentally, all the species examined from the floodplains represent the total tally of Cladocerans

known from Assam, which, in turn, is distinctly speciose than 58 species known from Meghalaya (Sharma and Sharma 1999; Sharma 2008), 56 species reported from West Bengal (Venkataraman 1999) and 49 species recorded from Tripura (Venkataraman and Das 2000).

The species comparisons with other states of India are not feasible because of incomplete inventories. Besides, our results record notably high generic diversity than 29 genera each reported from the states of Meghalaya and Tripura.

The Cladocerans richness from the Brahmaputra floodplains is higher than our report of 56 species

from the floodplains of Iral, Imphal and Thoubal river basins of Manipur state of NEI (Sharma and Sharma 2010). The present report is contrastingly higher than the record of only nine species from 65 wetlands of 24-Parganas district (Nandi et al. 1993) and 36 species from 20 wetlands of South eastern West Bengal (Khan 2003); 39 species from 30 wetlands of the Keoladeo National Park, Rajasthan (Venkataraman 1992) and 29 species from 25 wetlands of Melaghat Tiger reserve, Maharashtra (Rane 2005). Apparently, some of these differences are largely due to inadequate sampling, incomplete inventories or lack of adequate taxonomic expertise.

Our collections are characterised by the occurrence of the Australasian *Disperalona caudata*; the Indo-Chinese *Alona cheni*, *A. kotovi* and *Sarsilatona fernandoi*; the Oriental *Celsinotum macronyx*, *Chydorus angustirostris*, *C. reticulatus*, *Diaphanosoma tropicum* and *Kurzia (Rostrokurzia) brevilabris*. Of these, *Disperalona caudata*, known so far from India only from Assam and Manipur, shows an important link between the Cladoceran faunas of NEI, Southeast Asia and Australia. The presence of this species holds parallel to the reports of five Australasian species of Rotifera from and the Brahmaputra basin in particular and thus endorses our remarks (Sharma 2005; Sharma and Sharma 2005, 2012b) on interesting affinities of zooplankton communities of NEI with those of SE Asia and Australia.

The Indo-Chinese *Alona cheni*, a member of *A. costata*-complex, was described by Sinev (1999) based on the material examined from Aiwa Reservoir, Ahmedabad (Gujarat state). It is known elsewhere in India from Kerala (Subash Babu and Thomas 2007) while Sharma and Sharma (2013) extended its distribution to NEI. As remarked by Sinev (1999), *A. costata* in (sub) tropical Asia seemed to actually belong to *A. cheni* — the latter being a tropical congener. Sharma and Sharma (2014) proposed re-examination of all Indian reports of *A. costata* while Chatterjee et al. (2013) considered some Indian records of *A. costata* to be misidentifications of *A.*

cheni. We, hereby, confirm all reports of the former from Assam as belonging to *A. cheni*.

Sinev (2012) described the Indo-Chinese *Alona kotovi*, a member of *Alona quadrangularis*-group, from South Vietnam while Sharma and Sharma (2014) extended its distribution to the floodplains of the Majuli River Island. This Conger is well distinguished from the old world fauna (*A. quadrangularis*) and is considered as a connecting link between South American and Australasian Chydoridae (Sinev 2012). Sharma and Sharma (2014) proposed re-examination of other Indian records of *A. quadrangularis* while *A. kotovi* is not included in the Indian cladocera checklist by Chatterjee et al. (2013).

Sarsilatona fernandoi, another Indo-Chinese species, was poorly described by Rane (1983a) as *Latonopsis fernandoi* from Madhya Pradesh in Central India. Sharma and Sharma (1990) allocated it to *Sarsilatona* considering it as a junior subjective synonym of *S. serricauda* (Sars), based on “brief” examination of the “type material”.

Korovchinsky (2011) confirmed its validity based on material examined from South Vietnam but designated it as *Sarsilatona cf. fernandoi* due to his inability to investigate the “type material”. This rare Sididae in tropical Asia is found in few localities of India, South of Thailand and southern Vietnam (Sinev and Korovchinsky 2013) and is a new record from NEI. In the light of this report, our inadvertent misidentification of *S. serricauda* from Assam (Sharma and Sharma 2010) is, hereby, corrected as *S. fernandoi*. The Oriental *Celsinotum macronyx*, first recorded from NEI, from Meghalaya (Sharma 2008), is an addition to Assam Cladocera based on our report from Deepor Beel (Sharma and Sharma 2012). The first Indian report of this species referred to *Indialona jabalpurensis*, a new species described by Rane (1983b) from Madhya Pradesh which was designated as a synonym of *Alona macronyx* by Sharma and Sharma (1990). Later Sharma and Sharma (2014) assigned it to *Celsinotum* following Sinev and Kotov (2012). This chydorid is widely

distributed in the Oriental zone inhabiting India and Sri Lanka, Indochina, Indonesia, Philippines, and South China (Rajapaksa and Fernando 1987) and is recently reported from Vietnam (Sinev and Kotov 2012).

The Oriental *Kurzia brevilabris* was described from Sri Lanka (Rajapaksa and Fernando 1986) while Hudec (2000) allocated it to the subgenus *Rostrokurzia*. It is reported from India from the Brahmaputra basin from Deepor Beel (Sharma and Sharma 2012a) and wetlands of Majuli River Island (Sharma and Sharma 2014). The Oriental *Chydorus reticulatus* was recorded from Sri Lanka, India, Malaysia and Thailand.

