Proceedings of the International Conference on Biodiversity – Present State, Problems and Prospects of its Conservation

January 8-10, 2011
University of Chittgaong, Chittagong 4331, Bangladesh

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David J. Chivers (Eds.)

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NO 7491, Trondheim, Norway

University of Chittagong
Chittagong 4331, Bangladesh

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Cover photo: Mountains from Teknaf Wildlife Sanctuary, Cox's Bazar, Bangladesh is a part of Teknaf Peninsula and located in the south-eastern corner of Bangladesh near the Myanmar border. It was the first protected area in Bangladesh established in 1983 to protect wild Asian elephants (Elephas maximus). (Photograph © Per Harald Olsen, NTNU, Trondheim, Norway).

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Preface

The continued growth of human populations and of per capita consumption has resulted in unsustainable exploitation of global biological diversity, exacerbated by climate change, ocean acidification, and other anthropogenic environmental impacts. Therefore, the effective conservation of biodiversity is essential for human survival and the maintenance of ecosystem processes. Despite some conservation successes especially at local scales and increasing public, and government interest in living sustainably, biodiversity continues to decline. Although we now have a great deal of information on the state of biodiversity, the biological and social processes that affect it, and the pressures and underlying drivers that result in its continued decline, there are also some key knowledge gaps. There are few data on the status, trends, or functional importance of microbes, invertebrates, and many plant groups, or of wild genetic diversity. How different components of biodiversity contribute and relate to the provision of services or create resilience to environmental change is poorly understood. Our knowledge of ecosystem management and restoration is inadequate to meet the challenges of reconciling increased production with sustaining ecosystem services, or of ameliorating the negative effects of climate change. Existing knowledge, often including extensive traditional knowledge, is generally underused in decision-making at local, national, and international levels. There is an urgent need both to learn from practical experience and to disseminate research findings to practitioners. In addition, scientific capacity is not equally shared across the globe, and in particular is concentrated in rich developed countries rather than in the regions that face the most substantial challenges to maintaining and enhancing biodiversity.

Finally the Proceedings of the International Conference on *Biodiversity – Present State, Problems, and Prospects of its Conservation* (08-10 January 2011, Chittagong, Bangladesh) are completed. It took us more than a year! The editors would first of all like to thank the organising committee, particularly Professor Farid Ahsan, Professor Md. Abdul Gofur Khan, Professor Benazir Ahmed, and all their assistants from the Zoology Department – University of Chittagong, Bangladesh for a perfect conference. We would also like to acknowledge all the speakers and participants for interesting contributions and good discussions. Although this was an international conference – almost all papers were about biodiversity problems and challenges in Bangladesh, which is also reflected in these proceedings. Of the 5 keynotes and 18 papers presented in the conference, 3 keynotes and 13 papers are presented in these proceedings.

We would like to give a special thanks to Professor Mohammad Mostafa Feeroz, Jahangir Nagar University, Dhaka, Bangladesh, Mr. Craig Ryan Jackson, and Mr. Per Harald Olsen, NTNU, Norway for their contributions and inputs to these proceedings, and at least but not the least to Dr. A H M Raihan Sarker for his contributions behind the scene – both in organising the conference as well as in his endless work to finalise the proceedings report and layout.

March 2012

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David J. Chivers

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Message from Honourable Ambassador
Royal Norwegian Embassy, Dhaka, Bangladesh

The United Nations marked the year 2010 as the *International Year of Biodiversity*. Protecting the environment and pursuing sustainable development are two essential and interconnected concerns for our time. There is an urgent need to conserve the biodiversity in order to ensure the resource availability to the future generations. The wildlife is an anchor of the forest ecosystem and one of the crucial links to the future. Governments have made commitments in multilateral and bilateral contexts. However, these global partnerships must be translated into action.

In response to this, the Royal Norwegian Government has undertaken many initiatives to assist in improving the biodiversity status of developing countries. Cooperation between universities and research institutions in Norway and corresponding institutions in developing countries, and efforts to promote increased South - South cooperation are part of these efforts. It also includes the project on *Ecology, behaviour, and conservation of some wildlife of Bangladesh*.

The Royal Norwegian Embassy in Dhaka appreciates the joint research venture between the Department of Biology, the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway and the Department of Zoology, University of Chittagong (CU), Chittagong, Bangladesh. This cooperation has been established within the framework of the Norwegian Council of Universities' Programme for Development Research and Education (NUFU) Cooperation for development, research, and education. It is financed by NUFU and the Norwegian Government. I am confident that by working together under a joint initiative between Norway and Bangladesh, which allows for sharing of knowledge, building capacities and exchanging best of practices will contribute to better protection of wildlife and habitats and make a real impact on the ground.

This international conference organised in collaboration between NTNU and CU on *Biodiversity- Presents State, Problems, and Prospects of its Conservation* at the University of Chittagong, is accordingly very welcome. I am hopeful that the Chittagong Conference 2011 will come up with useful recommendations and arrive at conclusions, which might contribute to the revival of the wildlife and the rejuvenation of forest in this tropical region.

I am wishing the success of the Chittagong Conference - 2011.

January 2011

Ragne Birte Lund
Ambassador
The Royal Norwegian Embassy
Dhaka, Bangladesh

Message from Rector
NTNU, Trondheim, Norway

The Norwegian University of Science and Technology, NTNU, Trondheim is highly appreciated to organise an international conference on *Biodiversity – Present State, Problems, and Prospects of its Conservation* to be held in January 2011 at the University of Chittagong, Chittagong, Bangladesh following the *International Year of Biodiversity 2010* declared by the United Nations. The conference is an initiative under the bilateral collaboration between the Norwegian University of Science and Technology (NTNU), Trondheim, Norway and the University of Chittagong, Chittagong 4331, Bangladesh for the period of 2007-11. It is being financed by the Norwegian Programme for Development Research and Education (NUFU) under the project entitled as *Ecology, behaviour, and conservation of some wildlife of Bangladesh*. The project is working on diversified issues in relation to conserve wildlife in Bangladesh that can be a valuable scientific guideline to the researchers as well as to the wildlife managers in Asia and Africa in near future. So far I know that part of the project research to be presented in the upcoming conference and therefore the major aim of this conference is to create a forum amongst all stakeholders involved in biodiversity conservation national, regional, and international level where critical and constructive discussion can occur in order to improve the quality of research in all fields of the conservation biology.

The recognition of the importance of biodiversity in today's world has rapidly increased. Climate change is one of the serious threats to sustainable biodiversity conservation and management. It poses adverse impacts on human health, food security, the environment, economic activities, and physical infrastructure. Among the possible consequences include lower agricultural yields, growing water stress, flooding of low-lying areas, and spread of infectious diseases to new and warmer areas. These changes in the natural ecosystems threaten biological species thereby adding pressure to the terrestrial and marine ecosystems that are already stressed by land use change, pollution, over-harvesting, and introduction of alien species. Although the projected impacts of climate change on biodiversity have been articulated by many, the contributions of biological resources to reduce the impacts of climate change on people and food production have not been fully appreciated. The link between biodiversity and climate change is not one-way. As climate change alters the state of biodiversity, changes in biodiversity can likewise affect the world's climate. Biodiversity resources and biodiversity conservation strategies may thus offer adaptation and mitigating measures to climate change.

However, one of the major goals of the conference is to promote research in conservation biology and find ways to integrate future collaboration among all stakeholders from all corners of the world in order to improve the situation. I also hope that, this conference will contribute towards enhancing conservation biology related research at the University of Chittagong as well as at the NTNU in biology and related disciplines.

I compliment the Department of Zoology at the University of Chittagong and the Department of Biology at the NTNU and the main organising committee of the conference.

January 2011

Professor Torbjørn Digernes
Rector
Norwegian University of Science and Technology, NTNU
Trondheim 7491, Norway

Message from Vice-Chancellor
University of Chittagong, Chittagong, Bangladesh

It is my pleasure to welcome the proceedings of the international conference on *Biodiversity – Present State, Problems, and Prospects of its Conservation* held on January 8-10, 2011 at the University of Chittagong, Bangladesh. We are well aware that human activities especially in our protected areas deeply affect the natural environment. The lack of hard scientific information is a glaring handicap in our understanding and prediction of the impacts of these activities. As the human population increases in our country like other developing countries in Asia and Africa and the use of our natural resources continues to intensify, the issue of sustainable use of natural resources becomes more critical.

Bangladesh in particular relies heavily on its living natural resources. It is important for us to understand the critical processes, status and diversity of these resources for us to be able to use them wisely. We cannot take for granted that the natural resources will tolerate more of human's abuse. It is therefore essential that in our desire to sustain or even improve our natural ecosystems, we emphasize the fundamental knowledge required to understand these living worlds.

The conference proceeding on biodiversity is timely. Many species are extinct and some species become endangered in the country today. Global warming, over-exploitation, and conflict between human and nature are now familiar topics making headlines across the globe. We rely heavily on our scientists to advise us on what to do to remedy this situation and to prepare for the future. Therefore, the proceedings published the research works of scientists from home and abroad will continue the mission to improve the future of our protected areas as well as biodiversity.

Our appreciation goes to the conference organisers and members of the scientific committee whose hard work has made this event possible.

Thank you.

January 2011

Professor Anwarul Azim Arif
Vice-Chancellor
University of Chittagong
Chittagong 4331, Bangladesh

Programme Schedule

Day 1	8 January 2011	
Venue		**Auditorium, RCMPS, University of Chittagong (CU), Chittagong 4331, Bangladesh.**
	09:00 - 09:30	**Registration**
	09:30 - 10:30	**Inauguration** Special guest – Professor Dr. Md. Alauddin, Vice-Chancellor (In-Charge), CU. Special guest – Professor Dr. Md. Nural Anwar, Dean, Faculty of Biological Science, CU. Special guest – Professor Dr. Eivin Røskaft, Department of Biology, NTNU, Norway. Special guest – Professor Gitiara Nasreen, Department of Mass Communication & Journalism, Dhaka University, Bangladesh. Special guest – Professor Dr. Jamal Nazrul Islam, RCMPS, CU. Special guest – Dr. David J. Chivers, Anatomy School, Cambridge University, U.K. Special guest – Ms. Guri Eggan, NUFU Coordinator, NTNU, Norway.
	10:30 – 11:00	**Tea / coffee break**
Technical Session-1	11:00 - 11:25	**Chairman: Professor Dr. Eivin Røskaft** *Department of Biology, NTNU, Norway.* **Rapporteur: Professor Dr. Md. Abdul Gofur Khan** *Department of Zoology, University of Chittagong, Bangladesh* **Keynote address; Primate Conservation in South - East Asia – Past, Present and Future.** ***Speaker: Dr. David J. Chivers, Reader*** *Department of Physiology, Development and Neuroscience, University of Cambridge, U.K.*
	11.25 – 11.45	**Resource Partitioning among the Sympatric Primate Species of West Bhanugach Forest Reserve of Bangladesh.** *M. M. Feeroz* *Department of Zoology, Jahangirnagar University, Dhaka, Bangladesh.* ***Speaker: Professor Dr. M. M. Feeroz***
	11:45 –11:55	**Discussion**
	11.55 – 12.15	**Space sharing by Hoolock Gibbons (*Hoolock hoolock*) in Lawachara National Park, Bangladesh.** *M. K. Hasan and M. M. Feeroz* *Department of Zoology, Jahangirnagar University, Dhaka, Bangladesh.* ***Speaker: M. K. Hasan, Assistant Professor***
	12:15 – 12:25	**Discussion**
	12:25 – 13:05	**Lunch Break**
	13.05 – 13.25	**Feeding Behaviour and Ecology of the Common Langurs (*Semnopithecus entellus*) of Keshabpur in Bangladesh.** *Mst. Ummay Habiba Khatun [1], M. Farid Ahsan [1], Eivin Røskaft [2]* *[1]Department of Zoology, University of Chittagong, Chittagong, Bangladesh.* *[2]Department of Biology, NTNU, Trondheim, Norway.* ***Speaker; Mst. Ummay Habiba Khatun, PhD Research Fellow***
	13:25 – 13:35	**Discussion**
	13:35 – 13:45	**Summary report**
	13:45 – 13:55	**Tea / coffee break**
Technical Session-2	13:55 – 14:20	**Chairman: Professor Dr. Jamal Nazrul Islam** *RCMPS, University of Chittagong, Chittagong, Bangladesh.* **Rapporteur: Professor Dr. M. M. Feeroz** *Department of Zoology, Jahangirnagar University, Dhaka, Bangladesh.* **Keynote address: Importance of the Eastern Region of Bangladesh in Insect Conservation with Special Reference to Odonata.** ***Speaker: Professor Dr. Shafique Haider Chowdhury*** *Ex - Faculty member, Department of Zoology, University of Chittagong, Chittagong, Bangladesh.*
	14:20 – 14:40	**A DNA Bar - Coding Initiative in Bangladesh for Molecular Taxonomy and Biodiversity Conservation.** *Badrul Amin Bhuiya [1], Santosh Mozumdar [1], Mostafa Kamal Pasha [2]* *[1]Department of Zoology, University of Chittagong, Chittagong, Bangladesh.* *[2]Department of Botany, University of Chittagong, Chittagong, Bangladesh.* ***Speaker: Professor Dr. Badrul Amin Bhuiya***
	14:40 – 14:50	**Discussion**
	14:50 – 15:00	**Tea / coffee break**
	15:00 – 15:20	**Bird Parasites – their Community Structure, Epidemiological Aspect, Interactions and Relationships with Host Phylogeny and Food Habits.** *Md. Abdul Gofur Khan [1], Aftab Hossain [1], Eivin Røskaft [2], Soma Chowdhury Biswas [3]* *[1]Department of Zoology, University of Chittagong, Chittagong, Bangladesh.* *[2]Department of Biology, NTNU, Trondheim, Norway.* *[3]Department of Statistics, University of Chittagong, Chittagong, Bangladesh* ***Speaker: Professor Dr. Md. Abdul Gofur Khan***
	15:20 – 15:30	**Discussion**
	15:30 – 15:50	**Breeding Ecology of the Bank Myna, *Acridotheres ginginianus* (Latham 1790), in Chapai Nawabganj, Bangladesh.**

		M. Farid Ahsan and M. Tarik Kabir
		Department of Zoology, University of Chittagong, Chittagong, Bangladesh.
		Speaker: Professor Dr. M. Farid Ahsan
	15:50 – 16:00	**Discussion**
	16:00 – 16:10	**Tea / coffee break**
	16:10 – 16:30	**First Record of Land Molluscs *Macrochlamys lubrica*, *Girasia hookeri*, *Euaustenia cassida*, and *Sitala attegia* (Mollusca: Stylommatophora: Ariophantidae) from Bangladesh.**
		Md.SarwarJahan [1] ; Mahiuddin Md.Shahjahan Bhuiyan [1] , Md.Redwanur Rahman [1] , Minu Hoque [2]
		[1] Institute of Environmental Science Rajshahi University, Rajshahi, Bangladesh.
		[2] Dr. Khandaker Mosharraf Hossain College, Daudkandi, Comilla, Bangladesh.
		Speaker: Dr. Md. Redwanur Rahman, Assistant Professor
	16:30 – 16:40	**Discussion**
	16:40 – 16:50	**Summary report**
Technical	16:50 – 17:15	**Chairman: Professor Dr. M. Farid Ahsan**
Session-3		*Department of Zoology, University of Chittagong, Chittagong, Bangladesh***.**
		Rapporteur: Dr. Md. Aktar Hossain
		*Assistant Professor, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh***.**
		Keynote address: Species Conservation in Bangladesh and Beyond.
		Speaker: Professor Dr. Jamal Nazrul Islam
		RCMPS, University of Chittagong, Chittagong, Bangladesh,
	17:15 – 17:25	**Tea / Coffee break**
	17:25 – 17:45	**Changing Trends in Biodiversity of the Mangroves of Bangladesh.**
		Neaz Ahmad Siddiqi
		Bangladesh Forest Research Institute, Chittagong, Bangladesh.
		Speaker: Dr. Neaz Ahmad Siddiqi. Ex - Chief Research Officer
	17:45 – 17:55	**Discussion**
	17:55 – 18:15	**Diversity of Finfish and Shellfish of the River Halda with Notes on their Conservation.**
		Mohammad Ali Azadi and Mohammad Arshad-ul-Alam
		Department of Zoology, University of Chittagong, Chittagong, Bangladesh.
		Speaker: Professor Dr. Mohammad Ali Azadi
	18:15 – 18:25	**Discussion**
	18:25 – 18:45	**Present Status of Wetland Biodiversity - A Study in Sujanagar Upazila, Pabna, Bangladesh.**
		Md. Shafiqul Islam
		Institute for Sustainable Development, University of Liberal Arts Bangladesh, Dhaka, Bangladesh.
		Speaker: Md. Shafiqul Islam, Assistant Professor
	18:45 – 18:55	**Discussion**
	18:55 – 19:05	**Summary report**
	19:05 -	**Official dinner by the authority of the University of Chittagong, Chittagong**
DAY 2	**9 January 2011**	
Venue		**Auditorium, RCMPS, University of Chittagong, Chittagong 4331, Bangladesh.**
Technical	09:00 – 09:25	**Chairman: Dr. D. J. Chivers**
Session-4		*Reader, Department of Physiology, Development and Neuroscience*
		University of Cambridge, Cambridge, United Kingdom.
		Rapporteur: Professor Dr. Niaz Ahmed Khan
		Country Head, IUCN, Dhaka, Bangladesh.
		Keynote address: Human - wildlife Interactions in Africa and Asia: A Special Reference to Tanzania and Bangladesh.
		Speaker: Professor Dr. Eivin Røskaft
		Department of Biology, NTNU, Trondheim, Norway.
	09:25 – 09:45	**A Probe into the Threats to Asian elephant (*Elephas maximus*) and Human - Elephant Conflicts in Bangladesh**
		Mohammad Abdul Motaleb, Sayad Mahmudur Rahman, Niaz Ahmed Khan
		IUCN Bangladesh, Dhaka, Bangladesh.
		***Speaker*: Mohammad Abdul Motaleb, Project Officer**
	09:45 – 09:55	**Discussion**
	09:55 – 10:05	**Tea /coffee**
	10:05 – 10:25	**An Assessment of Sustainability of Community Based Forest Management of Tropical Forest: A Case Study from Two Buffer Zone Community Forest of Chitwan District, Nepal .**
		Niranjan Dhungana
		Institute of Forestry, Pokhara, Nepal.
		Speaker: Niranjan Dhungana, MSc. Student
	10:25 – 10:35	**Discussion**
	10:35 – 10:55	**A Critique on Sustainable Natural Resources of Bangladesh and their Management: the Role of the Media.**
		Sudhangshu Sekhar Roy
		Department of Mass Communication and Journalism, University of Dhaka, Dhaka, Bangladesh.
		Speaker: Dr. Sudhangshu Sekhar Roy, Assistant Professor
	10:55 – 11:10	**Discussion**
	11:10 - 11:20	**Summary report**
	11:20 – 11:30	**Tea /coffee break**
Technical	11:30 – 11:55	**Chairman: Dr. Neaz Ahmad Siddiqi**
Session-5		*Ex - Chief Research Officer, Bangladesh Forest Research Institute, Chittagong, Bangladesh.*

		Rapporteur: Dr. Tapan Kumar Nath *Associate Professor, Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh.*
		Keynote address: A Reconnaissance of the Trend and Characteristics of the Natural Resource Management in Bangladesh. ***Speaker: Professor Dr. Niaz Ahmed Khan*** *Country Head, IUCN Bangladesh, Dhaka, Bangladesh.*
	11:55 – 12:15	**Floral Diversity of Indigenous Community Conserved Forests of Chittagong Hill Tracts, Bangladesh.** *Farid Uddin Ahmed* *The Arannayk Foundation, Dhaka, Bangladesh.* ***Speaker: Farid Uddin Ahmed, Executive Director***
	12:15 – 12:25	**Discussion**
	12:25 – 12:45	**Tree-Species Diversity of a Remnant Natural Dipterocarp Forest versus Mono-plantation in Rajghat, Cox's Bazar (North Forest Division) of Bangladesh.** *M. K. Hossain and M. A. Mamun* *Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh.* ***Speaker: Professor Dr. M. K. Hossain***
	12:45 – 12:55	**Discussion**
	12:55 – 13:40	**Lunch**
	13:40 – 14:00	**An Evaluation of Endemism and Endemics in Bangladesh Flora.** *M. K. Pasha* *Department of Botany, University of Chittagong, Chittagong, Bangladesh* ***Speaker: Professor Dr. M. K. Pasha***
	14:00 – 14:10	**Discussion**
	14:10 – 14:20	**Conservation of Guava (*Psidium guajava*) Germplasm Using Wilt - resistant Rootstock of Poly Piara (*Pisidium cattleianum*).** ***M. A. Rahim[1], K. K. Islam[1], M. S. Islam[2], M. S. Alam[1], F. Islam[3], and N. Naher[4]*** *[1]Department of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh.* *[2]Department of Agriculture Economics, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh.* *[3]HRC, BARI, Gazipur, Bangladesh.* *[4]Intercooperation, BARC, Dhaka, Bangladesh.* ***Speaker: Professor Dr. Md. Abdur Rahim***
	14:20 – 14:30	**Discussion**
	14:30 – 14:40	**Tea / coffee break**
	14:40 – 15:00	**Propagation of *Flacourtia jangomas*: An Approach Towards the Domestication and Conservation of a Wild Fruit Species in Bangladesh.** *Mandira Sen [1], I.U. Jwel [1], Md. Alamgir Kabir [2 & 3], Md. Aktar Hossain [1 & 3]* *[1]Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh.* *[2]Department of Agroforestry, Patuakhali Science and Technology University, Patuakhali, Bangladesh.* *[3]Division of Biotechnology, College of Life sciences and Biotechnology, Korea University, Seoul, Republic of Korea.* ***Speaker: Dr. Md. Aktar Hossain, Assistant Professor***
	15:00 – 15:10	**Discussion**
	15:10 – 15:20	**Summary report**
	15:20 – 15:50	**Group discussion for recommendations**
	15:50 – 16:40	**Group presentation for recommendations**
	16:40 – 16:55	**Final recommendations**
	16:55 – 17:00	**Closing remarks, Team Leader, NUFU Project, NTNU, Trondheim, Norway**
	17:00 – 17:05	**Special guest –** Mr. Ishtiaq Uddin Ahmad, Chief Conservator of Forest, Bangladesh Forest Department, Dhaka. Bangladesh.
	17:05 – 17:10	**Special guest –** Dr. Niaz Ahmed Khan, Country Head, IUCN-Bangladesh, Dhaka, Bangladesh.
	17:10 – 17:15	**Chairman / Vice-Chairman, Conference Committee**
	17:15 -	**Official dinner – Courtesy by the NUFU project, University of Chittagong, Chittagong.**
DAY 3	**10 January 2011**	
	07:00 – 18:00	**Field Trip-Bandarban Forest Division, CHTs Bangladesh**
	19:00 – 20:00	Official dinner by the Chittagong Conference-2011

Contents

Keynote 1: Primate Conservation in South-East Asia – Past, Present and Future

David J. Chivers
Wildlife Research Group, The Anatomy School, University of Cambridge, U.K.
E-mail; djc7@cam.ac.uk

Abstract

Primates and rain-forests in South-east Asia are declining rapidly. Over 40 years their ecology and behaviour has been documented, along with the loss of forests. Conservation needs to embrace protection of key habitats, especially watersheds, and sustainable management of large areas, so that 50 % of the land area can be kept forested. Shifting cultivation and selective logging have roles to play, but monocultures are a real threat. Translocation and reintroduction have increasing roles to play in preventing extinction. Education of peoples, locally and globally, and of governments, are crucial.