Diaphanosoma tropicum, another Oriental species, was described by Korovchinsky (1998) from South India and recorded also from the Brahmaputra floodplains (Sharma and Sharma 2009). It was erroneously identified as “*D. modigliani* Richard” from South India by Kanduru (1981). *D. tropicum* is a relatively large bodied species; its large size negatively affects distribution of such taxa in tropical waters, with high predation pressure. This is a rare species from the tropics of Asia occurring from the Philippines to South India and Sri Lanka (Korovchinsky 2004).

Leydigiopsis, an interesting Neotropical genus described from Brazil (Sars 1901), was reported from north-east Thailand (Sanoamuang 1998) while Sharma and Sharma (2007) extended its distributional range to NEI considering these disjunct populations as possible example of human introduction. The latter statement endorsed the comments of Dumont (1997) regarding emphasis on such cladoceran introductions in different parts of the globe. The Indian material belongs to *L. curvirostris* while species status of Thai specimens is yet undetermined.

Our collections include various other examples of biogeography interest: namely *Bosmina* (*Bosmina*) *tripurae*, *Diaphanosoma senegal*, *D. volzi*,

Dunhevedia serrata, *Simocephalus acutirostratus*, *Macrothrix odiosa*, and *Pleuroxus* (*Picripleuroxus*) *laevis*. The first species was described by Korinek et al. (1999) based on “type-specimens” examined from Tripura (NEI) and Tamil Nadu (South India) but was allocated to the subgenus *Sinobosmina*. Korinek (personal communication) believed it to occur in Indonesia, China and Japan. Kotov et al. (2009) considered this species as a primitive member of the subgenus *Bosminas*. str., instead of *B. (Sinobosmina)*. *Diaphanosoma senegal* is so far known from Africa, India and Bangladesh; *Simocephalus acutirostratus* is recorded from Australia and Southeast Asia; *Macrothrix odiosa* is known from Sri Lanka, Africa, Sunda islands, Madagascar and S. Europe; and *D. serrata* is reported from Sri Lanka, Africa, Indonesia, Thailand, Philippines and New Guinea. *Pleuroxus* (*Picripleuroxus*) *laevis* is an interesting Paleotropical species (Smirnov 1996).

The cladocerans are long been considered as a group showing cosmopolitan distribution while the recent bio-geographical considerations focus attention on their geographical vicariants or equivalents (Van Damme et al. 2010, 2011). The documented species, however, exhibit broadly equal occurrence of Cosmopolitan (16.1 per cent) and Pantropical species (16.1 per cent) while cosmotropical species (17.9 per cent) marginally exceed.

Referring to the last two categories, *Diaphanosoma excisum* and *D. volzi* occur in tropics and subtropics of eastern hemisphere; *D. sarsi* and *Pseudosida szalay* inhabit tropics of eastern hemisphere; *Latonopsis australis* inhabits tropics and subtropics of western and eastern hemisphere; *D. dubium* is an Asian tropical-subtropical species; and *Moinodaphnia macleayi*, *Macrothrix spinosa*, *M. triserialis*, *Guernella raphaelis*, *Grimaldina brazzai*, *Chydorus eurynotus*, *C. pubescens*, *C. ventricosus* and *Dadaya macrops* are circumtropical species. These features impart a “tropical character” to the Cladoceran fauna of the Brahmaputra floodplains concurrent with the composition of other tropical Cladoceran communities (Fernando 1980; Fernando

and Kanduru 1984; Dussart et al. 1984; Sharma and Michael 1987; Michael and Sharma 1988; Sharma 1991; Sharma and Sharma 2008).

Chydoridae comprises a dominant component (40 species, 79.4 per cent) of the Cladoceran fauna of the Brahmaputra floodplains with 22 species of Aloninae and 18 species of Chydorinae. The chydorid dominance concurs with the reports of Khan (2003) and Sharma and Sharma (2008). Daphniidae (11 species) > Sididae (10 species) > Macrothricidae (7 species), together, comprise important component (~39.0 per cent).

Our collections are characterised by the prominence of littoral or periphytic species of the Chydoridae and littoral taxa of Macrothricidae, Ilyocryptidae, *Pseudosida*, *Sida* and *Simocephalus*. On the other hand, various planktonic species include *Diaphanosoma sarsi*, *D. excisum*, *Ceriodaphnia cornuta*, *Bosmina longirostris*, *Bosminopsis deitersi*, *Moina micrura* and *Moinodaphnia macleayi*. *Chydorus* (seven species) and *Diaphanosoma* (six species) are speciose genera. The paucity of *Daphnia* is characteristic in the Brahmaputra floodplains; this genus is represented by two species namely *D. lumholtzi* and *D. pulex* known exclusively from Deepor Beel.

To sum up, Cladocera of the floodplains of the Brahmaputra river basin is characterised with the richest and diverse assemblage known from India and one of the richest diversity from South and Southeast Asia. It shows various globally interesting elements including the Australasian, the Indo-Chinese and Oriental taxa in particular.