Keywords; *orang-utans, gibbons, langurs, macaques, socio-ecology, conservation, sustainable management, education.*

Introduction

I used to be an optimist, but in recent years I have become a pessimist. Whatever we scientists do, it is proving ineffective and endangered wildlife, especially the primates – near the top of the pyramid of production – are spiralling to oblivion. I report on 40 years of increasing gloom.

For the first 20 years, we showed through our research the needs of the various primates – the widespread gibbons, langurs, and macaques – in the forests, in terms of food and space and how to conserve them. For the last 20 years, there have widespread and vigorous campaigns – in the North and South – to implement such measures, which originate with the local people and local scientists. Primate populations have become increasingly fragmented and threatened with extinction. Inevitably, given my research career, gibbons are central to this discussion.

Evolutionary background

The Sunda Shelf emerged out of the sea, as a consequence of volcanic activity, about 12 million years ago. It owes its uniquely rich fauna (and flora) to an admixture of immigrants, first from the Indian sub–continent - the Siva–Malayan fauna - and then, later from China – the Sino-Malayan fauna (Figure 1). Chivers (1977) proposed a model of gibbon evolution, relating to the frequent changes of sea level during the latter part of the Pleistocene, as ice formed and the Sunda Shelf was exposed as one land mass, and as the ice melted and the Shelf was flooded, leaving a number of islands. The isolated gibbon populations speciated, wholly or partly, and then migrated when land bridges were restored (Figure 2). The key point is that, after the initial spread of three of the genera into different parts of the Sunda Shelf, gibbon speciation occurred within the Shelf (Figure 3), with subsequent, sequential spread back to the mainland, with the hoolock (fourth genus, in the van) - rather than species spreading out from the Asian mainland. The pileated and lar gibbons followed, and the Kloss, Bornean and Javan gibbons originated on the edges of the Shelf, with agile and lar in the 'centre'. During the periods of lowest sea level, the centre of the Shelf dried out, and the key rain-forest relicts, into which gibbons and other forest animals retreated and out of which they spread when sea level rose, were in eastern Indo-China and southern China, north-east Borneo, west Java, north Sumatera and southern Burma, as well as the Mentawai Islands.

There has been thorough re-analysis of all morphological and behavioural characters by multivariate techniques (Geissmann 1993). It had been difficult to resolve whether siamang, concolor or hoolock are the most primitive (see above), but the most parsimonious picture has the hoolock gibbon branching off first, followed by concolor and then siamang; Kloss follows, and then Mueller's, moloch, pileated, lar and agile. Patterns vary according to whether one uses cranial and dental, pelage, song or all variables. It is of significance to Bangladesh that the hoolock may be closest to the ancestor of gibbons. Similar scenarios can be devised for the langurs, for whom seas and rivers are also barriers to spread, but the macaques are not so restricted and the same two species occur across the Sunda Shelf.

The primates

The primate communities of South-east Asia (and South Asia) generally comprise at least two species of macaque (*Macaca*), two species of langur (*Trachypithecus* and *Presbytis*) and the occasional odd-nosed monkey – *Nasalis*, *Pygathrix* or *Rhinopithecus*), and one or two species of ape

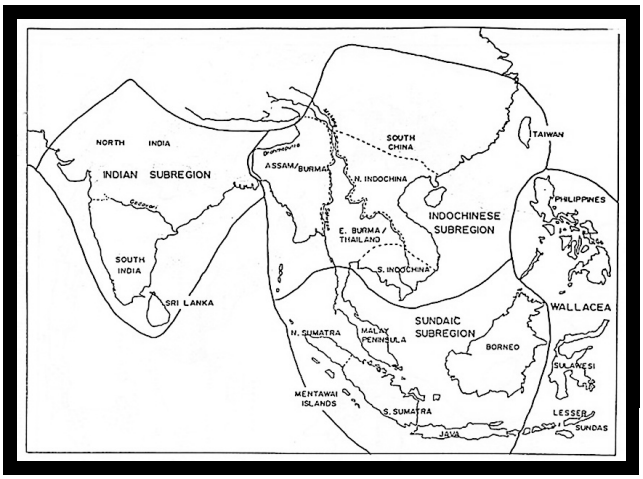

Figure 1 *The Oriental region and sub-regions (Marsh 1987).*

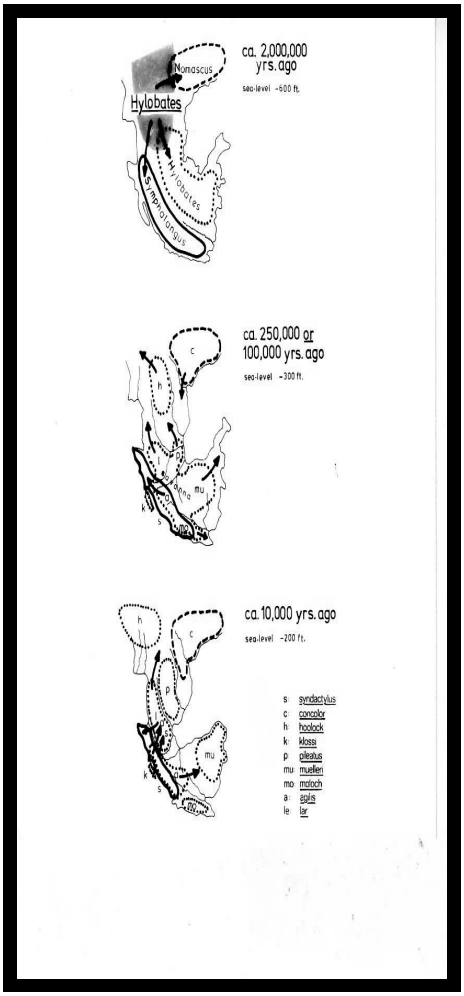

Figure 2 *Late Pleistocene movements of gibbons leading to speciation (Chivers 1977).*

(Hylobatidae, *Pongo*), in addition to the nocturnal slow loris (*Loris*) and tarsier (*Tarsius*). They are closely integrated and complementary. The species of gibbon and langur vary geographically (see above).

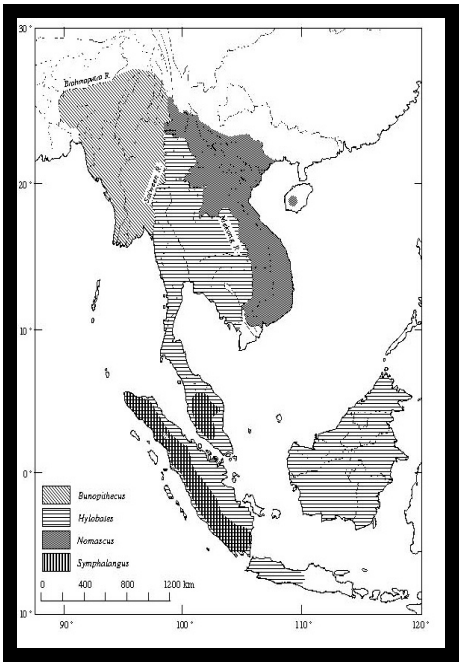

Figure 3 *Distribution of gibbon sub-genera (Geissmann 1995); References: (Chivers 1974; Chivers & Gittins 1978; Fooden et al. 1987; Ma & Wang 1986; Zhang et al. 1992).*

The macaques live in large multi-male multi-female social groups in overlapping home ranges and subsist mainly on fruit; the langurs live in one-male groups in smaller territories and are adapted to

Table 1 *Ecological grades in Malayan forest primates (Chivers 1986).*

	Loris	**Tarsier**	**Macaque**		**Langur**		**Gibbon**		**Orang-utan**
	Nycticebus coucang	***Tarsius spectrum***	***Macaca fascicularis***	***Macaca nemestrina***	***Presbytis obscura***	***Presbytis melalophos***	***Hylobates lar***	***Hylobates syndactylus***	***Pongo pygmaeus***
Habit	Nocturnal	Nocturnal	Diurnal		Diurnal		Diurnal		Diurnal
Habitat	Forest edge	Forest edge	Forest edge	Forest	Forest	Forest edge	Forest		Forest
Positional behaviour	Slow climber	Vertical cline and leap	Quadrupedal-run, walk trees + ground		Quadrupedal/leaping		Suspensor-hang, climb, brachiate		Quadrumanual climb + swing
Social organization	Solitary	Monogamous territorial	Multimale polygyny multilevel		One-male polygyny occ. territorial		Monogamous territorial		Solitary
Group size	1	4	23	33	14	12	4	4	1.5
Body weight Adult female (kg)	0.7	0.1	3.5	7	6.5	6.5	5.5	11	40
Group wt. (kg)	0.7	0.3	73	74	72	60	16	31	60
Biomass (kg/km^2)	15	23	180	45	240	286	29	97	100
Diet	Frugivore (Faunivore)	Faunivore	Frugivore (Faunivore)		Folivore/frugivore		Frugivore/folivore		Frugivore
leaves (%)	0	0	20	13	56	39	30	48	28
fruit (%)	71	0	63	74	43	58	61	44	58
animals (%)	29	100	17	13	1	3	8	8	14
Day range (km)	0.49	0.20[1]	1.08	~3.0	0.76	0.95	1.67	0.87	0.64
Home range (km^2)	0.05	0.01[2]	0.40	~8.3	0.30	0.21	0.55	0.32	1.50
DR/BW	0.7	2.0	0.3	0.4	0.1	0.2	0.3	0.08	0.02
HR/BW	0.07	0.10	0.11	1.19	0.05	0.03	0.10	0.03	0.04

[1] *While mean values are given – for comparative simplicity-such behavioural scores can be very variable over an annual cycle and between groups of the same species.*
[2] *Estimates*

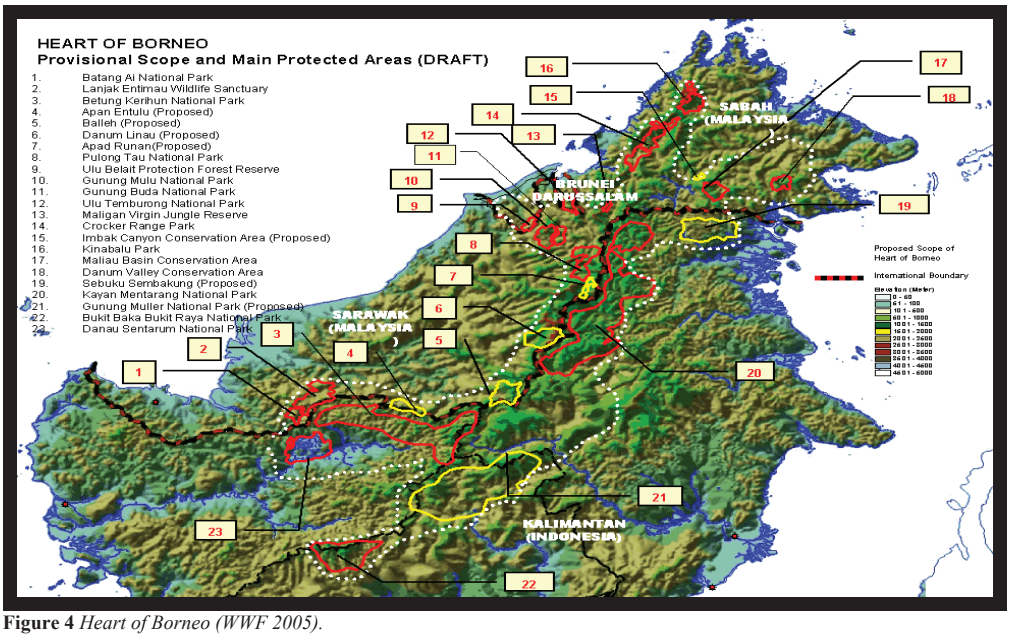

Figure 4 *Heart of Borneo (WWF 2005).*

leaf-eating, but also consume varying amounts of unripe fruit and seeds, and the gibbons are monogamous, territorial, and frugivorous (ripe fruit) (Table 1). The orang-utan is also frugivorous and semi-solitary, based on a harem system, and tarsiers are monogamous, territorial, and insectivorous, with the loris more frugivorous. Gibbons and langurs live higher in the forest canopy, with macaques at the forest edge and also on the ground.

The problem

While the needs of the human population are paramount, the health and extent of the natural ecosystems are very relevant. Large areas of forest – at least 40 % of the land area in monsoonal countries – are essential to maintain water and soil balance crucial to human welfare. In Borneo, only 7 % of the forests are in National Parks, 10 in Kalimantan, 3 in Sabah, 15 in Sarawak and 1 in Brunei, 5.1 Mha in all (4.6 Mha in Kalimantan) (WWF 2005). Despite the escalating devastating floods and soil erosion, seriously impairing the quality of human life, governments are being far too slow in rectifying the damage, even though it has been shown conclusively that forests are more valuable economically in the long term, than being cut down for the one-off sale of timber, with replacement by 'ecological deserts' of mono-culture. They are also locally devastated by mining for coal and gold. The rains are increasingly less frequent but much heavier.

Indonesia, with which I am most familiar over the last 25 years, is a vast country. The forests of Sumatra and Borneo are key islands for the welfare of Indonesia and the world – crucial 'lungs' for the planet, along with the equatorial forests of Africa and South America. Global warming is attributed in part to forest clearance, including the changes in Pacific currents. Increasingly frequently, El Nino causes unusually long periods of drought, highly atypical of the humid tropics, with serious fires raging for weeks or months, with concomitant damage to human welfare, not just to the local population, but with serious effects on health from persistent smoke across the region, widely disrupting air travel. Malaysia has protested vigorously, yet it was their logging companies that started on Indonesian forests, both legally and illegally, once supplies in the Peninsula were seriously depleted.

In 1975 about 74 % of the land area of Borneo was forested; by 2005 this figure had plummeted to about 50 %, and is probably around 44 % today and predicted to be only 33 % by 2020 (WWF 2005). Illegal logging was rife but controllable, but after 1999, when control of the forests was handed over to the provinces by central government, instead of sound management of their own forests, the corruption and illegal clearing of forests escalated, despite the efforts of central government – hence my current despair! Around 2003 about 80 % of the timber exported from Indonesia was illegal.

Central government, however, confused the issues. On the one hand they signed an agreement with Malaysia and Borneo to protect the *Heart of Borneo* (22 Mha, 25 % of the island's land mass) and manage it sustainably (although the 23 small areas for protection are inadequate), on the other they issued many concessions in this crucial area

for open-cast coal mining, gold mining and oil-palm plantations (often several for the same location!). The significance of the Heart of Borneo is to protect the watersheds of the three main rivers of the island – the Barito draining to the south, the Kapuas flowing west, and the Mahakam flowing south-east (Figure 4). To prevent further devastation would improve the lot of the majority of the people of Borneo, including those living on the numerous small rivers flowing south.

Sumatra has comparable problems, augmented by the horrific earthquakes and tsunamis of increasing frequency and intensity. The same is true with increasing severity across Asia – southern China, Vietnam, Laos, Cambodia, Thailand, Myanmar, Bangladesh, India, and Sri Lanka – especially during the monsoons.

Conservation

Key strategy

Conservation embraces, in the field, both the total protection of key areas (e.g., watersheds, rare/unique ecosystems, refuge of key animal/plant species) and management of forests for the benefit of animals (and plants), as well as people (Table 2). Forest clearance is the greatest threat to the survival of primates and many other animals, and to human welfare. For local and global environmental and economic welfare one needs to keep close to 50 % of tropical countries forested; once the area dips below that proportion climatic changes and water and soil problems seem to escalate catastrophically. Since few countries seem able to afford to keep more than l0 % of their forests totally protected, the remaining 40 % needed has to be managed for sustained yields of a wide variety of products (Myers 1983; Myers 1984).

Managed forests provide a buffer zone for protected forests, which provide replenishment of plants and animals. Thus, the shapes and sizes and spatial relationships of such areas need to be planned carefully, on the basis of systematic research, much of which still has to be conducted. The third part of the strategy is to use to maximum efficiency the land already cleared of forest or so degraded that its role as forest cannot be redeemed.

The loss of income from timber (pulp and sawn) through such practice has to be balanced (easily exceeded in the long-term) by income from other (not minor) forest products. This is another key subject for investigation, so that the exploitation of such forests, and the benefits for

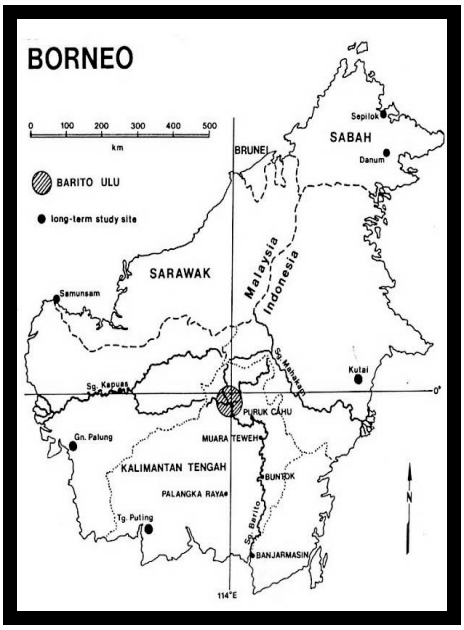

Figure 5 *Borneo: showing provinces, major rivers, and the Barito watershed (Chivers & Burton 1988). Map of Borneo showing (1) the main sites of long-term primate studies and (2) Kalimantan Tengah, with main towns and rivers, and the Barito Ulu study area.*

Table 2 *Conservation of Tropical forests – values, pressures, solutions (Chivers 1986).*

Values (long-term)	Pressures	Solutions
Water and soil balance	Hunting	Total protection of watersheds and significant
Climate	Harvesting	representatives of each ecosystem, especially those
rainfall pattern	Farming	with high plant/animal diversity.
atmospheric gas balance		
40-50 % world's plant and animal species	Pet trade	Wide-ranging management of buffer zones to reserves
genetic diversity pivotal plant/animal links	Power	for sustained yields.
	water	
	oil	
Sustainable yields	Selective logging	Agro-forestry and agriculture in areas cleared of
timber, canes, fibres, gums,	Clear-felling	forest, with improved efficiency.
waxes, resins, foods-plant and	for timber	
animal medicines	for fuel	
	for agriculture	
Education and research		
Recreation		

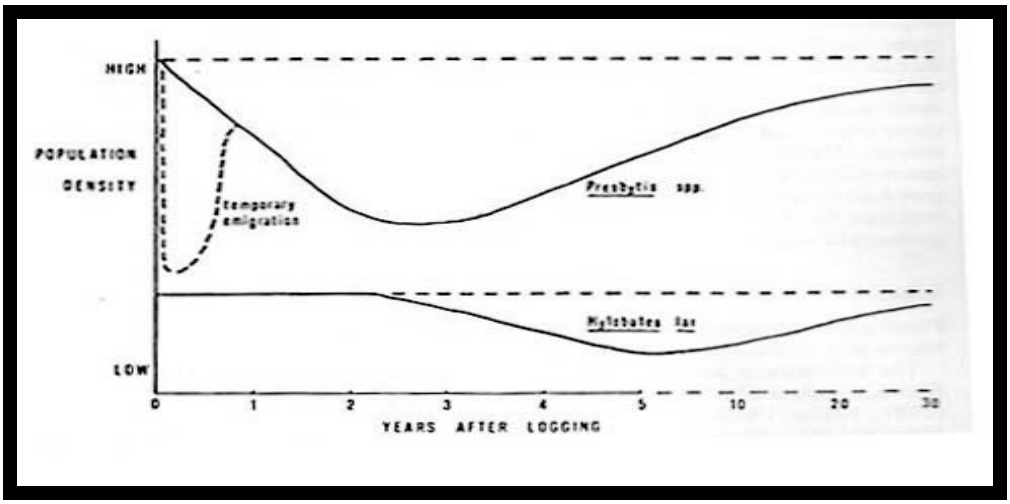

Figure 6 *Hypothetical long-term effects of selective logging on gibbons and langurs (A.D. Johns, in Marsh & Wilson 1981).*

humans, can be maximised through knowledge of key animal-plant relations promoting the regeneration of such resources. The target has to be less damage to the forest and more produce, on a sustainable basis. Project Barito Ulu in the centre of Borneo is one effort to provide the necessary information (Figure 5).

What is needed is the improved protection of watersheds and national parks representing all ecosystems, especially the richest, lowland ones, with the efficient, sustainable management of large buffer zones, and the more productive use of land already cleared of forest (Chivers 1986; Chivers 1989). Such a strategy should ensure that viable populations of all primate taxa survive in perpetuity, but it will not be easy.

Selective logging

Selective logging represents the compromise between human and animal needs in the long term, but it will only work if timber extraction is very light and carefully controlled. This approach has been developed in numerous sites, especially in Sungai Tekam by Johns (1986, 1987), under the management of the Forest Department and Forestry Research Institute Malaysia (FRIM). Even if only l0 trees/ha are extracted (4 % of trees), 45 % of the total stand (68 % of plant biomass) is damaged during access, felling, and extraction. Johns continues to monitor the changes as the forest regenerates. It is the larger and more frugivorous species, which are the most vulnerable, but their populations should recover fully within 20-30 years (if there is no further interference) (Figure 6). For example, gibbons and langurs adapt their foraging strategies by eating more leaves, as fruit availability declines in newly-logged forest. Gibbons maintain their territories, but the stress affects their breeding. Langurs may emigrate temporarily from the disturbed area, and there is increased mortality of immature monkeys (because of travel difficulties across gaps), which adds to the breeding loss.

Selective logging enhances the diversity of microhabitats characteristic of the mosaic of successional stages of climax forest; it is these colonising plants of immature forest, which provide more nutritious less chemically-defended foods. Bird communities maintain much the same trophic structure, but species composition may be changed markedly: dietary generalists survive better than insect and fruit-specialists, whose food supply may be much disrupted temporarily. Mosaics of primary and logged forest can maintain viable populations of the large wide-ranging hornbills.