These distinctive features together with biodiversity rich Deepor Beel) and ecosystem diversity of wetlands of the Majuli River Island, an interesting fluvial landform of interesting geographical origin, reflect environmental heterogeneity imparting the Brahmaputra floodplains special biodiversity and biogeographic value. Molecular and/ or ecological analysis of cryptic diversity in certain species-groups

and of geographic vicariance in various taxa is likely to show higher richness than documented.

ACKNOWLEDGEMENTS

One of the authors (BKS) is thankful to the Ministry of Environment and Forests (Govt. of India) for sanctioning a research project No. 22018-09/2010-CS (Tax) under its AICOPTAX program for the present study.

Thanks are due to the Head, Department of Zoology, NEHU, Shillong for laboratory facilities and Messer's M. Hatimuria, T. Pou, N Noroh and J. D. Mali for help in field collections on various occasions.

We are thankful to IUCN, India office, New Delhi for sponsoring our participation in the International Symposium and to the Organizers to facilitate our participation and invite this presentation.

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32. River Terrapin (*Batagur baska*) Captive Breeding in Bangladesh - A. G. J. Morshed¹ and Istiak Sobhan², ¹Wildlife Biologist, Vienna Zoo, Austria and ²IUCN - Bangladesh, Dhaka (Bangladesh).
33. Spatial Pattern of the Freshwater Fish Diversity in the Tributaries of Ganges Basin: Application of Multiple Indices and Identifying Priority Sites - U. K. Sarkar, National Bureau of Fish Genetic Resources (NBFGR), Lucknow, (India).

34. Species Richness of Freshwater Diatoms and Fish in the Mountain Chains of the Indian Subcontinent: Examining the Spatial Scales, Area-Richness Model, the Role of Historical Factors and Threats to Native Iconic Mahseer (fish) species - Prakash Nautiyal et al., H. N. B. Garhwal University, Srinagar-Garhwal (India).
35. Study of Breeding and other Behaviours of Greater Adjutant in Kosi River Floodplains of Naugachia (Bhagalpur Dist.), Bihar - D. N. Choudhary, T. N. B. College, Bhagalpur (India).
36. The Floodplains of the Brahmaputra River Basin – Globally Interesting Eco-tones with Rich Rotifer (Rotifera: Eurotatoria) Biodiversity - B. K. Sharma and Sumita Sharma, North-Eastern Hill University, Shillong (India).
37. The Rich Biodiversity of Cladocera (*Crustacea: Branchiopoda*) in the Floodplains of the Brahmaputra River Basin - Sumita Sharma and B. K. Sharma, North-Eastern Hill University, Shillong (India).
38. Trans-boundary Sanctuary between India and Bangladesh for Gharial (*Gavialis gangeticus*) Conservation - S. M. A. Rashid et al., Centre for Advanced Research in Natural Resources & Management (CARINAM), Dhaka (Bangladesh).
39. Use of Mollusc Shells in the Button Industries by Local Artisans in Mehshi, East Champaran, Bihar (India) - Gopal Sharma, Gangetic Plains Regional Centre, Zoological Survey of India, Patna (India).
40. Professor Dr. Muhammad Abdur Rouf, Fisheries & Marine Resources Technology Discipline, Khulna University, Bangladesh.

List of Poster Presentations

S. N.	Title	Presenter
1.	Study of Breeding and other Behaviors of Greater Adjutant in Kosi River Floodplains of Naugachia (Bhagalpur Dist.), Bihar.	Dr. D. N. Choudhary, Department of Zoology, T. N. B. College, Bhagalpur (India)
2.	Diversity of Zooplankton in the Middle Lower Reaches of Ganges in Bihar.	Dr. D. K. Kedia, Environmental Biology Laboratory, Department of Zoology, Patna University, Patna (India)
3.	Conservational Need of Two Freshwater Soft-shelled Turtles <i>Lissemys punctata</i> and <i>Aspideretus gangeticus</i> in Ponds and Rivers in and around Bhagalpur, Bihar.	Prof. K. C. Mishra, Department of Zoology, T. N. B. College, Bhagalpur (India)
4.	Assessing the Status of a Sewage-fed Pond at Patna with Reference to Plankton and Macro-zoobenthos.	Dr. Neetu, Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
5.	River Terrapin (<i>Batagur baska</i>) Captive Breeding in Bangladesh.	Dr. A. G. J. Morshed and Dr. Istiak S., Wildlife Biology Division, Vienna Zoo, Austria, and IUCN Bangladesh, Dhaka (Bangladesh)
6.	Ganges River Dolphin (<i>Platanista gangetica</i>) in the Padma, Jamuna and Hurasagar-Baral rivers of Pabna District, Bangladesh.	Dr. S. M. A. Rashid, Centre for Advanced Research in Natural Resources & Management (CARINAM), Adabor, Dhaka (Bangladesh) Centre for Advanced Research in Natural Resources & Management (CARINAM), Adabor, Dhaka (Bangladesh)
7.	Ichthyofaunal Diversity of the Damodar River System (India) during Dry Season.	Dr. Lina Sarkar, Sri Chaitanya College, HABRA, West Bengal (India)
8.	Use of Mollusc Shells in the Button Industries by Local Artisans in Mehshi, East Champaran, Bihar.	Dr. Gopal Sharma, Zoological Survey of India, Gangetic Plains Regional Centre, Patna (India)
9.	Conservation Strategies for the Dolphin (<i>Platanista gangetica</i>) found in the Barak River in Southern Assam.	Mr. Masood Siddique, Center for Natural Resource Studies (CNRS), Banani, Dhaka, (Bangladesh)