Thus, the persistence of primary forest in an area may be crucial to the survival of certain animal species, and it is the relationships between these two types of forest that need to be investigated urgently. Additional information on the effects of selective logging is available from West Malaysia from the surveys of primary and variously disturbed forest (Marsh & Wilson 1981) and from East Kalimantan (Wilson & Wilson 1975). In contrast to the tolerance of gibbons and langurs, orang-utans and proboscis monkeys are seriously affected by selective logging.

Shifting cultivation

Shifting cultivation has been practised for centuries, especially along rivers, with peoples living in harmony with the forest, since the forest has recovered by the time people return. Increased population, and less forest, means that return time is so reduced that this practice is no longer sustainable.

Monoculture

Rubber plantations have a long history, especially

in Peninsular Malaysia, but their effect on the forest has been eclipsed in recent years by oil-palm plantations, especially in Indonesia. Between 1998 and 2003, oil-palm estate increased from 2.54 to 3.32 Mha in Malaysian Borneo (annual growth of 5.6 %), and from 1.65 to 2.94 Mha in Indonesia (annual growth 12.4 %, 13 % Sabah, 15 % in Central Kalimantan, 20 % in East Kalimantan) (WWF 2005). Annual forest lost in Kalimantan has averaged about 1 Mha between 1984 and 2002. The effect on the forest estate and on wildlife is proving devastating, not least for the orang-utan.

Translocation, captive breeding, and reintroduction

1) Gibbons

Mather (1992) developed the invaluable approach of analysing gibbon food trees from all previous studies to compare with the density of gibbons in each area (Table 3a and 3b, see Chivers 2001). He shows that there is a direct correspondence between gibbon biomass and the abundance of these preferred gibbon foods (Table 4a and 4b). Group size increases in localities with more fig trees. It enables one to assess whether a gibbon population is at carrying capacity, or below (because of human disturbance), or above (because of immigration from nearby disturbed areas). The suitability of proposed sites for reintroduction or translocation can be assessed, and stocking density determined, and, where there is selective logging, the reduction in carrying capacity can be determined.

Our improved taxonomic and socio-ecological understanding of this diverse group of apes (as summarised above), and of their tropical rain-forest habitat (e.g., Leighton & Leighton 1983; Whitmore 1984) improves our chances of their effective conservation. Clearer recognition of species and sub–species, and improved quantification of their use of resources (social structure, feeding, and ranging) in relation to what is available, is essential to effective protection and/or management.

Table 3a *Dominant forest tree families (Mather 1992).*

Site	Dipterocarpaceae (%)	Leguminosae (%)
Kuala Lompat, W. Malaysia	1.0	13.0
Sepilok, Sabah, E. Malaysia	27.0	3.0
Danum Valley, Sabah, E. Malaysia	32.0	1.0
Barito Ulu, Kalimantan, Indonesia	43.0	4.0

The predictions of a drastic reduction in gibbon populations by Chivers (1977) are being realised, with the Kloss, moloch, and concolor gibbons the most endangered. As the clear-felling of forest declines, however, their prospects are boosted, if adequate selectively-logged forest (with low extraction rate) persists, since gibbons have shown themselves to be very adaptable to such disturbance (Johns 1986; Johns 1987; Marsh & Wilson 1981).

Little progress has been made in developing techniques of translocation - to move social groups from doomed to protected habitat - presumably because of the physical difficulties involved, and the lack of empty suitable habitat (but see Cheyne & Brule 2004). It remains a possible solution where populations become critically endangered, but adequate preparation, care (with veterinary supervision), and monitoring are essential.

Table 3b *Important tree families as Gibbon foods (Mather 1992).*

Family	Number of food species
Moraceae	40
Euphorbiaceae	25
Leguminosae	19
Myrtaceae	18
Annonaceae	18
Rubiaceae	15
Guttiferae	14
Anacardiaceae	12
Total	**161 (ca 45 % of all known gibbon food species)**

Table 4a *Density of Fig Trees and Gibbon biomass (Mather 1992).*

Site	Figs/ ha	Groups / km²	Group size	Biomass (kg/km²)
Sepilok, Sabah	0.0	1.5	2.7	24.0
Tanjung Puting, Kalimantan	1.0	2.9	3.0	34.8
Siberut, Mentawai Islands	1.3	2.1	3.7	42.0
Sungai Tekam, W. Malaysia	2.0	2.5	3.3	32.6
Danum, Sabah	2.3	2.1	3.5	25.2
Pasoh, W. Malaysia	4.0	2.1	4.0	33.6
Kutai, East Kalimantan	6.6	3.6	4.0	57.6
Kuala Lompat, W. Malaysia	8.0	4.1	4.0	65.0
Ketambe, N. Sumatera	27.0	4.3	4.5	98.0

Captive breeding worldwide provides invaluable publicity (of the plight of rain-forest animals) and education, with fund-raising opportunities for conservation activities. It also helps to conserve the gene pool, with meticulous

stud-books. The prospects of reintroduction to the wild habitat are gloomy, given the costs involved and the lack of available habitat (but see below for orang-utans). If habitat is available, it is much more cost-effective and successful to translocate social groups from doomed forest fragments to any under-stocked protected forest. The prime effort must be to protect natural habitat and to conserve wildlife within it.

Table 4b *Abundance of Gibbon food trees and Gibbon biomass (Mather 1992).*

Site	Food Trees (% of plot)	Gibbon Biomass (kg/km²)
Sepilok, Sabah	11.2	24.0
Danum, Sabah	12.9	25.2
Sungai Tekam, W. Malaysia	20.6	31.6
Tanjung Puting, Kalimantan	23.2	34.8
Kuala Lompat, W. Malaysia	24.2	33.6
Siberut, Mentawai Islands	34.8	42.0

Kalaweit in the Bukit Baka National Park in Central Kalimantan offers a beam of hope. Facilities are being developed to accommodate confiscated gibbons, to form pairs, and when ready to reintroduce them to protected forest. A possible area is being developed nearer to Palangka Raya, provincial capital of Central Kalimantan (Cheyne & Brule 2004).

2) Orang-utans

Even more emotive, if that is possible, is the plight of the orang-utan. In about 1950 there were about 30,000 orang-utans in Sumatra and 200,000 in Borneo. Today there are less than 7,000 in Sumatra and less than 50,000 in Borneo (Figure 7); more have died in the last 30 years than are alive today! Orang-utans were present in 21 localities in Borneo in 1992, but by 2002 they were extinct in 8 of them, probably because of hunting (WWF 2005).

Thus, numbers are declining through 50,000 for the two species and there are more than 1,000 in captivity, rescued from devastated and burned forest and from plantations, and confiscated from smugglers and pet-owners. Given the decline in the wild, these animals could be crucial to the survival of the species. Programmes of rehabilitation have been underway for nearly 20 years – in Bukit Lawang and Ketambe in Sumatra, and Tanjung Puting, Wanariset and Nyaru Menteng in Kalimantan, and Sepilok in Sabah. Now another centre has been established in North Sumatra and one in Sarawak. In most locations reintroductions have been carried out, with varying, but improving, degrees of success. This has to be a critical activity to help ensure the survival of the orang-utan. It depends on thorough veterinary care and training for life back in the wild, long-term monitoring and effective protection of the forest … all of which are gradually being achieved.

Education

Education is essential at various levels, as successful programmes in many countries demonstrate (e.g., Rwanda, Brazil, Peru, Costa Rica, Malaysia, and Indonesia). In the long term, education of local people (whose lives are most immediately affected by destruction of forests) and the young (the next generation) the world over is essential. Most critical, however, is the need to influence the decision makers of today - the governments of tropical countries (who now mostly see what has to be done) and, more importantly, the governments of "user countries" and the heads of international and national commercial concerns - so that policy and activities are changed rapidly, to avert impending catastrophes. Values have to be changed, and resource flow significantly altered, if this planet is not to be irreparably damaged. An international network concerned with disseminating this inter-disciplinary bio-environmental approach could have a critical role to play in this process (Chivers 1989).

Threatened primates

'Indo-China' is the key to gibbon conservation; indeed to all primate conservation (it contains about 8 of the 20 most endangered primates in the world). The four crested gibbon species in the north (*Nomascus concolor*), in southern China are seriously threatened, but the most endangered are the Hainan (China) and Cao Vit (north-east Vietnam) gibbons (*Nomascus nasutus*), with less than 20 individuals. Efforts are being to ensure that they all flourish. The rarer they are, the more effort the local people can be encouraged to give. The northern and southern white-cheeked gibbons in Vietnam and Laos (*Nomascus leucogenys*) are also struggling, but the yellow-cheeked gibbon (*Nomascus gabriellae*) in southern Vietnam and Cambodia seems to be the most numerous of the genus. Several langur species (*Trachypithecus* spp) and, in particular, the odd-nosed monkeys (*Rhinopithecus* and *Pygathrix* spp) are also close to extinction.

The other most endangered gibbons, because of habitat loss, are the Javan or silvery gibbon (*Hylobates moloch*) (surviving only in the west of island) and the Kloss gibbon on the Mentawai Islands (*H. klossii*). The status of the hoolock gibbon (*Hoolock hoolock*) is unknown in Myanmar, and perhaps a cause for serious concern; numbers in Bangladesh and eastern India are not large, and are being depleted rapidly. The pileated gibbon (*H. pileatus*) is restricted in Thailand and, increasingly, in Cambodia. Otherwise, the more widely-distributed siamang (*Symphalangus syndactylus*),

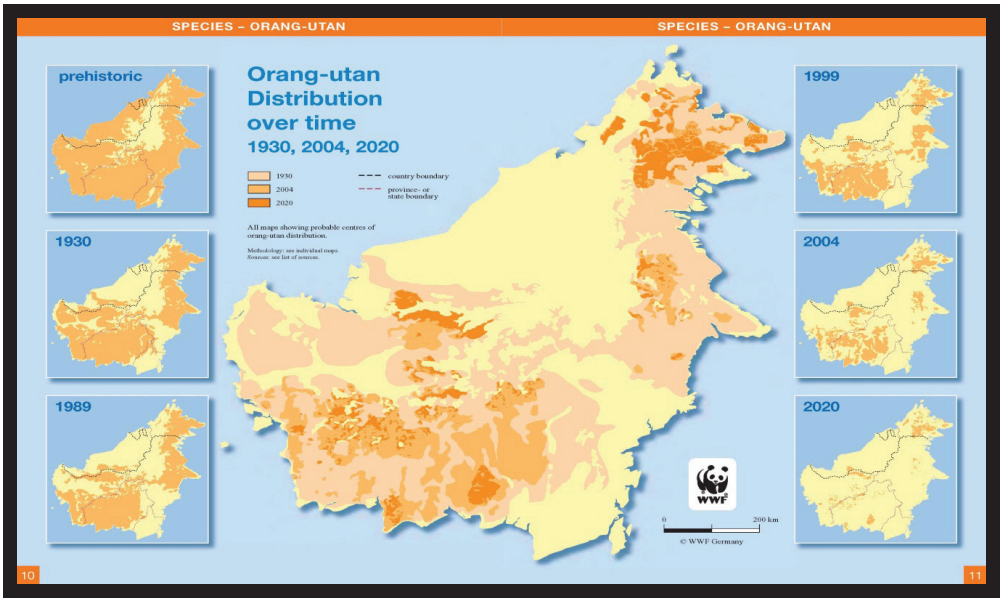

Figure 7 *Decline of the Bornean orang-utan since 1930 (WWF 2005).*

lar, agile and Bornean gibbons (*H. lar*, *H. agilis* and *H. muelleri*) are present in good numbers where forest remains, even in selectively-logged forests.

Conclusions

The rain-forests of the tropical regions of Asia, Africa, and the Americas play a vital role in the maintenance of environmental stability for the whole planet. They are being depleted at an alarming rate, to the detriment of the long-term economies of the countries concerned, as well as to their climate. Such irreparable damage will continue so long as there continues to be such disregard of the consequences, and so long as there is so excessive a net flow of resources from tropical to temperate countries - from the South to the North. The key forested countries are Brazil, Zaire, and Indonesia; they hold at least one of the keys to human welfare on this planet.

Such forests must be maintained in perpetuity for the benefits of the countries in which they occur, and for the whole planet. These benefits are economic, as well as climatic, which must give hope for success. Evidence increasingly shows that 40-50 % of the land area of the countries involved need to be maintained under tropical forest. Total protection of the main watersheds ensures water and soil balance for the full extent of the river to the sea, and a significant contribution to plant and animal diversity.

Protection of the richest lowland ecosystems increases significantly the protection of genetic diversity (biodiversity). Such protection rarely exceeds more than 10 % of the land area. Management of forests covering 30-40 % of the land area is essential for the achieving the needs specified above. Sustainable use of a wide range of forest products, rather than excessive exploitation for timber, will ensure far greater economic returns in the long term. Both climate and trade, therefore, will benefit the whole planet through the right balance of protection and sustainable use.

Education is essential at various levels, as successful programmes in many countries demonstrate (e.g., Rwanda, Brazil, Peru, Costa Rica, and Indonesia). In the long term, education of local people (whose lives are most immediately affected by destruction of forests) and the young (the next generation) the world over is essential. Most critical, however, is the need to influence the decision makers of today - the governments of tropical countries (who now mostly see what has to be done) and, more importantly, the governments of "user countries" and the heads of international and national commercial concerns - so that policy and activities are changed rapidly, to avert impending catastrophes. Values have to be changed, and resource flow significantly altered, if this planet is not to be irreparably damaged. An international network concerned with disseminating this interdisciplinary bioenvironmental approach could have a critical role to play in this process.

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Keynote 2: Importance of the Eastern Region of Bangladesh in Insect Conservation with Special Reference to Odonata

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Abstract

Studies on Odonata of the eastern region of Bangladesh revealed some interesting intraspecific variations. The landscape of this region with hills and forests has resulted into isolated habitats for the weak-flying odonates. Such isolation causes intensive inbreeding and resultant intraspecific variations are likely to lead to speciation. Early measures of protection of this area are recommended for conservation of odonate species.

Keywords; *conservation, odonata, eastern region, Bangladesh.*

The eastern region of Bangladesh from Cox's bazaar to Sylhet and Sunamganj is bordered by Myanmar in the south and then by Mizoram, Indian Tripura, and Assam gradually north-ward and by Assam and Meghalaya in the north. It is now generally accepted that in the past, insects spread through migration mainly from the east and south-east Asia gradually to the Indian sub–continent. It is also assumed that large-scale migration/dispersal took place after the rise of the Himalayas. The region in this paper (eastern region of Bangladesh) falls along this route. Continuous distribution of a large number of odonate species from:
a) Australia to Peninsular India,
b) Malaysia to peninsular India, and
c) Indo-China, all through the Gangetic plains and Assam bear testimony to this.

In doing so, the eastern region of Bangladesh acted as the corridor (Figure 1). Now, let us take a look at the geography, vegetation, and general climatic pattern of this all important region. The concerned area falls in the Moulvi Bazar and Sylhet districts in the north and Chittagong and four Hill Tracts districts in the south.

The landscape of two northern districts is a mixture of hillocks (locally known as *Tillas*) and broad plain land. The hillocks range from 100 to 200 feet msl in its northern part and from 50 to 100 feet msl in the south. The hillocks are occupied by patchy forests and about 130 tea gardens and the valleys by paddy fields. Earlier reports show that these lands once supported rich forests. The annual temperature ranges from 8.3^0C to 32.7^0C. This area has the highest rainfall in Bangladesh and humidity consequently is high, but there is also a prolonged dry season from November to mid-May. The mercury occasionally dips down to 0^0C. A large number of mountain streams, almost all with sandy bottoms course down the hills and across the valleys. Some are slow and others quite swift flowing. Thick growth of shrubs adorns their banks.

The southern districts are bound by the Bay of Bengal in the south, by Myanmar in the entire east side, and by Indian Tripura in the north. The hills in this part are much taller, some rising to approximately 1,200 feet msl. The temperature ranges from 12.7^0C to 31.6^0C. Annual rainfall amounts to 2,540 mm in the southern part and 3,558 mm in the north. Humidity is high almost all year round. The climate is typically subtropical and there is a dry season from November to May. A number of hilly rivers run through this area and also a large number of small to large streams. Some of these have sandy bottoms whereas others, mostly in the Chittagong Hill districts, flow over stones.

The forests of the entire area are under consideration is basically of the same type, except the coastal forests of in the extreme south and some moist deciduous forests of Sylhet. The forests of the entire region are classified as tropical evergreen and semi evergreen. The top canopy ranges from 30 to 50ft. The second canopy is from 15 to 25ft. The third story mostly comprises of the saplings. There is a thick undergrowth of bamboos, canes, ground orchids, Eupatorum spp, *Lantana camara*, and a profusion of creepers. Vast areas of forest have been clear-felled for plantation of commercially important species like teak, garjan, gamari, mahogany, telsur, and jarul (Queen's flower).

This area supports a large variety of odonate species occupying various biotopes. The odonate fauna of eastern India, Gangetic plains, and Assam are closer to the Indo-Malayan forms (Mitra 2002). The fauna of the eastern region of Bangladesh are no different. The area with hills and valleys make very suitable biotopes for different species of Odonata. Various species show intra-specific variations, which Mitra (2002) did not consider to be of taxonomic significance. Here, I cite some of these variations not recorded earlier.

Potamarcha obscura: In one of my specimens the discoidal cell in the fore wing is distal to that of the hind wing and the tibial spines in hind legs longer. Both these features are similar to that of the genus Lathrecista and Kirbyi.

Figure 1 *Map of the concerned region.*

Orthetrum glaucum: In one male specimen only segments 1 to 5 are pruinosed; whereas the specimen from Rangamati (CHTs) segments 1 to 8 are pruinosed as described by Brauer.

Libellago lineata: Specimens from both Sylhet and Rangamati are closest to *L. l.indica*, but colour markings on the dorsum of abdomen are not exactly similar. Fraser (1933) has erected six sub–species on the basis of these markings. Following the same principle my specimen should be a new sub–species. I desist from so doing till further material show these differences to be generally applicable to all our specimens. Also the black tip of the fore wing is barely 2 mm instead of 3 mm or more as recorded by Fraser (1933).

Coeliccia vacca: One of my specimens differ from the original description by Laidlaw as follows: (i) Fore wing with 18 (not 19) postnodals, (ii) Pterostigma with three sides (not only the costal side) with a fine white line, (iii) 9th segment entirely yellow on dorsum and (iv) Yellow spots on dorsum of 10th segment near base or a narrow basal area yellow.

Coeliccia didyma: I have a pair in copula in which the female resembles *C. loogali* in thoracic marking – a narrow stripe unlike *C. didyma* which has two pyriform spots.

Copera annulata: One male specimen in my collection is differs from Selys's original description as follows: (i) three black dots on the labrum, (ii) white areas on the frons and vertex are rather brownish, particularly the two small ones near antennal base.

Copera assamensis: In one male specimen the 2nd and 3rd tibia are distinctly dilated and the whole of the 10th segment, greater part of the 9th and apical third of the 8th segments are blue. The blue colour of the 10th segment is very similar to that of *C. vittata*. That makes it doubtful if these two species are different as also thought by Fraser.

Copera marginipes: I have the Bengal form as well as the Sri Lankan and Assam forms often from the same locality. Fraser noted this species as stream breeders; however I have found them to breed in good numbers in still waters as well.

Pseudagrion rubriceps: In some specimens there is a distinct mixture of Assam and Coorg forms.

These intraspecific variations are probably not of taxonomic importance, as Mitra opined, but they do indicate the variability of the species. Of particular interest is the presence of Assam and Sri Lankan forms within our territory. This bears testimony to the fact that both forms originated here

and migrated further northward to Assam and southward to Sri Lanka.

Also the use of both still water and running streams by C. *marginipes* is of significance as capability of adapting to both habitats. The valley surrounded by hillocks and dense vegetation has effectively broken up the area into smaller zones. The population, particularly of the weak-flying Zygoptera unable to cross these barriers, have been broken into small populations thus reducing population pressure and calling into play population effect boosting speciation.

With rapidly rising human population forests and valleys are under pressure of urbanization. Changing vegetation and damming of the streams will surely destroy the biotopes ideal for the Odonata and bring an end to the natural process of speciation. In the absence of in depth studies it is not possible to say what's happening to other groups of insects. However, it is certain that the eastern region of Bangladesh also acted as the corridor for westward migration of other insect groups as well. My personal collection of butterflies from this region and comparison with Indian species indicates the same.

Actions for preserving the rich insect fauna of this region are certainly called for. Effective implementation of strict conservation laws brooks no delay if we want to conserve these beautiful insects which are also known as useful biological control agents for pests and disease vectors.

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Keynote 3: Human - Wildlife Interactions in Africa and Asia: A Special Reference to Tanzania and Bangladesh

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Abstract

Africa and Asia have a rich and world heritage biodiversity, but, human population growth and density, together with poverty, increase the pressure on natural resources, and thereby, human-wildlife conflict. Involvement of local people – education and investment in biological resources are necessary for sustainable use of the remaining biological resources. Studies all over the world are necessary to understand how natural resources can be more sustainable used in the future; although there are some general patterns. We must also understand local cultural engagement in order to conserve our future heritage.

Keywords; *human population size, conservation of biological resources, lions, elephants, Asia, Africa.*

Introduction

Causes of human-wildlife conflicts

The world human populations are steadily growing from about one billion people by the turn of the 19th century to more than 6 billion people by the turn of this century. The Indian region of Asia has the highest population density in the world, while Africa has the fastest-growing population. A big challenge is that the human population is still growing rapidly, particularly in Africa, but also in Asia. We have already passed 7 billion people (Withgott & Brennan 2009).

It took all of human history to reach 1 billion people, which happened around the year 1800. In 1930, or 130 years later, we reached 2 billion. We added the most recent billion in about 12 years. Today we add about 80 million people to the total world population each year, which is about 2.5 persons/second. Today the rates of growth vary enormously from one region to the next. While Europe and North America basically are facing a negative growth, and are mostly growing because of immigration, many regions in Asia and Africa are facing annual growth rates of 1-3 %. At today's global growth rate of 1.2 %, the world population will double in 58 years, which mean we will reach 14 billion people round 2070.

During the 1950s and 1960s, China was facing a population growth rate of 2.8 %/year. If they had not introduced the one-child/family policy, China would have had 2 billion people in 2004. China's population continued to grow rapidly, however, even after the one-child policy was introduced, but has presently flattened out and now China is facing a negative growth rate.

Is population growth really a problem?

Why are human populations continuing to grow at such high rates? The answer is quite simple. Today we are facing such a population growth rate because of improved technology, improved medical care, improved sanitation, and better-quality food. Today we have reduced death rates, but in many parts of the world we have not reduced birth rates.

Some people, including politicians and many social scientists, are arguing that the human growth is not a problem, because new resources will replace depleted ones. This is too simple an argument, because some resources (i.e., biodiversity) are irreplaceable. Thus, quality of life will suffer with unchecked human growth. We will be facing less food, less space, less wealth, and more poverty per person.