Symposium Agenda

April 04-06, 2014; Venue: Ashoka Hall, Hotel Maurya, Patna (India)

DAY 1: April 04, 2014

08:30 am - 09:30 am	Registration
09:30 am - 11:00 am	Inaugural Session
11:00 am - 11:30 am	Tea Break
11:30 am - 01:30 pm	TECHNICAL SESSION – I: HIGHER VERTEBRATES
Chairperson: Mr. P. R. Sinha , Country Representative, IUCN India Country Office Rapporteurs: Prof. Prakash Nautiyal & Ms. Elisabeth F. Mansur	
Speakers 1. Current Status of Higher Vertebrates and Impacts of Anthropogenic Stresses on them in the Ganges-Brahmaputra-Meghna Basin by Prof. R. K. Sinha, Department of Zoology, Patna University, Patna (India) 2. Monitoring the Mortality of Freshwater Cetaceans in the Sundarbans, Bangladesh: Progress, Challenges, and Potential by Mr. R. M. Mansur, Wildlife Conservation Society, Bangladesh Cetacean Diversity Project, Khulna (Bangladesh) 3. Current Status of Ganges River Dolphin in Rivers of Uttar Pradesh, India by Dr. Sandeep Behera, WWF – India, River Basin & Biodiversity Unit, New Delhi (India) 4. Trans-boundary Sanctuary between India and Bangladesh for Gharial (<i>Gavialis gangeticus</i>) Conservation by Dr. S. M. A. Rashid, Centre for Advanced Research in Natural Resources & Management (CARINAM), Adabor, Dhaka (Bangladesh) 5. Identification and Ecological Characteristics of Freshwater Dolphin “Hotspots” in the Sundarbans, Bangladesh by Prof. Benazir Ahmed (on behalf of Mr. Zahangir Alom), Department of Zoology, University of Chittagong, Chittagong (Bangladesh) 6. Avian Diversity of the River Ganges and Gandak in the Stretch of Bihar by Dr. Anupma Kumari, Environmental Biology Laboratory, Department of Zoology, Patna (India)	
01:30 pm - 02:15 pm	LUNCH

02:30 pm - 04:30 pm	TECHNICAL SESSION – II: FISH AND FISHERIES
Chairperson: Prof. Benazir Ahmed , Department of Zoology, University of Chittagong (Bangladesh) Rapporteurs: Dr. R. K. Manna & Dr. S. M. A. Rashid	
Speakers 1. Fish Diversity Status of the Ganges-Brahmaputra-Meghna River Basin by Prof. W. Vishwanath, Department of Life Sciences, Manipur University, Imphal (India) 2. Spatial Pattern of the Freshwater Fish Diversity in the Tributaries of Ganges Basin: Application of Multiple Indices and Identifying Priority Sites by Dr. U. K. Sarkar, National Bureau of Fish Genetic Resources, Lucknow (India) 3. Impact of Anthropogenic and Natural Drivers on Ganges-Brahmaputra-Meghna River Fish Biodiversity Loss of Bangladesh by Ms. Gouri Mondal, Upazila Fisheries Office, Manikganj (Bangladesh) 4. Species Richness of Freshwater Diatoms and Fish in the Mountain Chains of the Indian Subcontinent: Examining the Spatial Scales, Area-richness Model, the Role of Historical Factors and Threats to Native Iconic Mahseer (fish) Species by Prof. Prakash Nautiyal, Aquatic Biodiversity Unit, Department of Zoology & Biotechnology, HNB Garhwal University, Srinagar (India) 5. Fish Species Diversity in the River Madhumati, Bangladesh by Dr. M. K. Rahman, Bangladesh Fisheries Research Institute Mymensingh (Bangladesh) 6. Fishes Inhabiting River Ganges and its Tributaries in West Bengal and Livelihood of Vulnerable Villages by Dr. Madhumita Mukherjee, National Fisheries Development Board, Hyderabad (India)	
04:30 pm – 04:50 pm	TEA
04:50 pm - 06:20 pm	TECHNICAL SESSION – III: FISH AND FISHERIES
Chairperson: Prof. W. Vishwanath , Department of Life Sciences, Manipur University, Imphal (India) Rapporteurs: Dr. U. K. Sarkar & Ms. Gouri Mondal	
Speakers 1. Ichthyo-faunal Diversity of the Ganges River System in Central Himalayas, India: Conservation Status and Priorities by Dr. A. K. Singh, Directorate of Coldwater Fisheries Research, Bhimtal (India) 2. Fish Population Diversity and Dynamics of Raktodaha Beel, a Floodplain of North-western Region of Bangladesh by Dr. Md. Amimul Ehshan, ¹Department of Fisheries Bangladesh, Chapainawabganj (Bangladesh) 3. Conserving Trans-boundary Hilsa (<i>Tenualosa ilisha</i>): a Bangladesh Experience by Prof. M. Niamul Naser, Department of Zoology, Faculty of Biological Sciences, University of Dhaka, Dhaka (Bangladesh) 4. Role of Fisheries in Conservation of River Biodiversity in Vikramshila Gangetic Dolphin Sanctuary, Bihar, India by Prof. Sunil Kr. Choudhary, Vikramshila Biodiversity Research & Education Centre, Bhagalpur (India) 5. Influence of Salinity Regime on Distribution of Fish Species in Rivers of Hooghly- Matlah Estuary by Dr. R. K. Manna, Central Inland Fisheries Research Institute, Barrackpore (India)	
07:00 pm – 08:30 pm	Cultural Programme
08:30 pm – 09:30 pm	Symposium Dinner