How do we protect biodiversity?

The greatest challenge we face with the growing human population is how to preserve our biodiversity at the same time as human welfare is prioritised. In most African countries, as well as in many Asian countries, we presently observe declining elephant populations. While the numbers of wild Asian elephants (*Elephas maximus*) are below 50.000, however, the African population of elephants (*Africana loxodanta)* is still around half a million (Table 1). The two countries in Africa with the highest elephant populations are Tanzania and Botswana. Together these two countries populate more than 50 % of all African elephants (Table 1). Why? By looking at the human populations in these two countries, those densities are still very low (Tanzania 46 people/km², Botswana 3.5 persons/km²), but both countries are facing fast human growth rates, and soon their populations will be several fold the present human population size. Tanzania had 8 million people at independence 50 years ago; today her population is more than 40 million, or 5 times the population of 1960. Thus, there is not only "poaching" by Asian demand that is threatening the African elephant population, but the fast-growing human population is also a big threat to the survival of elephants!

The elephant population of Bangladesh is presently around 200 individuals (Table 1). Bangladesh is the densest country in the world with a human density of more than 1,000 individual/km². Is it possible for wild elephants to survive in this country? At least those humans living close to elephants are facing an increasing level of conflict with these giants (Sarker 2010; Sarker 2011).

Table 1 *Elephant populations and percentage protected areas in selected countries in Asia and Africa in 2006 (Blanc et al. 2007).*

Country	Number of elephants	Protected land areas (%)
Bangladesh	211	1.6
India	22,500	5.3
Indonesia	2,900	14.1
Myanmar	5,500	6.3
Sri Lanka	2,550	20.8
Thailand	3,350	19.6
Malaysia	2,600	17.9
Total Asia	**43,321**	
Botswana	133,829	30.9
Kenya	23,353	11.6
Mozambique	14,079	15.8
Namibia	12,531	14.5
South Africa	17,847	6.9
Tanzania	108,816	27.7
Zambia	16,562	36.0
Zimbabwe	84,416	28.0
Total Africa	**428,182**	

Protected areas

The most important routine to protect biodiversity is by creating protected areas. The first national park in the world was established about 140 years ago in USA - the Yellowstone National Park. Since then many protected areas have been gazetted and countries with the highest proportion of protected areas are normally found in Africa (Table 1). Protected areas have long been recognised as the single most important mode of conserving wildlife and preserving biodiversity, and today it is been looked upon as the most important conservation tool to protect biodiversity, but the protectionism model of management of protected areas has often displaced people from their lands. Thus, the main approach to recent wildlife management schemes has been to include local people in planning and management, and share some of the benefits from conservation (Kideghesho 2010; Mfunda 2010a; Nyahongo 2010). Participation as a core paradigm of Community-Based Conservation (CBC) always opens a door for people to regain control over resource management and strengthening their decision-making capabilities. On the other hand, CBC faces numerous challenges emanating from cultural contexts, socio-economic factors, and the way projects are designed and implemented (Nyahongo 2010). Despite some degree of success, most programmes and projects have failed to achieve conservation and development objectives (Sponga 2008).

Human-wildlife interactions

There is considerable concern over the steadily-increasing human impact and encroachment on remaining unprotected natural habitats, as well as protected-area networks, in both industrialised and developing countries. Examining ecological impacts across gradients of human disturbance is, therefore, fundamental in understanding the effect of human populations on natural ecosystems (Nyahongo 2007; Nyahongo & Røskaft 2011; Sarker & Røskaft 2011a). Partially-protected areas often function as vital buffer zones to protected areas and usually allow some kind of consumptive use of natural resources within their boundaries. Permitting human exploitation of wildlife within these areas is often used to provide incentives for conservation to local residents.

Community-Based Conservation (CBC) initiatives have been implemented in an attempt to reduce unsustainable exploitation of wildlife. CBCs incorporate local people in conservation of wildlife resources by providing local communities with incentives derived from partially-protected Areas. Although initially praised as a promising approach, there are now criticisms of the approach (Sponga 2008). Moreover, the effect of wildlife-related benefits on human behaviour remains poorly studied, although it is reported that incentives may change conservation attitudes (Mfunda 2010a; Nyahongo 2010). Providing communities with wildlife-related benefits might not, however, automatically reduce unwanted behaviour. Local people may instead use the new sources of benefits to complement existing income, rather than as substitute for it. For instance, modelling suggests that CBCs relying on money transfers do not act to conserve wildlife, especially when benefits are low compared to wildlife-induced damage or the potential income gained from illegal hunting (Mfunda 2010a; Nyahongo 2010). The disproportionately-low level of benefits, or uneven distribution thereof, are implicated as key elements in the continued persistence of illegal activities (Holmern 2007; Holmern 2010; Holmern *et al.* 2004; Holmern *et al.* 2007).

Below I will present some results from a joint project between Norwegian University of Science and Technology (NTNU) in Norway and Tanzania Wildlife Research Institute (TAWIRI) in Tanzania, as well as University of Chittagong in Bangladesh. I will provide some examples of human – wildlife conflicts, as well as human conservation attitudes. Elephants and carnivores are considered the most problematic species to conserve in this landscape, so I will also give a few examples of conflicts with such species. Tanzania in Africa and Bangladesh in Asia are two very different countries in many respects, although they are both facing similar

conflicts with wildlife (Table 2). Tanzania is seven times the size of Bangladesh, but has only about 25 % of Bangladesh's population, indicating a population density of only 5 % of that of Bangladesh. Tanzania holds almost 30 % of her land as protected, while less than 2 % of Bangladesh is protected. Finally, Tanzania has viable populations of both elephants and lions (*Panthera leo*), while a surviving elephant population in Bangladesh is dependent on Myanmar and India, while the tiger (*Panthera tigris*) population in Bangladesh is dependent on a small protected area in Sundarban (see Table 2).

Table 2 *Some comparisons between Tanzania and Bangladesh in relation to human populations, areas, elephants and big cats.*

	Tanzania	Bangladesh
Size of area (km²)	954, 000	157, 000
Total human population in 2010 (million)	44	160
Persons per km²	46	1,099
% of land area protected	27.7	1.6
Number of elephants	ca. 110, 000	ca. 200
Number of big cats	ca. 10, 000 lions	ca. 500 tigers

Attitudes towards large carnivores in Norway

In the early 2000s we did some research on Norwegian conservation attitudes, particularly towards the four large carnivore species in the country (brown bears, *Ursus arctos*; wolves, *Canis lupus*; lynx, *Lynx lynx*; and wolverines, *Gulo gulo*). We found that the most important factors shaping human attitudes towards these carnivore species were:

1. excitement of being able to see this species in the wild (developing positive attitudes),
2. age (more negative attitudes with age),
3. interest in game hunting (hunters inhabiting more negative attitudes),
4. number of carnivore species in the area (more species creating more negative attitudes),
5. having carnivores in the area is making people worry about their safety (negative attitudes),
6. those who have financial losses have more negative attitudes,
7. gender (women having more negative attitudes), and
8. education is creating positive attitudes (Røskaft *et al.* 2003; Røskaft *et al.* 2007).

Thus, we were interested to test if such factors would shape conservation attitudes in Africa and Asia as well.

What are the conservation challenges in Africa and Asia?

Human population increase rate in Africa is between 2-3.1 % per annum, while Asia has the highest human population density in the world. Particularly in Africa, an increasing human population size is experienced outside protected areas. In these two continents most people still live in rural areas. Poverty rate is high. A massive amount of people live under 1 US$ /day, which is considered the poverty edge. Thus an increasing encroachment of biodiversity resources (bush-meat, fodder, firewood, charcoal, medicine plants, house, and cover for livestock etc.) is experienced. Any conservation plans and actions must, therefore, take this human factor into account. If there is no protection of any wild species, most conservation efforts are likely to fail. On the other hand, a country like Tanzania is experiencing a massive growth in the tourism industry, which is currently one of the three most important industries in the country, but people living around protected areas experience a very low share of revenues from this industry. Thus, a conservation strategy is to allow local people living close to protected areas to receive a higher share of the revenues from tourism to protected areas (CBC). Such share, however, must be based on experiences from CBS regimes in other parts of the world, so that similar mistakes as experienced in these countries can be avoided (Sponga 2008).

Lion attacks on people in Tanzania

Tanzania is home to the world's largest lion population (see Table 2), but hosting such a large population of these big cats is not without problems. Between 1990 and 2004, lions killed at least 563 people and injured more than 308 persons in Tanzania (Packer *et al.* 2005; Packer *et al.* 2007), and 46 % of all reported cases occurred in six coastal districts in the southern part of the country. This area has long had the worst reputation for man-eating lions, but Government records show a striking increase in attacks since the late 1990s (Ikanda 2009). This 15-year increasing trend is most likely due to the human population increase in the country, which is causing an increasing pressure on natural resources. Thus, retaliatory killing of lions is common (Ikanda & Packer 2008). Another cause behind this increased pressure is probably an escalation in illegal bush-meat hunting that has removed much of the lions' prey outside the protected areas.

Attacks on humans are highly seasonal, with most cases occurring during the harvest season, when people are tending crops in agricultural fields (Ikanda 2009; Ikanda 2010). Also the moon plays a role; most attacks occurring during full moon (Packer *et al.* 2011). Lions gain access to humans as they sleep in makeshift huts to protect their crops

from nocturnal crop-raiding pests, such as bush pigs (*Potamochoeus procus*) (Ikanda 2009; Ikanda 2010). The number of lion attacks was highly correlated with the abundance of medium-sized prey and the abundance of bush pigs (Ikanda 2009, 2010).

Man-eating behaviour has been documented in lions of south-eastern Tanzania for over 100 years. Knowledge on lion hunting-group structure has highlighted different predation patterns on ungulate species, and can thus be applied to understand man-eating behaviour. Lions have the innate potential for human predation and would readily prey on humans where they could be safely killed. A minimum of 200 lions, forming group structures of solitary males, females, and mixed-sex groups were recorded in attacks (Ikanda 2009; Ikanda 2010). Female lions are more occasional man-eating, whilst males are more habitual. When both sexes are in larger mixed groups, habitual man-eating becomes more of the group's behaviour (Ikanda 2009; Ikanda 2010).

Finally, distance from village central position (where safety against lions is at maximum) is an important risk factor (Ikanda 2009; Ikanda 2010). Lions attacked more people on the basis of vulnerability and not on availability. Where lions actively seek humans as prey, preference is on habitats where they are more vulnerable and not necessarily where they are available as prey (Ikanda 2009; Ikanda 2010).

The Serengeti ecosystem as an example of African challenges

Serengeti National Park is a World Heritage Site, famous for its biodiversity and wildebeest (*Connochaetes taurinus*) migration (Mfunda & Røskaft 2011a), but the ecosystem experiences an increasing degree of habitat loss and hunting - due to an increased population growth rate of 2-3 % per year. People around the park experience that their property is lost and damaged. In addition, people are even killed by elephants, so there is little tolerance of wildlife outside the park (Kideghesho 2010; Kideghesho *et al.* 2007). We have found that people's attitudes are shaped by similar factors, as in Norway, because educated people, people with few livestock, and those who had access to benefits, engaged positive perceptions towards protected areas (Kideghesho *et al.* 2007). Uneducated people, people with many livestock, and those who had no access to benefits and natural resources portrayed negative perceptions.

People around the Serengeti National Park are familiar with how decisions are made and which institutions that make decisions (Mfunda & Røskaft 2011a), but people were inadequately consulted and involved in decision-making processes. Districts were affected differently by the decisions made. The age of respondents (in years), gender, household size, education level, benefits from conservation, and crop loss from wildlife, were important factors determining different levels of participatory management (Mfunda 2010a; Mfunda 2010b; Mfunda & Røskaft 2010; Mfunda & Røskaft 2011a; Mfunda & Røskaft 2011b). Thus similar factors are shaping perceptions towards conservation in Tanzania, as we found in Norway.

Bushmeat hunting in Serengeti

Bushmeat hunting is an important economic activity in the Serengeti Ecosystem (Holmern 2007; Holmern 2010; Holmern *et al.* 2004), but hunting preferences vary between Western and Eastern Serengeti - the latter prefer smaller animals, while the former prefer medium- to large-sized animals (Mfunda 2010b; Mfunda & Røskaft 2010). About 75 % of the people living around the national park rely on bushmeat as their source of protein. In Western Serengeti hunting takes place inside the protected areas, while in Eastern Serengeti, hunting takes place within villages. Bushmeat hunting is largely driven by ethnic background, number of livestock owned, immigration status of people, and gender (men). A low productivity in pastoral and agro-pastoral production systems increase the dependence on wildlife for food (Mfunda 2010b; Mfunda & Røskaft 2010).

The bushmeat hunting activities affect the behaviour and even populations of different species in the park. For instance, sex ratios of all species we have tested are skewed towards females; ostrich (*Struthio camelus*) (Magige 2008; Magige *et al.* 2009a; Magige *et al.* 2009b), impala (*Aepycerus melampus*) (Setsaas 2004; Setsaas *et al.* 2007), giraffe (*Giraffa camelopardalis*) (Marealle 2011; Marealle *et al.* 2010) and even elephant (Tingvold 2011). In addition, wildlife is more nervous in areas of illegal hunting activities (Holmern 2007; Nyahongo 2008; Setsaas *et al.* 2007).

Human perceptions towards conservation of protected areas in Bangladesh

In Bangladesh people responded unfavourably to conservation of protected areas. Distance the people are living from the boundary of protected areas and gender are the most important factors shaping such conservation attitudes (Sarker & Røskaft 2010; Sarker & Røskaft 2011b). People in northern Bangladesh, however, were generally more positive towards conservation of protected areas than people residing in south-east Bangladesh. Thus, it is of highest importance that management practices should use an integrated approach to put emphasis on the need for poor people to participate in the conservation work. The top-down approach in nature conservation must be changed immediately by involving resource users at every stage of co-management to ensure a win–win situation in sustainable biodiversity conservation (Sarker 2010;

Sarker 2011; Sarker & Røskaft 2010; Sarker & Røskaft 2011b).

Human-elephant conflicts and management options in Bangladesh

In Bangladesh crop-damaging species differ from site to site, but elephants are generally the most frequent offenders. Damage caused by wild elephants is all over mostly uncontrollable and intolerable, while damage caused by other wildlife is somewhat tolerable (Sarker & Røskaft 2011a). Tolerance for crop damage caused by wildlife other than elephant increases markedly with the distance from protected areas, being much higher in areas close to park boundaries. Non-tolerance of crop damage caused by wildlife is commoner in the south-east of Bangladesh. Similar to the high level of population growth and poverty, habitat destruction is a major cause for increasing human-elephant conflict. There is an urgent need for the adoption of an umbrella strategy in the use of conflict mitigation as a conservation tool for Asian elephants (Sarker 2011; Sarker & Røskaft 2011a).

Human attitudes towards conservation of Asian elephants

Wild elephants cause a great level of anxiety. The most important factor influencing attitudes of people towards conservation regimes for wild elephants is the distances the people live from the park boundary. People close to the boundary are more anxious and have more negative attitudes. People in northern Bangladesh are more likely to support the conservation of wild elephants in their nearest protected areas. The introduction of environmental studies into primary and secondary schools, and the promotion of public participation in planning, decision-making and management of protected areas, has been an important aspect for the sustainability of elephant conservation in Bangladesh (Sarker 2011; Sarker & Røskaft 2010; Sarker & Røskaft 2011b).

Conclusion

Due to increasing populations in Asia and Africa, the human wildlife conflict is increasing on both continents. A general pattern is found that gender, education level, degree of involvement with wildlife, distance to park boundary, and economic loss, are all factors shaping human attitudes towards conservation and protected areas and wildlife. On the other hand, human encroachment is affecting wildlife, making them nervous, occasionally aggressive and skewing their sex ratios.

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Chapter 1: Feeding Behaviour and Ecology of the Common Langurs (*Semnopithecus entellus*) of Keshabpur in Bangladesh

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Abstract

Feeding behaviour and ecology of common langurs, *Semnopithecus entellus* (Dufresne, 1797), were studied from September 2009 to August 2010. The study was based on 4-day dawn-to-dusk rotational observations each month, of four focal langurs (1 adult male, 2 adult females, and 1 sub–adult female). The studied animals were from a 15-member langur troop of Keshabpur Upazila in Jessore district of Bangladesh. Data were collected for 124 hours on the focal male and 290 hrs on the three focal females. A detailed vegetation survey was conducted on 28 x 0.25 ha areas to determine the abundance of food plants in the home range area of this common langur group. Food availability and temporal fluctuations of food plant species of the focal langurs were observed by productivity observations. A total of 91 plant species in 39 families were identified as food species of the langurs. The activity budget of focal langurs was determined as 52.1 % resting, 39.1 % feeding, 4.6 % moving, and 4.1 % other activities. Among the five food categories the percentage of feeding activity time on fruits was 53.2 %, young leaves 36.1 %, mature leaves 6.2 %, other food items 2.8 % and flowers 2.4 %. In 78.3 % of fruit- eating time, the langurs were consuming unripe and/or mature fruit. The most time spent on fruits was in April. The langurs ate leaves more when the preferred food items (fruits) were in short supply (October-January). We found that fruit availability was significantly positively correlated with feeding activity and time spent on fruit eating. Dietary diversity was relatively higher in winter than in the summer and rainy seasons. Fruit availability and scarcity in respective habitats might be the key factors of common langur's activity budget and feeding ecology.

Keywords; *feeding behaviour, common langur, group behaviour.*

Introduction

Semnopithecus entellus (Dufresne, 1796) belongs to the sub–family – Colobinae. It is a highly adaptable species largely restricted to India, Bangladesh, Nepal, Sri Lanka and the Himalayas (Bishop 1977; Bishop 1979; Boggess 1976; Curtin 1982; Khan & Ahsan 1981; Koenig & Borries 2001; Napier 1985). The characteristics distinguishing colobines from cercopithecines is a large sacculated stomach; a diverse micro-flora helps the colobines to ferment food as in ruminants (Bauchop 1978; Bauchop & Martyucci 1968; Hill 1966). This signifies that colobine primates, such as the common langur (*S. entellus*) are able to exploit a wider variety of leaves than other sympatric primate species (Chivers 1994; Kay & Davies 1994; Waterman 1984). Concerning the feeding ecology of colobines (e.g., *S. entellus, S. vetulus, Trachypitheus phayrei, and T. pileatus*), it is hypothesised that leaves are the main food category and proportion of mature leaves is high in their diet (Ahsan & Khan 2006; Aziz & Feeroz 2009; Hladik 1977; Rudran 1970; Stanford 1991). The high proportion of mature leaves indicates that their feeding ecology is related to their well-adapted digestive system (Chivers 1994; Kay & Davies 1994; Stanford 1991). The consumption of mature leaves is not as high as in other colobine species, i.e., young leaves are more preferable than mature ones e.g., silver langurs [*T. auratus sondaicus*]: (Kool 1993); guerezas [*Colobus guereza*]: (Fashing 2001b); white-headed langurs [*T. poliocephalus*]: (Li *et al.* 2003). They also prefer reproductive plant parts around the year or when seasonal food is highly available (e.g., *Presbytis senex* and *Presbytis entellus*: (Hladik 1977); black colobus monkeys [*Colobus satanus*]: (Mckey *et al.* 1981); banded langurs [*P. femoralis*]: (Bennett 1983); proboscis monkey [*Nasalis larvatus*]: (Yeager 1989); red langurs [*P. rubicunda*]: (Davies 1991); silver langur [*T. auratus sondaicus*]: (Kool 1993); black-and-white colobus [*Colobus polykomos*]: (Dasilva 1994); guerezas [*C. guereza*]: (Fashing 2001b). Composition of diet varies in relation to the abundance and seasonal availability of food items (e.g., Amerasinghe *et al.* 1971; Dela 2007; Rudran 1970).

Hanuman, hanuman langur or common langur is one of the four species of colobine primates and a common roadside, as well as forest-dwelling, primate in India. In Bangladesh it occurs, however, only in open wooded villages and not in forests (Ahsan 1984). About 50 years ago, this langur was locally common over 25 % of the country's area in the north and south. Now it is restricted to some isolated pockets in the greater districts of Jessore and Kushtia (Ahsan 1984). It is a critically-endangered species in Bangladesh, though at lower

risk globally (IUCN 2000). Several studies have been conducted on the feeding ecology of common langurs in forest habitats (e.g., Gupta & Kumar 1994; Koenig & Borries 2001; Roonwal & Mohnot 1977; Sayers & Norconk 2008; Vasudev *et al.* 2008), while very few studies have been conducted in human-modified habitats (Dela 2007) or in close association with humans (Ahsan 1984; Ahsan & Khan 2006).

Quantitative data on the feeding behaviour and ecology of a group of common langurs are provided in this study in order to: (1) quantify diet and activity patterns, (2) identify feeding preference and the relationship between consumption of food items and availability of food resources, (3) investigate the relationship between feeding activity and food availability, and (4) how temporal change of food items affects the langurs' diet.

Methods

Study area

This study was conducted at Keshabpur Upazila (a sub–county) under Jessore District in Bangladesh. Keshabpur is located approximately between $22^0 25^/$ to 23^0 N and $89^0 25^/$ to $89^0 38^/$ E with an area of 259 km^2. The Upazila (UP) is bounded by Manirampur UP to the north and Tala and Dumuria UPs to the south. Dumuria UP also covers the south-east part while Kalarua UP is to the west; the main rivers are the Kapotaksho and the Hariar. The major plant species of the study area are: coconut (*Cocos nucifera*), betel nut (*Areca catechu*), date palm (*Phoenix sylvestris)*, mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), mast tree *(Polylthia longifolia*), mahogany (*Swetenia mahogani)*, banyan (*Ficus benghalensis*), dumur (*Ficus glomerata*), and peepal tree (*Ficus religiosa*). Annual temperature varies from 11-33^0C, rainfall 1,524 to 1,752 mm and humidity is 78 % (Bari 1979).

Study group

The fieldwork started in September 2009 on two common langur groups, designated BBT-1 and BBT-2, in two villages (Brahmakati and Baliadanga) of Keshabpur UP. In September 2009 BBT-1 contained 15 members (1 adult male, 7 adult females, 1 juvenile, and 6 infants), while group BBT-2 comprised 21 members (1 adult male, 9 adult females, 4 juveniles, and 7 infants). Fieldwork was done on both BBT-1 and BBT-2 during September and October 2009, but in late October 2009 the entire BBT-2 troop was found to have left these two villages. The troop was absent from the study area during the subsequent months. We learned from the local people that BBT-2 was not a permanent resident of the two villages. Their visit to the area seems to be irregular. Hence, we had to drop BBT-2 from the study plan, because of the uncertain availability of the troop in the study area. BBT-1, on the other hand, was a permanent resident of the two villages. The availability of suitable trees, food, and positive attitudes of local people to keep them in the vicinity, possibly helped this group to live in the area. Another factor, which helped them in their permanent stay in these two villages, is that they could survive without the food-supply programme from a Government project. Hence, the study plan was revised in November 2009, and the fieldwork was confined to only BBT-1 for the remaining period.