DAY 2: April 05, 2014

09:00 am - 11:00 am	TECHNICAL SESSION – IV: RIVER BIODIVERSITY CONSERVATION: ISSUES AND OPPORTUNITIES
Chairperson: Prof. Ashwani Wanganeo , Department of Environmental Science and Limnology, Barkatullah University, Bhopal (India) Rapporteurs: Prof. B. K. Sharma & Prof. M. Niamul Naser	
Speakers 1. Conserving Riverine Biodiversity- A Himalayan Task? by Prof. Brij Gopal, Centre for Inland Waters in South Asia, Jaipur (India) 2. Management of Catchment Area of River Ganges and its Conservation by Prof. Ashwani Wanganeo, Department of Environmental Science and Limnology, Barkatullah University, Bhopal (India) Conservation Plan for Aquatic Fauna in the Brahmaputra Basin by Prof. S. P. Biswas, Department of Life Sciences, Dibrugarh University (India) 3. Multi-decadal Morphological Changes of the River Ganges near Patna using Remote Sensing and GIS Techniques by Mr. Shankar Dayal, Bihar State Disaster Management Authority, Patna (India) 4. Identifying Stakeholders in the Ganges Basin to Reconcile Conservation and Competing Land-uses and Processes in the Landscape by Dr. Samir Kr. Sinha, Wildlife Trust of India, Valmikinagar (India) 5. Geomorphic Condition of a part of the Ganges River System between Varanasi and Munger by Dr. Atul Aditya Pandey, Department of Geology, Patna University, Patna (India) 6. In the Womb of the Ganges: Gangotas and the Recent Existential Dilemmas by Prof. Jaismin Kantha, Department of History, St. Xavier 's College, Digha, Patna (India) 7. Pollution Load and Self -purifying Capacity of River Damodar – A Tributary of the Ganges by Prof. M. P. Sinha, Department of Zoology, Ranchi University, Ranchi (India) 8. An Educational Outreach Strategy for Freshwater Dolphin Conservation: Measuring the Results by Ms. Elisabeth F. Mansur, Wildlife Conservation Society Bangladesh Program, Bangladesh Cetacean Diversity Project, Khulna (Bangladesh)	
11:00 am - 11:30 am	TEA
11:30 am - 01:30 pm	TECHNICAL SESSION – V: PLANKTON AND BENTHIC ORGANISMS
Chairperson: Mihir Kanti Majumder , Dialogue Adviser, IUCN Bangladesh Country Office Rapporteurs: Prof. S. P. Biswas & Dr. Samir K. Sinha	
Speakers 1. River Biodiversity of Upper Ganges: Status, Stresses and Management by Prof. Ramesh C. Sharma, Department of Environmental Sciences, H. N. B. Garhwal University , Srinagar-Garhwal (India) 2. The Floodplains of the Brahmaputra River Basin – Globally Interesting Eco-tones with Rich Rotifer (Rotifera: Eurotatoria) Biodiversity by Prof. B. K. Sharma, Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University, Shillong (India) 3. Diatom Communities in Different Ecosystems of the Doon Valley by Dr. Rachna Nautiyal, Zoology Department, Government P.G. College, Dehradun (India) 4. Molecular Diversity of Phytoplankton Assemblages in Sundarbans Mangrove Wetlands Based on rbcL Gene Sequencing Approach by Dr. Punyasloke Bhadury, Integrative Taxonomy and Microbial Ecology Research Group, Department of Biological Sciences, Indian Institute of Science Education and Research, Kolkata (India)	
01:30 pm – 02:30 pm	LUNCH

02:30 pm - 04:30 pm	TECHNICAL SESSION –VI: PLANKTON AND BENTHIC ORGANISMS
Chairperson: Prof. Brij Gopal , Centre for Inland Waters in South Asia, Jaipur (India) Rapporteurs: Prof. M. P. Sinha & Dr. P. Bhadury	
Speakers 1. The Rich Biodiversity of Cladocera (<i>Crustacea: Branchiopoda</i>) in the Floodplains of the Brahmaputra River Basin by Prof. B. K. Sharma (on behalf of Dr. Sumita Sharma), Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University, Shillong (India) 2. Diversity with Identification Key to the Leech Species (<i>Annelida: Clitellata: Hirudinea</i>) of Gangetic Plains of Bihar by Dr. Gopal Sharma, Zoological Survey of India, Gangetic Plains Regional Centre, Patna (India) 3. The Role of Plant Diversity on the Stability of Wetland Ecosystem in the Indo-Gangetic Basin by Dr. Shardendu, Department of Botany, Patna Science College, Patna (India)	
04:30 pm – 05:30 pm	TEA (<i>Note: Visit to the displayed posters of the participants</i>)
05:30 pm – 06:30 pm	Valedictory Session: This session was graced by Mr. Dipak Kumar Singh, Secretary, Department of Environment and Forests, Government of Bihar (India); Mr. Mihir Kanti Majumder, Dialogue Adviser, IUCN Bangladesh Country Office, and Mr. P. R. Sinha, Country Representative, IUCN India Country Office. During this session recommendations of the Symposium were presented, discussed and finalised.
07:30 pm – 09:00 pm	SYMPOSIUM DINNER