From November 2009 the fieldwork continued monitoring the activity budget and feeding ecology of four selected members of the BBT-1; one adult male (dominant male, *am-1*), two adult females (*af-1*, *af-2*), and one sub–adult female (who by February 2010 became an adult female, hence, *sgaf*). The *af-1* and *af-2* were clearly distinguishable by difference in size and by some marks of physical appearance. The dominant male and the *sgaf* were themselves quite easily identifiable.

Activity budget and feeding ecology

These four focal langurs were closely observed from dawn to dusk every month from September 2009 to August 2010, using the scan sampling method (Altmann 1974) for focal individuals. The observation included their total activity budget and, specially, their food choice and feeding ecology. The activity pattern of the focal langurs was divided into four aspects - feeding, resting, moving, and others. These four terms were defined as follows: (1) *feeding* included handling of food, intake for mastication, chewing and swallowing of food items; (2) *resting* means cessation of all sorts of movements and motions; (3) *moving* behaviour means all activities such as changing place and position; and (4) '*other activities'* means grooming, monitoring, copulatory behaviour and all actions and behaviours beyond the purview of the main three behavioural categories.

Explanation of the categories of langur food items

Food items were categorised into five: (1) young leaves; (2) mature leaves, including leaf petiole; (3) flowers, including floral bud, complete flower, and also inflorescence; (4) fruits (fruit buds, immature and mature fruits, seeds, and also fruit coatings); and (5) 'other food items', this includes fungus, bamboo shoot, barks (rain tree), and condensed secretion (gum) of some trees (e.g., jeol, *Lannae coromendelica*) and, very unusually, soil during the winter.

Study plan for activity budget

For the study of activity budget four days dawn-to-dusk observations were carried out each month from September 2009 to August 2010, but

deviations from this plan did occur due to unavoidable reasons. For example, only one-day observation made in September 2009, and two days in February 2010 and three days in October 2009, January, March, June, and July of 2010. The following observation plan was normally followed.

On the first day of the four-day sampling in November 2009, observation was started at dawn (0630 h) on the activities of *am-1*. At every 10th minute the activity of the male was observed, e.g., feeding and, if lasting for five seconds or more, the action was recorded. If the male went out of sight at a scheduled time, the reading was not recorded. In this way observation and recording of activities were continued up to dusk of the first day. At dawn of the second day of that sampling month (e.g., November 2009) fieldwork was started with the first focal female, *af-1*. The same procedure and recording plan, was followed, but the second day's observation plan was of a fundamental difference than that of the male. Hence, if *af-1* went out of sight at a particular 20 minutes interval the recording was stopped and the other adult female individual (*af-2*) was selected as the focal animal. Similarly, the third and fourth days' work were on *af-2* and *sgaf*, respectively, following the same procedure as for *af-1*.

Vegetation and abundance of food plants in the study area

To record types and abundance of vegetation and food plants of the langur, the following study method was carried out. A 50 x 50 m grid was first marked, and then the number of food trees (of langur), non-food trees, and food plants belonging to the group - herbs, shrubs, and climbers were counted. Counts of 28 grids were selected randomly in the home range area of the langurs.

Temporal fluctuations of the major tree-food items of the langur

Three major food items - (1) young leaves, (2) flowers, and (3) fruits were first selected. Preliminary information on the food items and their availability was gathered initially from local inhabitants through questionnaires. Data on this aspect were collected on the first day of the four-day monthly field observations, either by one of us or by a trained field assistant by walking through the villages doing simultaneous recordings. Altogether 83 species of food-bearing plants from 31 families were recorded on the data sheet of which the temporal aspects of their availability could be marked.

Analysis of data

Throughout the study period, which spanned over 12 months, 414.8 hours with 2,489 recorded observations on the four activities of the four focal common langurs (*am-1* was observed for 124.2 hours with 745 observations - within 11 months). During the missing month (December 2009), the male was not available at the start of the first day, but he was present during the subsequent three days, but no data were recorded according to the fixed plan. The remaining three focal langurs were observed for nine, twelve, and six months respectively, for a total of 290.6 hours.

Kruskal-Wallis tests were applied to test for any differences of behaviour among the focal individuals. To evaluate the combined effect of three independent variables - young leaves, flowers, and fruits on the feeding activity (dependent variable) of langurs - data were first subjected to multiple regressions by the enter method. Subsequently, a stepwise regression was applied to see which of the variables had most significant influence on feeding activity. The Pearson-product moment correlation was applied to investigate whether there was any relation between the consumption time spent to a particular food item and the frequency of the availability of that particular food in the home range area of the langurs. To examine the variation in relative abundance of the food (young leaves, flowers, and fruits) plant species over time, data were recorded by looking at each plant for presence or absence of young leaves, flowers, and fruits. The dietary diversity was calculated as a Shannon-Wiener Index (H') from the frequencies of the consumption of the food species over the study period. Sorensen's Quotient of Similarity was used to find out the extant of overlap of food species among the seasons (summer: March to May; rainy season: June to September; winter: October to February). All the additional food items were excluded from the analyses. A Bonferroni Correction of p values was used for the Kruskal Wallis tests. The statistical package for social sciences (SPSS version 16) was used in the analyses.

Results

Activity budget

The focal langurs spent most of their time resting (52.1 %), followed by feeding (39 %) while only a little time was spent moving (4.6 %) and in other activities (4.1 %) (Figure 1). Under other activities, the percentage of activity time given to mating behaviour was highest in the male (70 %), whereas those values were 17.3 %, 7 %, and 5.6 % in the cases of *af-1*, *af-2*, and *sgaf*, respectively. No significant difference was found among the four focal langurs with respect to their activity budgets: moving behaviour [with Bonferroni Correction; $H = 8.28$, df = 3, n = 65, $p = 0.051$ (without Bonferroni p value is 0.0083 and with Bonferroni p value is 0.051); Table 1] resting ($H = 5.10$, n = 1303, $p = 0.16$), 'other activities' ($H = 4.92$, n = 162, $p = 0.17$), feeding ($H = 3.72$, n = 946,

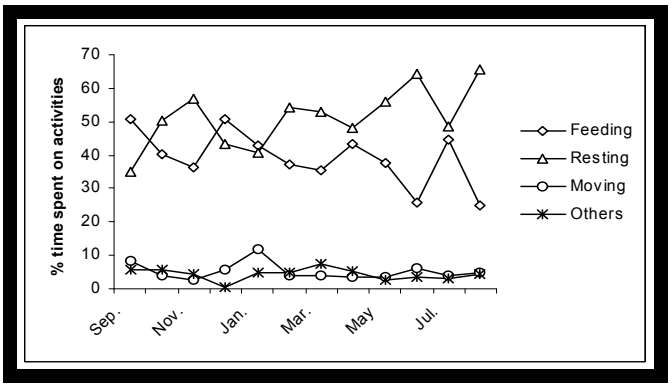

Figure 1 *Percentage of time the four focal common langurs spent on four different activities.*

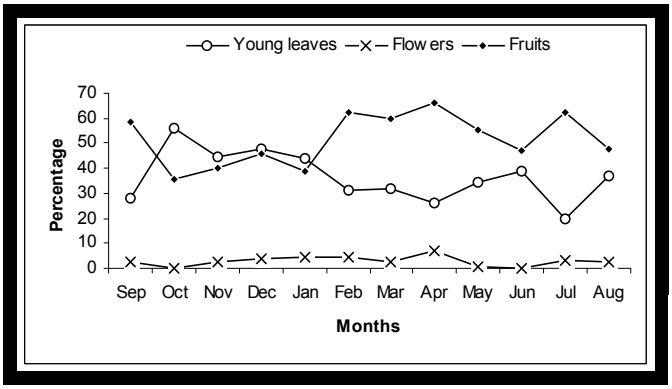

Figure 2 *Percentage of time the four focal common langurs spent on different food items.*

p = 0.29; Table 1). With respect to moving behaviour the group was always followed by the dominant male (*am-1*), when the troop was changing place, although always within the home range of the group.

Food habits

The focal langurs consumed food items from 91 different species of food plants belonging to 39 families (Appendix 1). The food items were young leaves (*ylv*), mature leaves (*mlv*), and leaf petiole (*lvp*), flowers (including flower buds), fruits (including fruit buds and seeds), and 'other food items' (bark, gum, bamboo shoot, soil, and fungus). The langurs also drank water from available sources (ponds, ditches, accommodated rainwater etc.). There was no significant difference between the focal langurs regarding preference of food items [(flowers: H = 5.10, n = 130, p = 0.16; fruits: H = 1.53, n = 456, p = 0.67; young leaves: H = 0.67, n = 386, p = 0.88); Table 1].

Fruits were the most preferred food item (53.2 %) followed by young leaves (36.1 %, Figure 2). The time used to consume mature leaves was 6.2 %, flowers 2.4 %, and 2.1 % for others food items (Table 1). Langurs heavily consumed the unripe/mature fruits (78.3 %); in terms of weight (roughly), they wasted about 67.5 % during fruit feeding.

Common langurs spent 68 % of their total feeding time on five of the 39 families (Appendix 1). These five families constituted 26 species out of 91 total consumed food species. Overall, langurs spent almost 52 % of the feeding time on only two families of the five (Leguminosae and Anacardiaceae). On the other hand, 10 species of food-plants comprised 65.3 % of the langurs' total feeding time (Appendix 1).

Vegetation and abundance of food plants in the study area

A total of 1,881 plants of 73 species belonging to 29 families were counted in the 0.25 x 28 ha area. The majority (n = 1,494; 79.4 %) were food plants (Figure 3) comprising 57 species (78 %). Most of the plant species (84.3 %) were trees in the surveyed area (Figure 4). Ten plant families were abundant; of them Meliaceae constituted the highest proportion (30.7 %) and Malvaceae the lowest (1.7 %; Figure 5). On the other hand, the five most abundant plant species, *Swetenia mahogani* comprised the highest proportion (29.7 %) and *Zizyphus maurituana* the lowest (2.4 %; Figure 6). The most abundant plant species was *S. mahogani* (29.7 %), merely provided food for the langurs; on which langurs spent only 0.3 % of total feeding time (Appendix 1). The locals are

Table 1 *Percentage time spent on different activities and food items among the focal individuals of the BBT-1 group (September 2009 - August 2010).*

	am-1 *n = 745*		**af-1** *n = 530*		**af-2** *n = 810*		**Sgaf** *n = 404*		**Total** *n = 2,489*		**Kruskal-Wallis test**
Activities	**Weighted mean**	**SD**	**Weighted mean**	**SD**	**Weighted mean**	**SD**	**Weighted mean**	**SD**	**Weighted Mean**	**SD**	***p***
Feeding	38.2	1.1	43.3	1.6	33.9	7.4	42.1	8.7	39.0	1.1	0.29
Resting	50.1	1.7	47.2	1.9	58.6	8.5	52.9	1.2	52.0	1.5	0.21
Moving	5.9	4.3	6.1	4.8	4.0	3.5	1.1	2.2	4.6	4.1	0.05
Others	6.3	4.6	3.4	3.6	3.6	2.2	3.8	3.7	4.1	3.0	0.17
Food											
Young leaves	35.2	1.5	36.7	6.6	41.0	2.1	36.4	2.7	36.2	1.9	0.88
Flowers	2.8	4.4	3.4	4.8	0.7	2.5	4.0	3.9	2.4	3.9	0.16
Fruits	53.8	1.7	47.0	1.1	51.3	1.9	50.4	2.6	53.2	1.8	0.67
Others	2.4	3.7	3.8	3.3	1.3	2.1	3.9	6.1	2.1	3.8	
Mature leaves	5.0	6.9	11.0	1.7	5.2	8.1	4.0	5.3	6.2	9.9	

interested in planting this species for timber as well as firewood and high market price. This finding suggests that langurs were facing scarcity for food in the home range area. The situation may be worsening if the locals continue planting the same trees in future.

The number of young leafing, flowering, and fruiting plant species fluctuated monthly over the study period in the home range of the langur group. Data were collected, based on monthly phenological observations (on vegetative and reproductive parts of food species) of the tagged (n = 83) food-bearing plant species. The highest number of leafing trees was recorded in April (n = 52) and the least in October (n = 4). Flower blooms were highest in February (n = 43) and lowest in May (n = 15) in the study area. Distribution of fruits was irregular in the study area throughout the year; the peak fruiting months were March and April (n = 38) (Figure 7).

The time spent on flower eating was generally low during the observation period, whereas the time spent on fruits was high in the majority (n = 8) of the months. Moreover, the highest time spent to fruit eating was observed in April (66.3 %), followed by February (62.5 %), and March (59.9 %). Lowest values of fruit eating were recorded in October (35.4 %) and November (39.8 %) (Figure 2), but time spent eating young leaves was low in almost all months. That on leaves was highest during the four months, when the favoured fruits were unavailable in the home range area (56.2 %, 44.3 %, 47.9 %, and 43.8 % during October, November, December, and January respectively; Figure 2).

Temporal changes of food items used by langurs were analysed to see how the availability of different food items (young leaves, fruits, and flowers) influence the langurs' feeding activity. A stepwise regression analysis revealed a significant positive relationship between the feeding activity and fruit availability ($r^2 = 0.829$, n = 12, $p < 0.001$; Table 2). Monthly fruit availability was positively correlated with fruit eating (Pearson product-moment correlation coefficient: r = 0.88, n = 12, $p < 0.001$), but there was no significant relationship between monthly young leaf and flower availability and young leaf and flower eating (young leaf: r = 0.42, n = 12, $p = 0.17$; flower: r = 0.38, n = 12, $p = 0.21$); nor was monthly fruit availability significantly correlated with monthly leaf eating (r = 0.16, n = 12, $p = 0.60$).

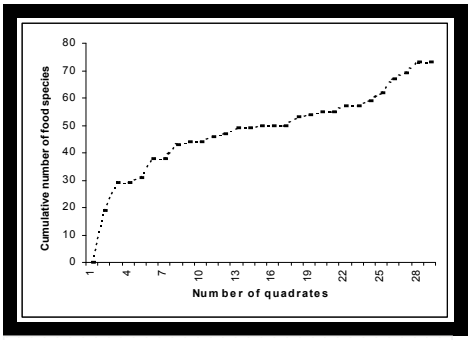

Figure 3 *Cumulative number of species plotted found in the plotted areas.*

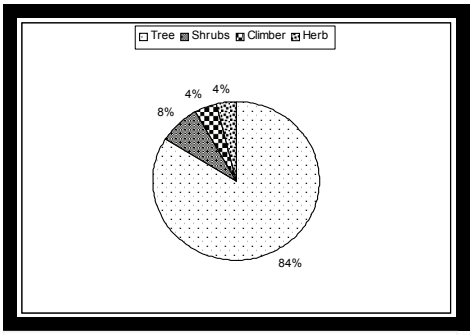

Figure 4 *Vegetation types found in the quadrates.*

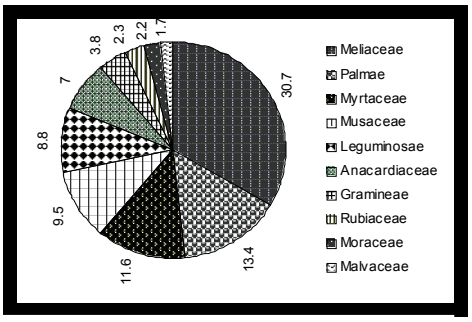

Figure 5 *Abundant plant families in the study areas.*

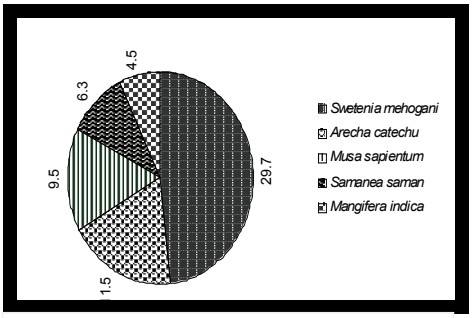

Figure 6 *Abundant plant species in the study areas.*

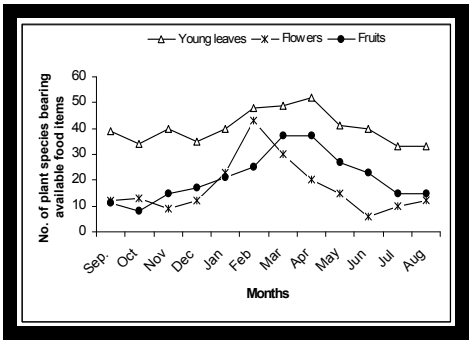

Figure 7 *Temporal fluctuations of available food items in the study areas.*

The dietary diversity of common langurs depended on the large number of plant species they consumed during the study period. The numbers of plant species varied temporally (46 in summer, 38 in rainy season, and 59 in winter). The extant of species over-lapping (Sorensen's Quotient of Similarity) was 35 % between seasons. The Shannon-Wiener Index (H') ranged from 2.85 - 3.36 lowest in summer and highest in winter. The diet in winter was more diverse than the other two seasons. Dietary diversity increased when available food items were scarce in the area.

Table 2 *Stepwise regression analysis with monthly feeding activity (mean for all four individuals) as a dependent variable and influence of monthly availability of young leaves, flowers, and fruits as independent variables.*

	Coefficient	SE	df	*p*
On monthly feeding activity				
Null			11	
Intercept	15.019	2.242		
Fruit availability	0.721	0.098	1	< 0.001
Leaf availability	0.377			0.137
Flower availability	0.085			0.569

Discussion

Langurs spent more than 50 % of their time resting. Similarly, based on a three-month study, Ahsan and Khan (2006) reported that common langurs spent about 50 % of their time sitting and resting, while Sayers and Norconk (2008) reported that the Himalayan langurs (*Semnopithecus entellus*) spent about 40 % of their time feeding, and 29 % resting. This discrepancy might be related to data collection methods [scan sampling of all focal animals at 5-min intervals in Ahsan and Khan (2006), scan sampling at 20-min intervals in Sayers and Norconk (2008), and scan sampling for four selected focal animals at 10-min intervals in this study]. Several recent studies have been finding variation in results of activity budgets. Thus, different data collection methods can result in marked differences in activity budgets (Teichroeb & Sicotte 2009). The common langur is shown to be a rest-preferring animal, spending a high proportion of their daily time resting in order to digest food. This has also been reported in other colobine species, for instance, *Trachypithecus pileata* (= *Presbytis pileata*) spent 40 % (Stanford 1989) and 59 % of time on resting (Stanford 1991); *Trachypithecus francoisi* allotted 52 % of time to resting (Zhou *et al.* 2007); *Colobus guereza* chose 63 % of activity time on resting (Fashing 2001b). Among the main activities, the langurs were also observed to drink water. Common langurs in South India may be able to live without water during 4-5 months during the dry season (Sugiama 1964), while they drink water from available water sources as frequently as they can (Roonwal & Mohnot 1977).

Ahsan and Khan (2006) identified 43 different food species used by the common langurs, while the group used food from 91 species of food plants from 39 families in this study. The low number observed by Ahsan and Khan (2006) is probably due to their short study period and because the species diversity was low in the study area at that time (M. F. Ahsan personal observation). Different numbers of food plant species have been recorded elsewhere (e.g., 40 food species at Gir forest (Rahman 1974); 53 plant

species at Rajaji National Park (Gupta & Kumar 1994); and 34 food species at Langtang National Park (Sayers & Norconk 2008). This variation might be due to different habitats and spatial distribution of food species in different study areas (Gupta & Kumar 1994; Hladik 1977; Krishnan 1972; Mohnot 1971; Sayers & Norconk 2008). This study was conducted in a human habitation area, where human edible fruits were available throughout the year. The group spent more than 90 % of their feeding time on seasonal plant parts. Variations occurred in fruit and foliage ratios with respect to the relative abundance of available food species over time during the study period. In several previous studies on the feeding ecology of the common langurs, a high level of leaf consumption and low dietary diversity (common langurs spent a bulk amount of about 75 % on foliage at Keshabpur (Ahsan & Khan 2006) has been indicated; Himalayan langurs spent maximum 57 % of their time on leaves at Langtang National Park, Nepal (Sayers & Norconk 2008); while common langurs, spent around 53 % on vegetation parts on plants in Rajaji National Park, Uttar Pradesh, India (Gupta & Kumar 1994). Relatively higher levels of fruit eating activity and high dietary diversity, however, have been reported in other studies. Dela (2007) studied two groups of *Semnopithecus vetulus nestor* at two sites at Panadura and Piliyandala in Sri Lanka, and they showed that more than 80 % of the diet consisted of seasonal plant parts, mostly fruits. Hladik (1977) studied two sympatric langur species, *Semnopithecus entellus* (= *Presbytis entellus*) and *Trachypithecus vetulus* (= *Presbytis senex*), in Sri Lanka and recorded that *S. entellus* ate more fruit than *T. vetulus*, and *S. entellus* switched to leaves during the non-fruiting season. In this study of common langurs, there were higher levels of fruit eating in almost all months of the fruiting and non-fruiting seasons and a preference for fruits instead of leaves, when both categories of food were available, but they preferred leaves to fruits during the low fruiting months (October to January) and showed high dietary diversity.

May be the possible explanations for the differences in the common langur's dietary patterns at Langtang National Park, Nepal, and at Rajaji National Park, Uttar Pradesh, India, were, firstly, the Langtang National Park is on the Tibetan border with altitudes varying from ca. 800 to > 7,200 m. The habitats in this area range from subtropical forest to perpetual snow (Sayers & Norconk 2008). At Rajaji National Park, the area is covered with three types of forest: (a) sal (*Shorea robusta*) forest, (b) mixed deciduous forest, and (c) riverine vegetations (Gupta & Kumar 1994). Secondly, the differences found in food composition might be due to differences in methods (see discussion above).

Moreover, contrary to earlier assumptions, colobines, like common langurs, exploit a large amount of leaves, several recent studies reported high levels of fruit consumption in response to local conditions (Dela 2007; Fashing 2001a; Hladik 1977; Koenig & Borries 2001), which is parallel to our study. It was observed that common langurs spent most of their feeding time on fruit eating during the peak fruiting season, indicating that fruit availability plays an important role in the feeding activity. Availability of fruit was positively correlated with fruit eating and feeding activity. The availability of fruit seems to affect significantly the activity budget, as well as the feeding ecology of common langurs in the study area.

Furthermore, in this study, besides ripe fruit, common langurs preferred to eat unripe and/or mature fruits and seeds than leaves. This activity pattern indicates that they may digest unripe fruits and seeds faster or more efficiently than young leaves or other food items. In this connection, it is notable that in several previous studies, fruits vary widely in biochemistry, and are composed of easily-digestible, non-structural carbohydrates which contain energy-rich sugars (Davies *et al.* 1988; Kay & Davies 1994; Waterman 1984). On the other hand, leaves contain more cellulose (e.g., Davies *et al.* 1988; Janzen 1975). The significant positive relation between fruit availability and monthly feeding activity indicates that fruit availability significantly affects the feeding activity of common langurs. In contrast with earlier findings, leaves are the main food categories of colobines. Several recent studies reported that high levels of fruit consumption varied with local conditions [e.g., *P. rubicunda*: (Davies 1991); *C. guereza*: (Fashing 2001a)].

Common langurs spent more than 50 % of their feeding time on two food plant families, and they spent more than 65 % of their feeding time on 10 food plant species while Ahsan and Khan (2006) reported that 17 species provided most of the food items. Dietary diversity increases when preferred foods are in short supply (Bennett & Davies 1994; Davies 1984; Oates 1988; Yeager 1989), as was also observed in our study. The occurrence of 10 heavily-used food species in their diets also supports the idea that langurs diversified their diets when more favoured food items were scarce in their home range. In the study area, human edible fruits from cultivated trees and gardens fluctuated temporally throughout the year and this could have resulted in the observed dietary diversity. So, planting their general diets (10 species) in the public areas should be the key factor for better survival as well as their conservation in the area. A better understanding about the dietary and behavioural adaptations of colobines in general, as well as common langurs in particular, is an important consequence of this study. The necessary

next step is to investigate the dietary and ethological adaptations in a fluctuating habitat, and to develop an understanding about possible human-langur conflicts that would play a vital role in the future species specific conservation.

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Appendix 1 *Percentage time spent on different food (leaves, flowers, fruits, and others) in respect to food species.*
*(** top five families, ylv = young leaves; mlv = mature leaves; fr = fruits; fl = flower; br = bark, sht = bamboo shoot; gu = gum).*

Family	Food species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Anacardiaceae**	*Lannae coromendelica*				gu 1.6							gu 2.2	ylv 8.5	1.1
	Mangifera indica	ylv 19.4	ylv 11.0	ylv 13.3	ylv 0.8	ylv 8.9	fl 6.3	fr 5.6	ylv, fr 22.5	ylv, fr 23.4	ylv, fr 32.1	ylv, fr 36.6	ylv, fr 23.9	16.6
	Spondius dulcis	fr 8.3	fr 11.0	ylv 6.1	fr 5.6					fr 12.1	fr 10.7	fr 11.8	fr 5.6	6.1
Annonaceae	*Annona squamosa*							fr 2.8						0.2
	Polylthia longifolia									fr 4.7			fr 1.4	0.6
Apiaceae	*Coriandum sativum*					ylv 2.5								0.2
Apocynaceae	*Alstonia scholaris*										ylv 3.6			0.2
	Carissa carandans			fr 2.0				fr 1.4						0.3
Asclepiadaceae	*Calotrophis procera*									gu 0.9				0.1
Averrhoaceae	*Averrhoa carambola*								fr 2.2					0.2
Cardiospermaceae	*Cardiospermum halicacabum*											fr 2.2		0.2
Caricaceae	*Carica papaya*					ylv 3.8				ylv 7.5	ylv 16.1	ylv 6.5	ylv 5.6	3.2
Ceasalpinaceae	*Tamarindus indica*				ylv, fr 4.0	fr 2.5								0.7
Chenopodiaceae	*Spinacea oleracea*					ylv 3.8	ylv 4.2							0.5
Combretaceae	*Terminalia catappa*				fr 1.6	fr 5.1	fr ,6.3							1.0
Compositae	*Eupatorium odoratum*		ylv 1.4											0.1
	Mikenia scandens		ylv 1.4											0.1
Cruciferae	*Brassica campestris*				ylv 3.2									0.4
	Brassica capitata				fr 5.6									0.7
	Brassica gangylodes				ylv 5.6									0.7
	Brassica napas				fl 1.6									0.2
	Raphanus sativus					fr 1.3	fr 8.3							0.5
Cucurbitaceae	*Citrullus vulgaris*								fr 1.1					0.1
	Citrus decumena	fr 5.6		fr 2.0										0.4
Dioscoreaceae	*Dioscorea species*				fr 6.5			fr 1.4			fr 1.8		ylv 2.8	1.3
Euphorbiaceae	*Euphorbia gossipifolia*											gu 1.1		0.1
Fabaceae**	*Dalbergia sisso*							ylv 5.6	fl 2.2					0.6
	Vicia faba			ylv, fl 9.2	ylv, fr 8.9	fr 5.1	fr 4.2						ylv 1.4	2.9
	Cassia fistula								fl 1.1					0.1

Family	Food species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Gramineae	*Bambosa arundinacea*					br 1.3								0.1
	Oryza sativa				fr 0.8									0.1
	Zea mays				fr 1.6									0.2
	Triticum estivum					fr 2.5								0.2
Leguminosae**	*Acacia nilotica*	ylv 1.1	ylv 2.7		ylv 9.7	ylv 10.1	ylv 6.3		ylv 10.1		fr 3.6		ylv 7.0	4.8
	Albizzia procera								ylv 3.4					0.3
	Cicer arietum				fr 0.8									0.1
	Leucaena leucocephala	fr 25.0		ylv, fr 8.2	ylv, fr 15.3			ylv 2.8	ylv 6.7					4.7
	Phaseolus mungo			lv 1.0	fr 0.8									0.2
	Phaseolus vulgaris		fr 4.1		fr 0.8									0.4
	Samanea saman		ylv 6.8	ylv 15.3	ylv, br 9.7	ylv, br 22.8	ylv 39.6	ylv, fl, 42.3	ylv, fl, 22.5	ylv 15.0	ylv 1.8	ylv, fl, 6.5	ylv, fl, 9.9	15.8
	Vigna radiata				fr 0.8									0.1
	Lens esculentum					fr 5.1								0.4
	Lathyrus sativus					fr 2.5	fr 8.3							0.6
	Lens culinaris					fr 6.3								0.5
	Vigna sesquipedalis	fr 11.1					fr 4.2							0.6
Liliaceae	*Allium cepa*					ylv 1.3								0.1
Meliaceae	*Swetenia mahogani*								ylv 3.4					0.3
	Melia azadirachta									ylv 0.9		flv 1.1	flv 1.4	0.3
Malvaceae**	*Abelmoschus esculentum*		fr 1.4	fr 1.0			fr 6.3							0.5
	Hibiscus-rosa sinensis					fl 1.3								0.1
	Salmalia malabarica	ylv 8.3							ylv 2.2	flv 4.7	flv 8.9	flv 3.2	flv 7.0	2.4
	Abutilon indicum				fr 2.4									0.3
	Bombax malabaricum					fr 6.3								0.8
Moraceae	*Artocarphus heterpphyllus*		ylv 6.8	ylv 2.0	ylv 1.6	fr 2.5				fr 1.9	ylv 1.8	fr 2.2		1.7
	Artocarphus lacucha									fr 0.9	fr 1.8			0.2
	Ficus benghalensis				ylv 0.8									0.1
	Ficus religiosa							ylv 4.2		ylv1.9				0.5
	Streblus asper											fr 2.2		0.2
Moringaceae	*Moringa oleifera*		ylv 2.7	ylv 3.1	ylv 1.6				ylv 1.1		ylv 1.8	ylv 6.5	ylv 2.8	1.8
Musaceae**	*Musa sapientum*	fr 5.6	fr 26.0					fr (8.5)	fr 3.4	fr 0.9	fr 5.4	fr 6.5	fr 1.4	5.6

Family	Food species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Myrtaceae**	*Eugenia jambos*									fr 1.9				0.2
	Psidum guava				fr 2.4					fr 9.3		fr 5.4	fr 14.1	3.0
	Syzigium cumini	ylv 5.6		ylv 2.0					fr 2.2	fr 1.9				0.8
	Syzigium malaccens								fr 4.5	ylv 0.9				0.5
	Eugenia operculata									fl, 1.9				0.2
Palmae	*Phoenix sylvistris*								fr 1.1					0.1
Papilionaceae	*Arachis hypogea*							fr 8.5		fr 1.9	fr 1.8		fr 2.8	2.3
	Delonix regia			ylv 3.1				fl 2.8		ylv 2.8				0.8
Piperaceae	*Piper betle*											ylv 1.1		0.1
Rhamnaceae	*Zizyphus maurituana*			ylv, fr 7.1	fr 1.6		fr 6.3						fr 2.8	1.5
Rubiaceae	*Gardenia jesminoides*				ylv 0.8									0.1
	Anthocephalus cadamba		ylv 2.7											0.2
Rosaceae	*Rosa centifolia*					fl 1.3								0.1
Rutaceae	*Aegle marmelos*					ylv 1.3								0.1
	Feronia limonia									ylv, 0.9				0.1
Sapindaceae	*Litchi chinensis*							fr 4.2						0.3
	Nephelium longana											fr 3.2		0.3
Sapotaceae	*Acris sopeta*		fr 4.1		fr 1.6			ylv, fr 7.0	fr 3.4	fr 3.7	fr 7.1	fr 2.1		3.2
	Mimusup elengi											fr 1.1		0.1
Solanaceae	*Capsicum annum*					fl 1.3								0.1
	Cestrum nocturnum										ylv 1.8			0.1
	Lycopersicum esculentum							fr 1.4						0.1
	Solanum melongena			fr 3.1	fr 0.8	fr 1.3		fr 1.4					fr 1.4	0.7
Tiliaceae	*Corchorus olitorious*								fr 3.4					0.3
Tiliaceae	*Sesamum indicum*								fr 3.4					0.3
umbelliferae	*Daucus carota*				ylv 0.8									0.1

Chapter 2: Resource Partitioning among the Sympatric Primate Species of West Bhanugach Forest Reserve of Bangladesh

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Abstract

A study was conducted on sympatric primates – *Macaca leonina*, *Macaca mulatta*, *Trachypithecus pileatus,* and *Hylobates hoolock* - in West Bhanugach Forest Reserve of Bangladesh - to ascertain resource partitioning among these species by which they minimise competition for food and space. Time spent in different activities by these species varied significantly. Considering diet composition, *T. pileatus* is folivorous, while the other three species are frugivorous. They use 104 plant species for 174 food items. Among the plant species they eat, 82.7 % are shared by more than one species. Although they shared the same food species, they chose different food items from the same tree. Time spent at different forest height and use of substrate by these species also varied significantly. *M. leonina* and *T. pileatus* mostly use the middle canopy, *H. hoolock* use the upper canopy, while *M. mulatta* spent most of its time on ground. Home range, day range, and pattern of range use also varied among these species, which allow them to use the same tree at a different time of the day or different trees at the same time of the day. This primate community of the study area competes with each other for food resources, but they successfully avoid major conflict by partitioning the resources using their food preferences, use of different forest strata, ranging pattern, and differing in activity budgets.

Keywords; *sympatric species, resource partitioning, diet, ranging, forest strata use, time allocation.*

Introduction

Five species of diurnal, and one species of nocturnal, primates use the resources from the habitat of the West Bhanugach Forest Reserve (WBFR) in Bangladesh. Several primate taxa are known to coexist in many habitats (Chivers 1980; Dunbar & Dunbar 1974; Emmons *et al.* 1983; Leighton & Leighton 1983; Nakagawa 1999; Tutin *et al.* 1997). It is generally thought that such coexistence can only occur where there is niche separation between the species concerned (Gause 1934). In some forest habitats, however, where food is superabundant, niche separation may be minimal, and different species can coexist without significant competition occurring (Gautier & Gautier-Hion 1969; Gertlan & Struhsaker 1972). Polyspecific association, however, has been recorded among a number of Neotropical primates (Buchanan-Smith 1999; Pontes 1997; Porter 2001), as well as in some African primates (Cords 1987; Mitani 1991). These associations are likely to represent a compromise between competition and compatibility. In order to travel and forage together, associated species must have some degree of ecological similarity, which allows coordination of group activities (Terborgh 1983). This kind of association has never been observed in any Asian primates, rather, sympatric primates in Asia showed different strategies to avoid competition, while using the same resources from the habitat (Aldrich-Blake 1980; Caldecott 1985; Feeroz *et al.* 1994; Gittins & Raemaekers 1980; Guillotin *et al.* 1994; Rodman 1991; Singh *et al.* 1997; Ungar 1995). More detailed research has been done on the ecology of individual species than on the primate communities in such habitats. The evolution and adaptation of each species can be enumerated by studying each of them within the community, since the diet of each species and pattern of resource partitioning and niche separation evolved not in isolation but within the communities (Waser 1987).

The WBFR supports two macaque species, the pig-tailed macaque (*Macaca leonina*) and rhesus macaque (*Macaca mulatta*), which are sympatric with three other diurnal primate species e.g., capped langur (*Trachypithecus pileatus),* Phayre's langur *(T. phayrei)*, and hoolock gibbon *(Hylobates hoolock).* A nocturnal species, slow loris *(Nycticebus coucang)* is also found in this area. Pig-tailed macaques (*Macaca nemestrina nemestrina*) are sympatric with a congeneric species, long-tailed macaques (*Macaca fascicularis*) in the Malaysian region. This species also overlaps with Assamese macaques (*M. assamensis*) in some parts of south Asia (Roonwal & Mohnot 1977). Ecological niche differentiation of the Malayan pig-tailed macaques (*Macaca nemestrina nemestrina*) and long-tailed macaques (*Macaca fascicularis*) has been studied by some researchers (e.g., Crockett & Wilson 1980; MacKinnon & MacKinnon 1980), but no information is available about the sympatric mainland pig-tailed (*M. leonina*) and rhesus macaque (*M. mulatta*).

Because of the very low density of *T. phayrei* in the WBFR, rarely seen in the study site, direct resource sharing with other species has never been observed. The other four diurnal species share the

resources from the same area with various degrees of conflict. Data were collected for each of these four species on group size, activity budgets, ranging behaviour, and dietary preferences. The main objective was to collect comparative data for the different species in the study site over the same period of time; thus, differences found could be attributed to genuine differences in adaptation and preferences between the species, which will eventually help to understand how these sympatric primate species coexist in the same area by using the same resources. Resource partitioning between the pig-tailed macaque (*M. leonina*) and rhesus macaque (*M. mulatta*) will be discussed here for the first time, with two other sympatric primate species, which will eventually help us to develop a conservation management plan for the primates of West Bhanugach Forest Reserve.

Methods

Study area

The West Bhanugach Forest Reserve ($24^0$32' N and $91^0$47' E; altitude 22 m) is situated in the north-east of the Moulavi Bazar Forest Range of Sylhet Forest Division of Bangladesh. The forest is covering an area of 2,738 ha composed of three forest beats - Lawachara, Kalacharaand, and Chawtali. Lawacharawas declared as a National Park in 1996. The undulating area with slopes has hillocks, locally called *Tila*, ranging from 10 to 50 metres and scattered in the forest. Numerous streams flow through the forest. The south-east, south, and east sides are bordered by tea gardens and the west by coffee plantation. A rail road and a metalled road cross the forest from east to west. Numerous trails and tracks are found within the forest, created by the local people for collecting wood from the forest. This forest is isolated from the nearest forest by about 10 km, because of surrounding plantations of tea, coffee, and the cultivation of rice. There are three tribal villages on the periphery. The tribals (Khasia) cultivate betel, collect fuel wood, and hunt inside the forest.

Most of the West Bhanugach Forest Reserve was clear-felled, and then planted in different blocks since the 1920s by the Forest Department. The blocks differ in size and each block was planted with a particular plant species, most of which are timber yielding and commercially important. A mixture of both evergreen and deciduous species was planted by the Forest Department, but the majority of plant species found in this forest have grown naturally during the last 75 years or so (Feeroz & Islam 2000). At present, the number of naturally-grown trees is higher than the planted trees; hence it is very difficult to categorise West Bhanugach Forest Reserve as any one recognised forest type. It is not very markedly evergreen, but the majority of the small trees are evergreen and most of the tall trees are deciduous(Feeroz 1999). A total of 112 plant species was identified, of which 78 are forest tree species and 21 are vines, lianas, stranglers, and seasonally-cultivated crops; thirteen tree species were recorded from the human settlement and beside the railroad. Tree density in the study area was 271trees/ha (Feeroz 1999).

The study site shows the general weather conditions of Bangladesh, but it is the coldest place in the country. Mean monthly temperature varied, highest in August (mean = 32.2^{o}C) and lowest in January (mean = 11.7^{o}C). The monthly humidity recorded in the study site varied from month to month (mean = 82.2, SD = ± 8.1), the highest in September (86.8 %) and lowest in March (71.2 %). Rainfall in winter seasons, (December to February), was the lowest and pre-monsoon (March-May) received more rain than post-monsoon (October-November), while the monsoon, lasting from June to September, received maximum rainfall.

Data collection

Major data used in this paper were from the field work conducted between May 1996 and September 1997 (Feeroz 1999), but partial data were also used from (Feeroz 1991; Feeroz 2001; Feeroz 2004; Feeroz *et al.* 1994). Following Ross *et al.*(1993), I estimated the population density of the primate community in the study area from a thorough survey of the total area (27 km^2), by using all the groups that were recorded during the whole study period. A transect census was also conducted, but the density results generated underestimated the actual density; thus, these were used only for extra animal observations. Using the average body weight of adult males and females and multiplying it by the respective individual density calculated the biomass of each species. Metabolic biomass was calculated by considering 0.75 of body weight, as in (Eisenberg *et al.* 1979; Kohlhaas 1988; Pontes 1997). This allows for 50 % of the group being immature, thus markedly lowering group weight. Adult body weights for these species are taken from the literature *M. mulatta* (Napier & Napier 1967); *M. n. leonine* : (Fooden 1975), *T. pileata* : (Stanford 1989); and *H. hoolock*: (Chivers 1977). The relation between group density, body weight, biomass, individual density, mean group size, and home range size were analysed by the simple regression model: log D = log A+b log$w$ and logarithmic transformation of both axes to fit the linear model, which is equivalent to the power function: $D = aW^b$ (Sokal & Rohlf 1981).

Animal observation

Since *T. phayrei* rarely seen to forage in the home range of other species and data were discretely collected on this species, in this paper I will only compare the data on the other four sympatric

species studied systematically over the period. Data on the study species (*M. mulatta, M. leonina, T. pileatus*, and *H. hoolock*) were collected by scan sampling (Altmann 1974), using 15-min. intervals, where different activities were grouped into five major categories, namely, feeding, foraging, travelling, resting, and social activities.

The foods of these species were recorded in seven main categories, e.g., fruit, fig, flower, foliage, seed, animal matter, and miscellaneous. The percentage of time spent on different food items was calculated by the following equation: Tf = (nf x 100)/N (Gupta & Kumar 1994); where, Tf = time spent on particular food item as % of total feeding time; nf = number of feeding records on a particular food item; and N = total number of feeding records. In each scan, one food item was recorded for one individual macaque, i.e., when one individual macaque eats one item from one individual food tree, a single score for this item was recorded. This particular item from the same tree was not scored again. Unless it was eaten by the same monkey after the interval of one scan or by a different individual.

During scan sampling, the position of the individual was recorded as (1) the height of the animal above the ground; and (2) distance of the animal from the tree trunk. The first set of data provided the pattern of forest level used by the group and the second set of data provided the different substrates used by the group in different activities.

A grid system (100 x 100 m) was established to collect data on ranging, as well as on food-tree distribution and use. In the study area 43.9 % quadrates had less than 25 individual food trees, 24.5 % had 25 to 50, 15.7 % had 51 to 75, and only 13.5 % had more than 75 individual food trees. No food tree was found in 2.4 % of the quadrates in the home range. Among the food species, the genus *Ficus* (fig) were commonest. More than 81 % quadrates have at least 1 fig tree; the number of individual fig trees in these quadrates varied from 1 to 19 (mean = 5.6, SD = ± 2.1, n = 261), and the number of fig species found in these quadrates varied from 1 to 4.

Day range is the cumulative distance travelled by the group from dawn to dusk. Position of the group in each scan was recorded with reference to tree and quadrate numbers. After completing the dawn-to-dusk observations, the route travelled by the group throughout the day was drawn on a grid map (1ha) of the study area from the reference of quadrate and tree numbers recorded in each scan. The day range was then measured from the map by using a digital mapping wheel.

Data on composition, structure, and seasonal productivity (phenology pattern) of the habitat were recorded from the enumerated trees (1736 individuals) along two transects in each month. Normally it took 5 days/month to monitor all these trees and was mainly done in the second week of each month.

All statistical nomenclature used here follow that of Siegel and Castellan (1988). Before doing any statistical test, homogeneity of variance, and normality were checked. In most cases non-parametric tests were used, unless otherwise stated, because the independence and distribution of behavioural data are questionable (Siegel & Castellan 1988). Wherever suitable, parametric tests were also used. Test probabilities of all the statistical tests are two-tailed unless stated to contrary. The strength of relationship between two variables was determined by Spearman's rank correlation coefficient (r_s). Before performing regression analysis between two variables to measure and describe the form of the relationship and to predict values of one variable in terms of variations in the other, the normality, and homogeneity of the data were checked. Data were log-transformed before using, if not meeting these conditions. The linear regression model (r^2) was used, the aim of which is to fit a straight line to a graph showing the relationship between two variables under test (Kent & Coker 1992).

Results

Primates community

Six species of primates are found in WBFR, i.e., *Nycticebus coucang, Macaca mulatta, M. nemestrina leonina, Trachypithecus pileatus, T. phayrei,* and *Hylobates hoolock*. *Nycticebus coucang* was not sighted during the study period, but a live specimen was caught by a local hunter, indicating its presence in the forest. *M. mulatta* was the commonest primate in the area (Table 1) and was also found in the largest groups. *Macaca nemestrina leonina*, *T. pileatus,* and *Hylobates hoolock* were found at intermediate densities: 3.8, 2.6, and 1.2 individual/km^2, respectively. *T. phayrei*was the uncommonest (0.41 individuals /km^2, 3.7 ± 0.5, n = 3). Biomass and metabolic biomass of *M. mulatta* was the highest in the habitat (Table 1). There was a positive and significant relationship of the group's biomass and their group size, density, and home range (Figure 1). The home range of these species also significantly depended on their group size ($r = 0.946$, $r^2 = 0.871$, $p = 0.015$; Figure 1).