DAY 3: April 06, 2014

10:00 am – 01:00 pm	Visit to Dolphin Habitat in the Ganges
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List of Participants

S. N.	Name	Affiliation
1.	Ahmed, Benazir Prof.	Department of Zoology, University of Chittagong, Chittagong (Bangladesh)
2.	Aich, Dipankar Mr.	IUCN Bangladesh, Dhaka (Bangladesh)
3.	Behera, Sandeep Dr.	WWF – India, River Basin & Biodiversity Unit, New Delhi (India)
4.	Bhadury, Punyasloke Dr.	Dept. of Biological Sciences, Indian Institute of Science Education and Research-Kolkata (India)
5.	Bharatari, Anjali Ms.	Wildlife Activist, Patna (India)
6.	Biswas, S. P. Prof.	Department of Life Sciences, Dibrugarh University, Dibrugarh (India)
7.	Chand, G. B. Dr.	Department of Zoology, Patna University, Patna (India)
8.	Chandrashekhara, S. Mr., <i>IFS</i>	Department of Environment and Forests, Govt. of Bihar (India)
9.	Chatterjee, Archana Ms.	Ecosystems for Life (E4L), IUCN India, New Delhi (India)
10.	Choudhary, D. N. Dr.	Department of Zoology, T. N. B. College, Bhagalpur (India)
11.	Choudhary, S. S. Mr., <i>IFS</i>	Department of Environment and Forests, Govt. of Bihar (India)
12.	Choudhary, Sunil K. Prof.	Vikramshila Biodiversity Research & Education Centre, P.G. Department of Botany, T. M. Bhagalpur University, Bhagalpur (India)
13.	Dayal, Shankar Dr.	Bihar State Disaster Management Authority, Patna (India)
14.	D'souza, Sister Dorris Dr. AC	Principal, Patna Womens' College, Patna University, Patna (India)
15.	Ehshan, Amimul, Md. Mr.	Department of Fisheries (DoF), Sadar, Chapainawabganj (Bangladesh)
16.	Gopal, Brij Prof.	Centre for Inland Waters in South Asia, Jaipur (India)
17.	Haque, Masoodal Dr.	Department of Zoology, Patna University, Patna (India)
18.	Hossain, Aktar Md., Mr	IUCN Bangladesh, Dhaka (Bangladesh)
19.	Jyoti, Bharat Mr., <i>IFS</i>	Department of Environment and Forests, Govt. of Bihar (India)
20.	Kaiswal, Prabhat Kr. Mr., <i>IFS</i>	Department of Environment and Forests, Govt. of Bihar (India)
21.	Kantha, Jaismin Prof.	Department of History, St. Xavier's College, Digha, Patna (India)
22.	Kedia, Dilip Kumar Dr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
23.	Khan, B. A. Mr., <i>IFS</i>	Principal Chief Conservator of Forests, Govt of Bihar (India)
24.	Khan, Furquan Ahmad Md. Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
25.	Khan, P. K. Dr.	Department of Zoology, Patna University, Patna (India)
26.	Kumar Prem Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)

S. N.	Name	Affiliation
27.	Kumar, Arvind Dr.	Department of Zoology, Patna University, Patna (India)
28.	Kumar, Naveen Mr.	Bihar State Tourism Development Corporation, Patna (India)
29.	Sinha, Sanjay Kumar Dr.	Development Officer, Patna University, Patna (India)
30.	Kumar, Vinay Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
31.	Kumari, Anupma Dr.	Department of Zoology, Patna University, Patna (India)
32.	Mandal, Sushmita Ms.	IUCN India, New Delhi (India)
33.	Manna, Ranjan Kr. Dr.	Central Inland Fisheries Research Institute, Barrackpore (India)
34.	Mansur, Rubaiyat M. Mr.	Wildlife Conservation Society, Bangladesh Cetacean Diversity Project, Khulna (Bangladesh)
35.	Mansur, Elisabeth Fahrni Ms.	Wildlife Conservation Society Bangladesh Program, Bangladesh Cetacean Diversity Project, Khulna (Bangladesh)
36.	Mazumder, Mihir Kanti Mr.	IUCN Bangladesh Advisor, Dhaka (Bangladesh)
37.	Mishra, Amarendra Prof.	Professor of Statistics, and Dean, Faculty of Science, Patna University, Patna (India)
38.	Mishra, K. C. Prof.	Department of Zoology, T. N. B. College, Bhagalpur (India)
39.	Mishra, V. Prof.	Department of Zoology, Patna Science College, Patna (India)
40.	Mondal, Gouri Ms.	Upazila Fisheries Office, Singair, Manikganj (Bangladesh)
41.	Morshed, A. G. J. Mr.	Wildlife Biology Division, Vienna Zoo, Austria, and IUCN Bangladesh, Dhaka
42.	Mukherjee, Madhumita Dr.	National Fisheries Development Board, Hyderabad (India)
43.	Naser, M. Niamul Prof.	Faculty of Biological Sciences, University of Dhaka, Dhaka (Bangladesh)
44.	Nautiyal, Prakash Prof.	Aquatic Biodiversity Unit, Department of Zoology & Biotechnology, H. N. B. Garhwal University (A Central University), Srinagar-Garhwal (India)
45.	Nautiyal, Rachna Dr.	Zoology Department, Government P. G. College, Dakpathar, Dehradun (India)
46.	Neetu Dr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
47.	Nishat, Bushra Ms.	IUCN Bangladesh, Dhaka (Bangladesh)
48.	Pal, D. K. Dr.	Department of Zoology, Patna University, Patna (India)
49.	Pandey, Atul Aditya Mr.	Department of Geology, Patna Science College, Patna University, Patna (India)
50.	Paswan, K. N. Prof.	Head of University Department of Geography, Patna University, Patna (India)
51.	Poddar, P. K. Prof.	Principal, B. N. College, Patna University, Patna (India)
52.	Purusharthi, Gyan P. Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
53.	Rahman Khalilur, Md. Dr.	Bangladesh Fisheries Research Institute, Mymensingh (Bangladesh)