Activity budgets

Time spent in different activities by the different species varied significantly ($\chi^2 = 193.2$, df = 12, $p < 0.001$). Of all the species, *T. pileatus* spent most of its time feeding, while foraging was the dominant activity in *M. mulatta* and *M. n. leonina*. *H. hoolock* spent nearly similar portions of its time foraging, feeding, and resting. Social activities were seen

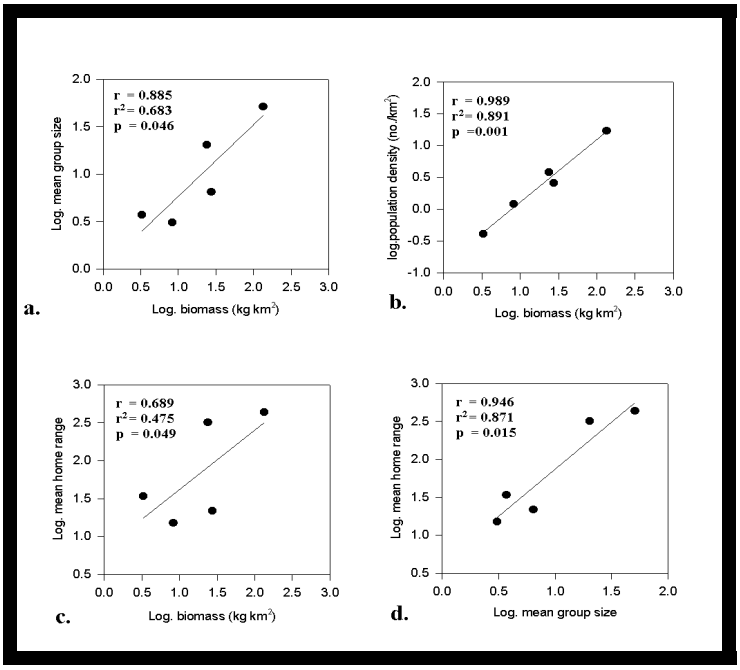

Figure 1 *Relationship between (a) mean group size and biomass; (b) population density (no. of individual/km²) and biomass ;(c) mean home range size and biomass; and (d) mean home range and mean group size of different primate species in WBFR.*

Table 1 *Group size, density, and biomass of primates of WBFR.*

Species	N groups	Group	Size	N groups/ km²	N individuals / km²	Body	Weight	Biomass (kg/km²) *D* x *BW*	Biomass (kg/km²) *D* x *BW* x 0.75
		Mean ± SD	Range			Mean	Range		
M. n. leonina	5	20.6 ± 3.9	15-24	0.19	3.8	6.3	4.4 - 9.1[a]	23.9	17.9
M. mulata	9	51.1 ± 11.4	43-78	0.33	17.1	7.9	4.4 - 10.9[b]	135.1	101.4
T. pileata	11	6.4 ± 1.6	4-9	0.41	2.6	10.5	9.5 - 11.6[c]	27.3	20.6
T. phayrei	3	3.7 ± 0.5	3-4	0.11	0.41	8.1	6.9 - 9.9[d]	3.3	2.5
H. hoolock	10	3.1 ±1 .2	1-5	0.37	1.2	7		8.4	6.3

a: (Fooden 1975); b: (Napier & Napier 1967); c: (Stanford 1989); d: (Napier 1985); e: (Chivers 1977)

least in all species, particularly *T. pileatus* and *H. hoolock,* who spent proportionally more time resting than the other two species and less time in social activities (Figure 2).

Day range, home range, and ranging pattern

Distance travelled each day varied markedly between the four species; *M. mulatta* travelled the longest distances, with a mean day range five times that of *T. pileatus* and twice the day range of *H. hoolock* (Table 2). *M. mulatta* had the largest home range, followed by *M. leonina, H. hoolock,* and *T. pileatus* (Table 2). The home range of *T. pileatus* and *H. hoolock* was completely inside the forest, while less than 2 % (6 ha) of the home range of *M. leonina* was outside the forest. In contrast, 45-52 % of the home range of *M. mulatta* was outside the forest. Within the home range of *M. mulatta* is a tribal village, one *Eucalyptus* forest patch, a portion of tea garden and two large paddy fields. No other primate species used these areas.

Home ranges of *H. hoolock* and *T. pileatus* were completely overlapped by *M. leonina* and *M. mulatta*, while 51-69 % of the home range of *M. leonine* was overlapped by the two *M. mulatta* groups. *T. pileatus* groups overlapped each other completely, while *H. hoolock* overlapped 6-10 % of other home ranges.

The food trees of the study species are distributed throughout their home range**.** A total of 8207 food trees were recorded, of which 3534 (43 %) individual plants were recorded as major sources for several food items (which were used more than twice by several species). Among these major food plants, 954 (26.9 %) come from a single genus *Ficus*. The number of food trees was significantly different between the quadrates (range= 1 -127, mean = 26.9, SD = ± 11.7,

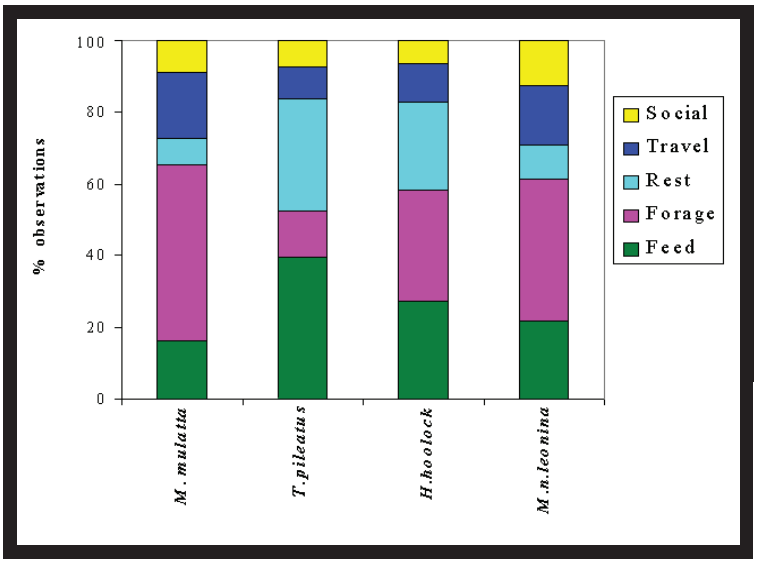

Figure 2 *Proportion of time spent in different activities by M. mulatta (n = 11236), T. pileatus (n = 9625), H. hoolock (n = 10743), and M. leonina (n = 21698).*

Table 2 *Day range length and home range size of the study species.*

Species	Day Range (m)			Home Range (ha)	
	Mean ± SD	Median	Range	Mean	Range
M. n. leonina	1746 ± 527.8	1640	950 - 3340	315.0	297 - 328
M. mulata	2696 ± 789.4	2655	1360 - 4010	435.0	419 - 451
T. pileatus	497 ± 189.8	425	300 - 900	21.8	19 - 24
H. hoolock	1289 ± 375.7	1300	650 - 800	34.4	29 - 40

n = 411; K-W 1-way ANOVA, $p < 0.001$). All primate species in the habitat used these resources, but range-use pattern varied between species. *M. mulatta* spent part of their daily time inside the forest and part in the adjacent cultivated areas. During the monsoon, when most of the trees in the forest were flowering and fruiting, *M. mulatta* spent more than 70 % of their daily active time inside the forest. In contrast, during winter (food crisis period), they spent most of their time outside the forest, in the paddy field or in the vegetable garden, and only returned to sleep.

H. hoolock is territorial and defends its territory by giving loud calls. They use very specific routes for their daily ranging. Among 26 sleeping trees recorded during the study period, 81 % of these were on the boundary of the territory. The group patrolled their territorial boundary in the early morning after leaving the sleeping trees and in the afternoon before entering the next sleeping trees, and crossed the home range in the middle of the day. They use food trees while travelling. *T. pileatus* travelled its home range very slowly. They ranged mostly in the early morning and afternoon, and were usually inactive during midday.

Depending on the availability of food in the forest, *M. n. leonina* showed three distinct ranging patterns: (1) *circling*: this involved the group circling over a small area, the number of quadrates used decreases less than 50 ha/month and used more than 50 % of the quadrates from the previous day's ranging. During the food crisis period: (2) *one-way:* the group foraged continuously over a chosen route, collecting only the good ripe fruit, visiting a maximum number of quadrates; the mean number of quadrates used in each month was 111 (range = 93-133, SD = ± 17.4, n = 7). During ranging the group never re-used the same sleeping site, so the linear distance between the two consecutive sleeping sites was the longest of all patterns. The mean day range was also the longest. During the monsoon when food was abundant in the forest: (3) *to and fro*: in this ranging pattern, the group overlapped at least 25 % of the route used in the previous day; as a result, 25-35 % of area used on the previous day was revisited.

Although these species used the same resources, very few direct confrontations were observed; they tended to avoid each other. Foraging in nearby quadrates (100 m x 100 m) by any of these two species was common, but in the same quadrate it was very rare. Only 150 occurrences were recorded when any two species were feeding or foraging in the same quadrate, at the same time. The occurrence of any two primate species in the same quadrate varied significantly between the seasons ($\chi^2 = 52.9$, df = 4, $p < 0.001$; Figure 3); it was seen most frequently in the winter, less during the monsoon.

In the case of *M. leonina*, the commonest

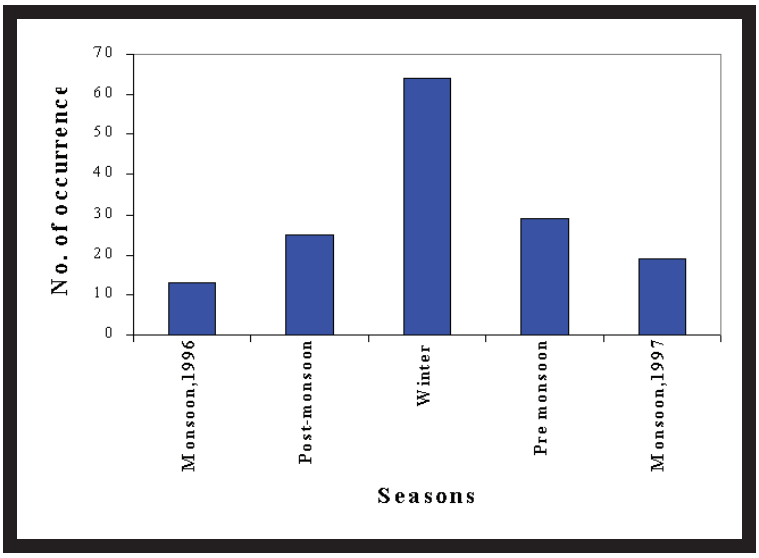

Figure 3 *Number of occurrences when at least two species were in the same quadrate in different seasons of the study period.*

neighbours (on the basis of % occurrence in the same quadrate at the same time) were T. *pileatus* (51.4 %) and *M. mulatta* (29.7 %), while *H. hoolock* was found only 6 times (16.2 %) in the same quadrate as *M. leonina*. Interactions between these species, during this time, were also noticeable. In all cases, aggressive encounters were observed between *M. leonina* and *H. hoolock*. Aggressive encounters between *M. leonina* and *T. pileatus* were observed in only two cases (10.5 %), and in seven cases (63.6 %) between *M. leonina* and *M. mulatta*. Phayre's langur was rare in the habitat and had very few contacts with any of the primate species.

Use of forest strata

Time spent at different forest heights by these species varied significantly ($\chi^2 = 544.2$, df = 9, $p < 0.001$). *M. mulatta* spent 60.8 % of their active time on the ground, while 23.2 % of time was spent up to 10m in a tree, and only 16 % of above 10m (Figure 4), but *T. pileatus* and *H. hoolock* did not use the ground, while *M. leonina* spent only 1 % of their total active time on the ground. *M. leonina* and *T. pileatus* spent most of their time in the middle canopy (5 to 15m), 87.5 % and 76.2 % respectively. *H. hoolock* spent 48.5 % on the upper canopy (16 to 25m) and 45.4 % on the middle canopy. Emergent trees were used mainly for sleeping by all species.

The use of substrate by these species also varied significantly ($\chi^2 = 113$, df = 12, $p < 0.01$). Tree trunks were used more frequently by *M. mulatta* (7.8 %) and the least by *H. hoolock* (3.4 %; Figure 5). All species spent more than 60% of their active time on the horizontal branches (large, medium, and small branches; Figure 5). Most time was spent on twigs by *H. hoolock* (31.3 %), while the least time was spent by *T. pileatus* (8.8 %).

Food species and food items: a total of 104 plant species was used for food by these primate species. *M. leonina* used 93 species (89.4 %), *M. mulatta* used 51 species (49.1 %), *T. pileatus* used 42 species (40.4 %), and *H. hoolock* used 61 species (58.7 %). The number of food species shared varied significantly between these species ($\chi^2 = 26.4$, df = 5, $p < 0.01$). Among the food species, 82.7 % (86 species) were shared by more than one species. *H. hoolock* shared its entire food species with more than one primate species. *H. hoolock* shared its entire food species with *M. leonina,* and 31 species (50 %) were also used by *T. pileatus and M. mulatta* (Figure 6). Seven species were only used by *M. leonina*, 9 species were only used by *M. mulatta*, and 2 species were only used by *T. pileatus* (Table 3).

Several food items of each plant species were eaten by one or more primate species; 174 food items (fruit, fig, foliage, flower, and seed) were used by these primate species. Different primate species used the same food item or different food items from the same tree. *M. leonina* used most food items (139) and *T. pileatus* used least food items (44). On the basis of all food items, *M. leonina* shared the most (43.1 %) food items with *H. hoolock* and the least (13.2) with *T. pileatus* (Figure 6). Time spent on different food items varied between different primate species (Figure 7), *M. leonina* and *H. hoolock* spent most time on figs (*Ficus* spp.) and fruit, while *T. pileatus* spent most of its time on foliage, but *M. mulatta* spent more than one fourth of its time on cultivated crops.

A considerable variation was observed in the ecological needs of the primates of West Bhanugach Forest Reserve (Table 4). Considering the diet composition of these primate species, it is clear that *T. pileatus* is folivorous (55.7 % foliage)

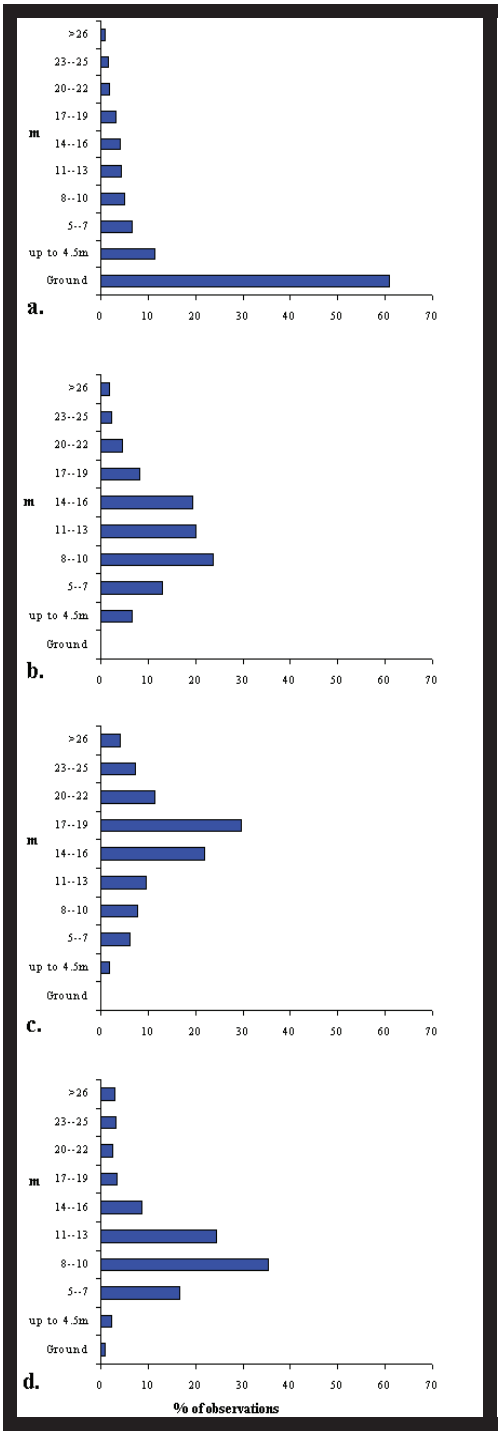

Figure 4 *Frequency distribution of occurrence of animals at different heights (a) M. mulatta (n =1117); (b) T. pileatus (n = 977);(c) H. hoolock (n = 1736); and (d) M. n. leonina (n = 2982).*

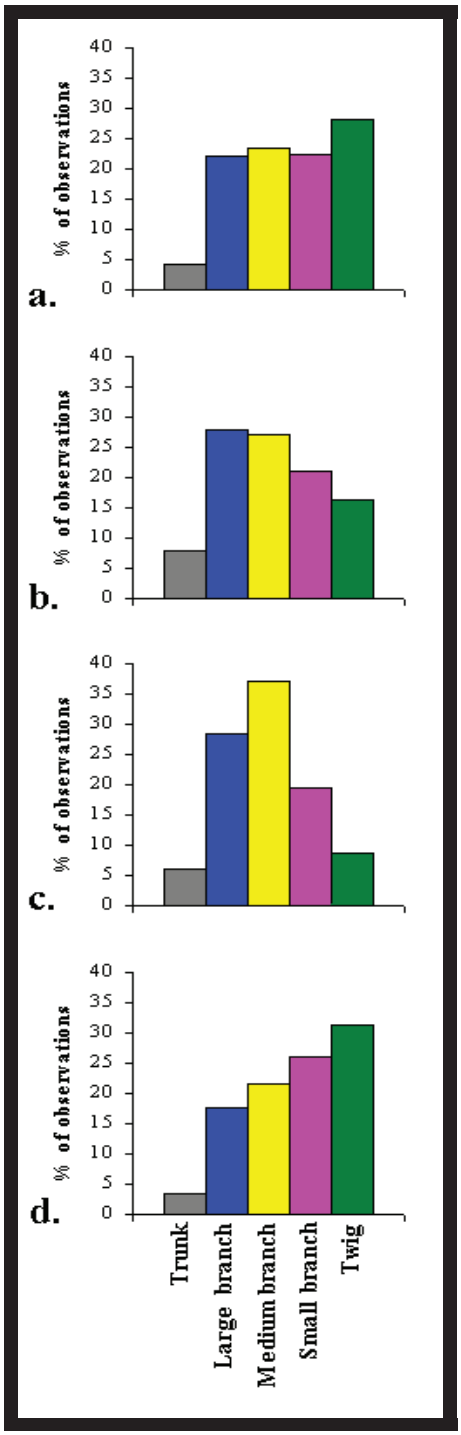

Figure 5 *Frequency distribution of different substrates used by four species of primates in WBFR; (a) M. leonina (n=3486), (b) M. mulatta (n = 1077), (c) T. pileatus (n=917), and (d) H. hoolock (n=1136).*

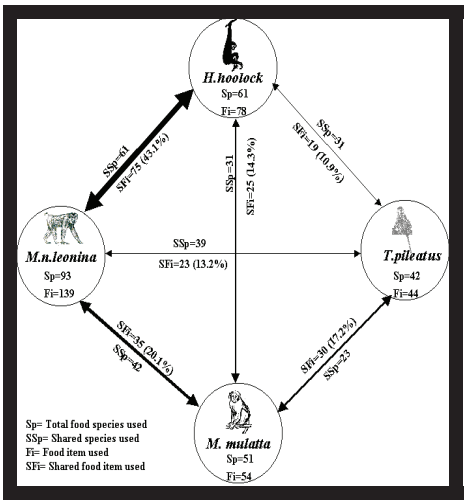

Figure 6 *Food species and food items shared between different primate species in WBFR (percentages are showing the overall food items shared by two primate species).*

and the other three species are frugivorous. Among the three frugivorous species, more than half of the fruit (26.4 %) of *M. mulatta*'s diet came from cultivated crops outside the forest and it competes for the other half (24.5 %). On the other hand, *M. leonina* and *H. hoolock*, both depend on the forest fruit and hence competition between these two species is more intense than between *M. leonina* and *M. mulatta*. Most food species were shared by these primate species, but a clear picture of dietary differences emerges, if the food items they chose from a tree are considered. *H. hoolock* and *M. mulatta* shared with *M. leonina* 61 species (100 %) and 42 species (82 %), respectively, but dietary overlap (food items shared) between *M. leonina* and *H. hoolock* was 43.1 %, while it was only 20.1 % with *M. mulatta*. *T. pileatus* shared 55-93 % of its food species with other sympatric primates, but dietary overlap (food items shared) between *T. pileatus* and any of the other species was less than 18 %. Although these species shared the same food species, they chose different food items; thus, dietary preferences play a vital role in resource partitioning and reduced competition among these sympatric species.