S. N.	Name	Affiliation
54.	Rashid, S. M. A. Dr.	Centre for Advanced Research in Natural Resources & Management (CARINAM), Adabor, Dhaka (Bangladesh)
55.	Rukhaiyar, S. S. Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
56.	Sarkar, Lina Dr.	Sri Chaitanya College, HABRA, West Bengal (India)
57.	Sarkar, U. K. Dr.	National Bureau of Fish Genetic Resources (NBFGR), Lucknow (India)
58.	Shardendu, Dr.	Department of Botany, Patna Science College, Patna (India)
59.	Sharma, B. K. Prof.	Department of Zoology, North-Eastern Hill University, Shillong, (India)
60.	Sharma, Gopal Dr.	Zoological Survey of India, Gangetic Plains Regional Centre, Patna (India)
61.	Sharma, Ramesh C. Prof.	Department of Environmental Sciences, H. N. B. Garhwal University (A Central University), Srinagar-Garhwal (India)
62.	Sharma, Sumita Dr.	Department of Zoology, North-Eastern Hill University, Shillong, (India)
63.	Siddique, Masood Mr.	Center for Natural Resource Studies (CNRS), Banani, Dhaka, Bangladesh
64.	Singh, A.K. Dr.	Directorate of Coldwater Fisheries Research, Bhimtal (India)
65.	Singh, Ajit Kr. Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
66.	Singh, Dipak Kumar Mr., IAS	Department of Environment and Forests, Govt. of Bihar (India)
67.	Singh, Gopal Dr., IFS	Department of Environment and Forests, Govt. of Bihar (India)
68.	Singh, Subhash C. Prof.	Bihar State Pollution Control Board, Patna (India)
69.	Sinha, Dolly Prof.	Magadh Mahila College, Patna University, Patna (India)
70.	Sinha, M. P. Prof.	Department of Zoology, Ranchi University, Ranchi (India)
71.	Sinha, P. R. Mr.	IUCN Country representative, New Delhi (India)
72.	Sinha, R. K. Prof.	Department of Zoology, Patna University, Patna (India)
73.	Sinha, Samir Kumar Dr.	Wildlife Trust of India, Field Station: Valmiki Tiger Reserve, Valmikinagar (India)
74.	Sinha, Shailendra Kr Mr.	Environmental Biology Lab., Dept. of Zoology, Patna University, Patna (India)
75.	Sinha, U. K. Prof.	Principal, Patna Science College, Patna University, Patna (India)
76.	Srivastava, S. K. Prof.	Department of Zoology, Patna University, Patna (India)
77.	Vishwanath, W. Prof.	Department of Life Sciences, Manipur University, Manipur (India)
78.	Wanganeo, Ashwani Prof.	Department of Env. Sc. & Limnology, Barkatullah University, Bhopal (India)
79.	Zaman, Najmuz Dr.	Patna University, Patna (India)

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Patna University, established by an Act XVI of 1917 passed by the Governor General India in Council on October 1, 1917, is the 7th oldest University of India and the first in Bihar. It has catered to the higher education needs of Bihar, Orissa and Nepal for many years.

The University has a full-fledged Law College, Engineering College, Medical College, Teacher's Training College, Science College etc. and several Post-Graduate Departments. It also provides the latest technological facilities. The University has also introduced a large number of new courses such as Biotechnology, Biochemistry, BCA, MCA, Environmental Science and Management, Gemology, Disaster Management, GIS and Remote Sensing among several others.

An overwhelming number of illustrious teachers, lawyers, judges, journalists, literateurs, scientists, engineers, doctors, politicians, bureaucrats are the proud alumni of Patna University.

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The foundation of the University of Chittagong was laid in the year 1964. The University offers courses in varied disciplines of Pure and Applied Sciences, Biological Sciences, Engineering, Social Sciences, Medicine, Arts and Humanities, Business Administration and Law functioning under eight faculties, 41 departments, eight institutes, and five research centres, with 859 efficient faculty members.

Among the University's stellar faculty has been Professor Dr. Mohammad Yunus who was awarded the Nobel Peace Prize in 2006, for his concept of Grameen Bank, a project started on the campus.

The University has consistently been engaged in organising workshops/ seminars on critical subjects and the recent symposium on "River Biodiversity: Ganges-Brahmaputra-Meghna River System" in collaboration with Patna University, India only adds to its engagement with topical issues.



Project Team

Brian J. Furze, *Project Director, IUCN*

Bushra Nishat, *Project Manager, IUCN Bangladesh*

Archana Chatterjee, *Project Manager, IUCN India*

Dipankar Aich, *Dialogue Coordinator, IUCN Bangladesh*

Sushmita Mandal, *Dialogue Coordinator, IUCN India*

AJM Zobaidur Rahman, *Communications Officer, IUCN Bangladesh*

Aditi Jha, *Programme Officer, IUCN India*

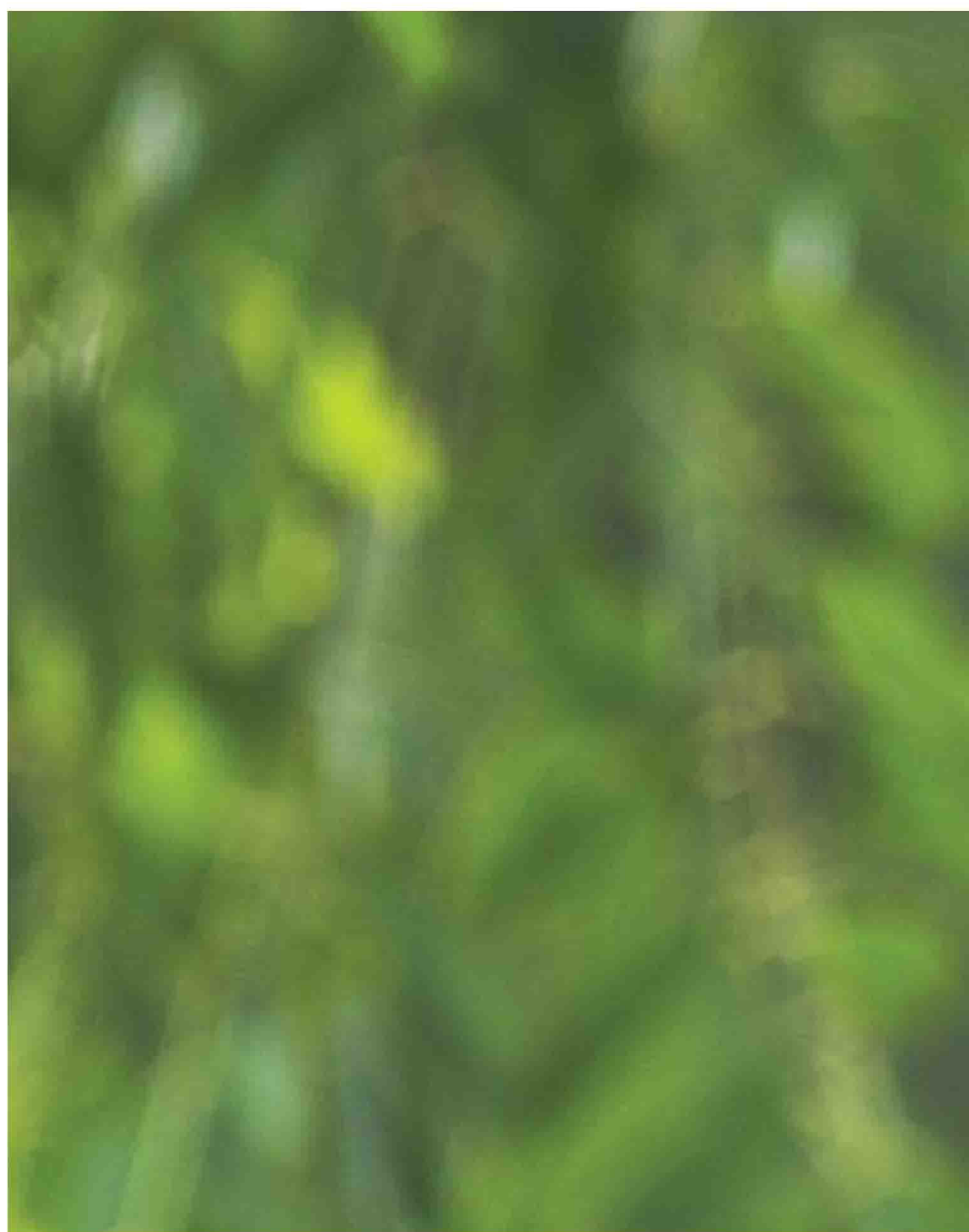


**INTERNATIONAL UNION
FOR CONSERVATION OF NATURE**

Asia Regional Office
63 Sukhumvit Soi 39
Bangkok 10110, Thailand
Tel: +66 2 662 4029
Fax: +66 2 662 4389
www.iucn.org/asia

Bangladesh Country Office
House 16, Road 2/3, Banani
Dhaka 1213, Bangladesh
Tel: +8802 9890423
Fax: +8802 9892854
www.iucn.org/bangladesh

India Country Office
B 88, Neeti Bagh
New Delhi 110049, India
Tel/Fax: +91 11 4605 2583, 26527742
www.iucn.org/india



ISBN 978-93-5196-807-8



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