Table 3 *Number of food species used by different primate species in WBFR.*

Name of species	Total species used	Number of food species shared with other primate species (%)	Number of food species not shared (%)
M. leonina	93	86 (92.4)	7 (7.6)
M. mulatta	51	42 (82.4)	9 (17.6)
T. pileatus	42	40 (95.2)	2 (4.8)
H. hoolock	61	61 (100.0)	0

Discussion

Every primate species in WBFR foraged at all levels in the canopy, but they differed significantly in their preferred feeding height. *M. leonina* and *T. pileatus* spent most of their feeding time in the middle canopy, while *M. mulatta* was most frequently seen feeding on the ground and in undergrowth; *H. hoolock* spent similar portions of their feeding time in the upper and middle canopy. Thus, height preference is another factor that reduces feeding competition between *M. leonina* and *M. mulatta*, and between *M. leonina* and *H. hoolock,* since the former species avoided upper canopy and the latter used both canopy levels. The observed feeding height differences may in large part reflect differences in food preferences. Different species of tree and liana fruits are

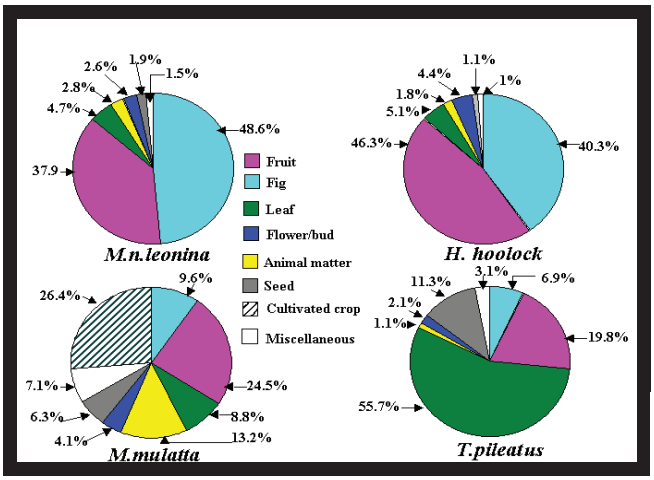

Figure 7 *Diet compositions of different primate species in the study area.*

Table 4 *Summary of the comparative ecological data of sympatric primate species.*

	M. n. leonina	*M. mulatta*	*T. pileatus*	*H. hoolock*
Mean Group size (±SD)	20 ± 3.9	51.1 ± 11.4	6.4 ± 1.6	3.1 ± 1.2
Adult body weight (kg) M	7.7	8.1	11.6	7
F	4.9	6.9	9.5	7
Biomass group (kg)	126.5	403.69	67.5	21.7
Mean day range (m)	1746 ± 527.8	2696 ± 789.4	497 ± 189.8	1289 ± 375.7
% travel time	16.8	18.2	9.2	11.1
% feeding time	21.7	16.2	39.8	27.1
% foraging time	39.6	49.1	12.9	31.1
Size of home range (ha)	320.0	491	23	40
Population density/km^2	3.8	17.1	2.6	1.2
Overall biomass kg/km^2	23.9	135.1	27.3	8.4
Degree of range overlap (%)	80.0	60.0	100.0	100.0
Total food species used	93.0	51.0	42.0	61
Dietary overlap (with 3 other species) (%)	13-43	14-20	11-17	11-43
Canopy used more frequently for feeding	Middle	Ground	Middle	Upper

typically found at different heights in the canopy, although some species of trees are also found in different heights (personal observation). Body size and locomotor patterns of different species allowed them to use different substrates, which may also play a major role in resource partitioning. The brachiation and suspensory locomotion of *H. hoolock* allowed them to spend more time on the very thin branches in the periphery of the crown, while relatively larger-bodied *T. pileatus* spent less time in the periphery. This is also reflected by their feeding preference. *T. pileatus* ate mostly the young and mature leaves, which are distributed throughout the canopy, while *H. hoolock* ate mostly the fruits, which are mainly distributed on the thin branches of the crown. Though *M. mulatta* is slightly smaller than *M. leonina*, it spent more time on the trunk or on large branches, while *M. leonina* spent one-third of its feeding time on the thin branches of the periphery. This is because *M. mulatta* preferred to eat some of the fruits that are grown on the trunk or on the surface of the large branches (e.g., *Artocarpus heterophyllus, A. chaplasha* and *Ficus variegata*). These fruits are large, especially *A. heterophyllus* and *A. chaplasha,* so required some processing before eating. They plucked *A. chaplasha* from the tree and ate it on the surface of the branch. Since *A. heterophyllus* is too large to handle, they always ate the fruit while attached to the tree. Most of the time several *M. mulatta* share one fruit of *A. heterophyllus*. They also ate termites under the dead bark of the trunk, especially in the part close to the ground. Thus, time spent feeding on the trunk was highest for *M. mulatta*.

Range-use pattern also varied from species to species, which allowed them to use the same tree at a different time of the day, or different trees at the same time of the day. The home range of *M. leonina* was 14 times larger than that of *T. pileatus* and 8 times larger than that of *H. hoolock*, but 27 % smaller than the home range of *M. mulatta*. Dietary overlap between *M. leonina* and *H. hoolock* was higher than with any other primate species, but the actual amount of competition between these two species is likely to be limited by the fact that the macaque occupied a larger home range and had a longer day range than the gibbon. This made it unlikely that the *M. n. leonina* group would spend more than a small portion of the day in the home range of *H. hoolock*. On the other hand, *M. mulatta* spent a portion of their daily active time outside the forest and, because of their large home range and long day range, their daily ranging did overlap slightly with the home range of *M. n. leonina*, but direct competition for food between *M. mulatta* and *M. leonina* was negligible.

These species also show marked variation in the amount of time spent in different activities. The proportion of day-time spent feeding, varied from 16.2-39.8 % between the four species. The folivorous *T. pileatus* spent one-third of its active time resting and less than 10 % travelling. Their day range is 33 % of the length for *H. hoolock*, 25 % of *M. leonina* and 17 % of *M. mulatta*. This negative association between day range length and the proportion of foliage eaten is supported by some other studies (Clutton-Brock & Harvey 1977). Feeding and foraging time was negatively related to the proportion of foliage eaten, since fruit, flowers, and animal matter are generally less abundant than foliage and more time needs to be spent in manipulation. For example, folivorous *T. pileatus* spent less time feeding and foraging than the frugivorous species.

The low population density of primates in WBFR, compared with Indo-Malayan forest (Caldecott 1983; MacKinnon & MacKinnon 1980), African forest (Tutin *et al.* 1997)and in South America (Pontes 1997), might have reduced the intra- and inter-specific competition in this area. Though there are certain levels of range overlap between the species, only a few occurrences were recorded when more than one group was foraging in the same quadrate. Direct competition for food sources was also scarce, as indicated by the rare occurrence of more than one species in the same quadrate at the same time.

In this study, the primate community competes with each other for food resources, but they successfully avoid major conflict by partitioning the resources using their food preferences, different forest strata used, ranging pattern and allocating time differently. Low population density of these species also plays a vital role for using the resources without conflict.

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Chapter 3: Space Sharing by Hoolock Gibbons (*Hoolock hoolock*) in Lawachara National Park, Bangladesh

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Abstract

Lawachara National Park is the single continuous habitat for the largest hoolock population north-east Bangladesh, which supports 40 individuals in 12 groups. A study was conducted between September 2008 and August 2009 on group identification and home-range overlap of these groups in Lawachara. Group size and composition of all groups were recorded with GPS coordination and each group was followed from dawn to dusk with recording of GPS Tracking path. Home ranges of all identified groups were enumerated from GPS Tracking path with GIS-based data plotting on Google map. Hoolock gibbons in this National Park used only 58.3 % area as their home range. Home range of these groups varied from 19.9 to 89.8 ha with the mean home range of 60.7 ha. Ten hoolock groups (83.3 %) were overlapping about 39.1 % of their home range with each other. Most of the groups ranged in the natural forest patches of the National Park in the south.

Keywords; *home range, hoolock gibbon, Lawachara, space sharing.*

Introduction

Hoolock gibbon, or white-browed gibbon, *Hoolock hoolock* is the only small ape found in Bangladesh. Gibbons are monogamous, living in a family of one female, her mate, and one to three of their offspring. Average group size ranges from 2 to 6 (Ahsan 1994; Feeroz & Islam 1992). Young gibbons leave their natal groups when they become adult. As hoolocks are territorial, they always defend their territory. Hoolock are completely arboreal and diurnal species. They prefer the upper canopy of the forest, and sleep and rest in emergent trees (Ahsan 1994; Feeroz & Islam 1992 ; Feeroz *et al.* 1994; Hasan *et al.* 2007; Leighton 1987). Each family group occupies a home range of about 14-55 ha (Alfred & Sati 1990; Feeroz 1996; Feeroz & Islam 1992). On average, a group covers a day range of about 600 to 1200 m (Ahsan 1994; Feeroz & Islam 1992).

During the last decade gibbon habitats all over the country have been destroyed at an alarming rate and Lawachara is no exception. Due to rapid habitat destruction and alteration of food trees in Lawachara National Park, the home range of gibbons have been changing and overlapping with other groups.

The status, distribution, ecology, behaviour, and conservation of hoolock gibbons of Bangladesh have been the subjects of several studies (Ahsan 1994; Feeroz 1991; Feeroz 1996; Feeroz 2001; Feeroz & Islam 1992 ; Hasan 2003; Hasan *et al.* 2007; Hasan *et al.* 2005; Islam *et al.* 2008; Muzaffar *et al.* 2007). By using GPS coordinates and tracking paths, the focus in this study was on the pattern of space sharing by hoolock groups of Lawachara National Park of the West Bhanugach Forest Reserve.

Methods

The study was conducted between September 2008 and August 2009 at Lawachara National Park. The whole area of the National Park was divided into eight compartments, based on accessibility, roads, infrastructure, trails etc. Survey was conducted on foot from dawn to dusk in each of the compartments to locate the presence of groups of hoolock gibbon within the compartments. Walking was conducted at a speed of 1 km per hour or less within the forest patch, with stops of a few minutes to look around for signs of hoolock gibbon presence. This included hearing calls, scanning the tree line with binoculars for hoolock gibbons in the canopy, and looking for important fruiting trees (such as species of *Artocarpus*, *Ficus* etc.). When loud territorial calls were heard, there was an attempt to assess the direction of the call and then to locate the group. Once located, group size and composition was recorded with GPS coordination and each group was followed from dawn to dusk with recording of GPS Tracking path. Group composition was recorded as infant, juvenile, sub–adult male, sub–adult female, adult male, and adult female. Home ranges of all identified groups were enumerated from GPS Tracking path with GIS-based data plotting on Google map. Home ranges of all groups were cross-referenced with the previous three studies (Feeroz 1991; Feeroz 1999; Hasan 2003).

Results and Discussion

Group size and composition

Forty hoolock gibbons in 12 groups were recorded from Lawachara National Park. Among these individuals were 24 adults and 16 non-adults (Table 1).

Table 1 *Group size and composition of hoolock gibbon population in Lawachara National Park.*

Group no	GPS coordination	Group composition						Group size
				Adult		Non-adult		
		AM	AF	SAM	SAF	JU	IN	
LG_1	N 24°19.332' E 91°46.989'	1	1	2			1	5
LG_2	N 24°19.678' E 91°47.261'	1	1				1	3
LG_3	N 24°19.788' E 91°47.309'	1	1		1	1		4
LG_4	N 24°19.865' E 91°47.220'	1	1			1		3
LG_5	N 24°19.223' E 91°47.264'	1	1	1			1	4
LG_6	N 24°19.037' E 91°47.028'	1	1	1		2		5
LG_7	N 24°18.924' E 91°46.734'	1	1					2
LG_8	N 24°18.891' E 91°46.609'	1	1					2
LG_9	N 24°19.058' E 91°47.264'	1	1					2
LG_{10}	N 24°20.060' E 91°48.489'	1	1			1	1	4
LG_{11}	N 24°19.465' E 91°47.377'	1	1	1			1	4
LG_{12}	N 24°18.713' E 91°46.395'	1	1					2
Total		**12**	**12**	**5**	**1**	**5**	**5**	**40**

Group size varied from 2 to 5 individuals with the mean group size 3.33 ± 1.15. Hoolock groups comprised 30 % males, 30 % females, 12.5 % sub–adult males, 2.5 % sub–adult females, 12.5 % juveniles, and 12.5 % infants (Figure 1).

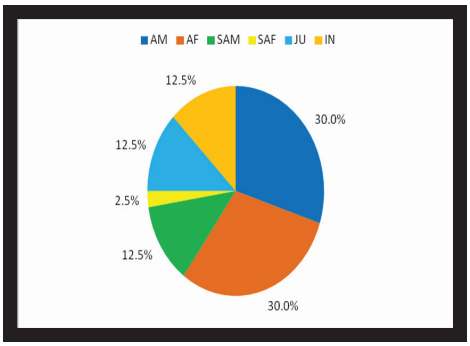

Figure 1 *Group composition of hoolock gibbons in Lawachara National Park.*

Hoolock gibbons in Lawachara National Park have been increasing over the last two decades. Feeroz & Islam (1992) recorded 20 gibbon individuals in seven groups; Ahsan (1994) mentioned that in 1988 there were nine gibbon groups with 25 individuals in Lawachara, and in 1990 there were 10 groups with 26 individuals. Hasan (2003) recorded 11 gibbon groups with 33 individuals and during this study 12 gibbon groups with 40 individuals were recorded from this National Park.

Group size and composition of hoolock gibbon varied with the dispersal of adult individuals from the natal group (Ahsan 1994; Feeroz & Islam 1992). Siddiqi (1986) mentioned that mean group size of hoolock gibbons in Lawachara National Park was 4.0, but, according to Feeroz (1999), it was 3.1. During this study mean group size was 3.33, which is also similar to the overall mean group size (3.40) of hoolocks in Bangladesh (Ahsan 1994). Mean group size of hoolocks in Lawachara was also similar to the gibbons of Assam (3.1; Choudhury 1990), Arunachal Pradesh (3.2, Mukherjee *et al.* 1988), Tripura (3.0, Mukherjee 1992), and Meghalaya (3.0, Alfred & Sati 1990) in India, but Islam *et al.* (2008) estimated average individuals in 96 groups in Bangladesh.

Space sharing

Hoolock gibbons in Lawachara National Park used only 58.3 % (728.29 ha) area of the whole National Park as their home ranges. Home range of these groups varied from 19.9 to 89.8 ha, with a mean home range of 60.7 ± 20.8. About 83.3 % hoolock groups overlapped their home ranges by 39.05 % with each other. A positive correlation was found between group size and home range ($r = 0.30$, $p < 0.001$). Most of the groups ranged in the natural forested parts of the National Park in the south (Jankichara part), hence the overlap was more frequent there.

Group 1 (LG_1)

The home range of this group was 76.31 ha, located in front of Lawachara Forest Beat Office, in between metal road and rail line (Figure 2). About 22.72 % (17.34 ha) of its home range was overlapped by LG_7 and LG_8 (Table 2).

Group 2 (LG_2)

Home range of this gibbon group was in between the southern side of rail line and metal road and from the Beat Office to near the Unicol Gas service station at Magurchara (Figure 2). Home range of this group was 19.92 ha and did not overlap any other group.

Group 3 (LG_3)

Home range of this group was located on the north side of the rail line beside the Forest Beat Office (Figure 2). This group occupied an area of 45.38 ha as its home range and about 33.83 % (15.35 ha) was overlapped by LG_4 (Table 2).

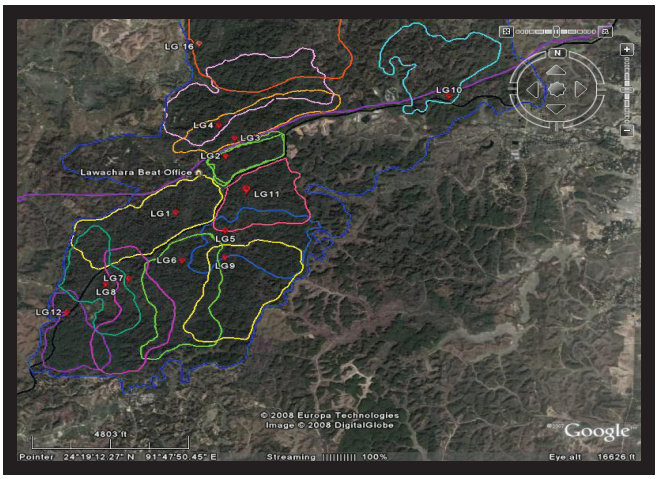

Figure 2 *Home ranges of hoolock gibbons in Lawachara National Park on Google image.*

Group 4 (LG_4)
This group was located on the west side of the mud road from Lawachara Forest Rest House to Chautoli (Figure 2). The home range of this group was 89.75 ha, of which 36.67ha area overlapped with LG_3 and LG_{16}, which was about 40.85 % of the total home range of the group (Table 2).

Group 5 (LG_5)
The home range of this group was 62.59 ha and located on the south side of the Sreemangal-Bhanugach road, just opposite to LG_1 (Figure 2). About 42.67 % home range of this group overlapped with LG_6 (8.49 ha), LG_9 (21.91 ha) and LG_{11} (12.28 ha) (Table 2).

Group 6 (LG_6)
Home range of this group was on the south side of the Sreemangal- Bhanugach road, near Jankichara Forest Beat Office. The home range of this group was 78.81 ha and about 44.76 ha (56.79 %) overlapped with three groups, LG_5 (8.49 ha), LG_7 (18.33 ha) and LG_9 (17.94 ha) (Table 2).

Group 7 (LG_7)
This gibbon group was found on the eastern side of Jankichara forest nursery. The home range of this group was 70.50 ha and about 60.01 % (42.31 ha) of its home range overlapped with four groups. In this overlapping zone, LG_1 overlapped 4.65 ha, whereas LG_6, LG_8 and LG_{12} overlapped 18.33, 14.11 and 0.57 ha, respectively (Table 2).

Group 8 (LG_8)
The home range of this group was also located beside the Jankichara forest nursery; it was 49.94 h and overlapped by LG_1 (12.69 ha), LG_7 (14.11 ha) and LG_{12} (0.57 ha), which was about 54.80 % of its total home range (Table 2).

Group 9 (LG_9)
The home range of this group was 84.09 ha and located at the south of Sreemangal- Bhanugach road, in between the Lawachara entry point and Jankichara forest beat (Figure 2). About 47.39 % of its home range of this group was overlapped by LG_5 (21.91 ha) and LG_6 (17.94 ha) (Table 2).

Group 10 (LG_{10})
The home range of this group was degraded habitat of betel-leaf cultivation, located behind the

Table 2 *Home ranges of hoolock groups in Lawachara National park.*

Group	No. of individuals	Home range (ha)			No. of overlapping groups
		Total	Overlap area	Non-overlap area	
LG_1	5	76.31	17.34	58.97	2
LG_2	3	19.92	0	19.92	0
LG_3	4	45.38	15.35	30.03	1
LG_4	3	89.75	36.67	53.08	2
LG_5	4	62.59	42.68	19.91	3
LG_6	5	78.81	44.76	34.05	3
LG_7	2	70.50	42.31	28.19	4
LG_8	2	49.94	27.37	22.57	3
LG_9	2	84.09	39.85	44.24	2
LG_{10}	4	64.71	0	64.71	0
LG_{11}	4	46.93	12.27	34.66	1
LG_{12}	2	39.36	5.79	33.57	2

Magurchara Khasia Pungee (village). It was 64.71 h, extending both sides of the Sreemangal-Bhanugach road (Figure 2).

Group 11 (LG_{11})
The home range of this group was 46.93 ha, extending from Lawachara entry point to the tea gardens near Magurchara. About 26.14 % home range (12.27 ha) of this group overlapped with LG_5 (Table 2).

Group 12 (LG_{12})
This gibbon group was located on the north side of the Sreemangal- Bhanugach road and just opposite side the Jankichara forest beat office. The home range of this group was 39.36 ha and about 10 % overlapped with LG_7 (5.22 ha) and LG_8 (0.57 ha) (Table 2).

Home range of hoolock gibbon depends on the distribution and availability of food sources throughout the year (Feeroz & Islam 1992). In Lawachara, about 79.6 % diet of hoolock gibbons come from fruit (Ahsan 1994) and mostly (42 %) from figs (Feeroz 1991; Hasan *et al.* 2005). Distributions of fruit trees, as well as fig trees, are important for the home range of any gibbon groups. Mean home range of hoolock gibbons in Lawachara was 35 ha (Feeroz & Islam 1992), while Ahsan (1994) mentioned it to be about 36 ha, but during this study mean home range was estimated as 60.69 ha. During the last few years habitats of hoolock gibbons in Lawachara National Park have been destroying at an alarming rate due to illegal logging, excessive tourist pressure, and other anthropogenic effects. Number of fruit trees, as well as canopy cover is also reduced in natural forest patches. In this situation gibbon groups need to explore more widely for their food and shelter. This is the probable reason for the expansion of their home range.

The southern part of the Lawachara National park was rich in natural vegetation, including fruit trees (Ahsan 1994; Feeroz 2001; Hasan 2003), and most gibbon groups ranged there. As a result, home range overlap was more frequent, and that of one group was overlapped by another 4 groups. Territorial conflicts were also more frequently observed there.

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Chapter 4: Tree-Species Diversity of a Remnant Natural Dipterocarp Forest versus Mono-plantation in Rajghat, Cox's Bazar (North Forest Division) of Bangladesh

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Abstract

The study was carried out to assess the floristic composition, distribution, quantitative structure and natural regeneration of native tree species of Rajghat Forest Beat, Fulchari Range in Cox's Bazar (North) Forest Division, Bangladesh. A total of 50 sample plots of 50 m x 50 m in size were taken from the natural forest and 100 sample plots of 5 m x 5 m in size were taken for regeneration study. A total of 907 individual stems of 13 native tree species were recorded from 12.5 ha sampled area, where *Dipterocarpus costatus* was dominant (n = 743) followed by *Swintonia floribunda* (n = 71). Total basal area for all trees with ≥10 cm dbh was 1,047.50 m^2 and average basal area was 83.95 m^2 ha^{-1}. *D. costatus* showed highest Importance Value Index (201.48) followed by *S. floribunda* (37.86). *D. costatus* showed highest cylindrical volume (629.47 m^3 ha^{-1}) followed by *S. floribunda* (57.04 m^3 ha^{-1}). Plantation plots of FRMP (Forest Resources Management Project), woodlot, participatory and enrichment plantation comprised 42, 30, and 40 ha, respectively, where *Acacia auriculiformis* was highest (789 stems ha^{-1}). A total of 26 regenerating tree species were recorded from the natural forest. In the hill top, tree species regeneration was 11,387 seedlings ha^{-1}, where *D. costatus* represents highest (4,080 ha^{-1}) followed by *S. floribunda* (1,733 ha^{-1}). Recruitment is not successful, because of removal of seedlings and saplings by the local wood collectors and ground fire. This natural forest is a harbour of valuable native tree species (*D. costatus*, *S. floribunda*, *A. scapula*, *C. indica*, *M. sylvatica*, etc.), especially for their ecological, economic, and aesthetic values. This remnant forest needs to be conserved through proper management and protection of the native tree species, especially through protection of natural regeneration.

Keywords; *tree biodiversity, forest, plantation, Cox's Bazar*

Introduction

The total forest area of Bangladesh is 2.56 million ha (Mha), of which 1.53 Mha is managed by the Forest Department (FD) and 0.73 Mha of Unclassified State Forest (USF) is administered by the civil administration (District Commissioner, DC); 0.27 Mha village forest land (Khan *et al.* 2004). The natural forests of Bangladesh have a rich biological heritage, containing about 5,700 species of angiosperms (Khan 1991). Out of these, 2,260 species are present in the hilly region of Chittagong (Haque *et al.* 1997; Hassan 1995; Heining 1925). The biodiversity of the forest, however, has been heavily disturbed during the last few decades due to rapid population growth, energy deficit, resource shortage, myopic planning, poor management, and lack of motivation for the needs of biodiversity conservation, which has resulted in the loss of wild biodiversity at an alarming rate (Haque *et al.* 1997; Hassan 1995). Many plant and animal species, widely distributed in the past, have either become extinct or can only be found in some local areas at very low population density (Das & Alam 2001). Quantitative floristic inventories are fundamental to understanding the ecology of tropical forests and for developing national forest management strategies (Campbell *et al.* 1986). Natural forests of Bangladesh are not managed under an environmentally-sound system and consequently, depletion has taken place both in area and quality (FMP 1992) but the natural forests of the hilly areas of Bangladesh are gradually being converted into production plantation forest through felling and artificial regeneration since 1871 (Hossain 1998).

In Bangladesh, it has become imperative to save the remaining natural forests from further destruction. Fulchari Reserve forest under Cox's Bazar (North) Forest Division is a part of the hill forest, which is faces serious disturbance. Rajghat Beat once had a good quantity of tree coverage, but is gradually degraded and converted into denuded areas. The present study site is in the natural forests of Rajghat Forest Beat, under Fulchari Range of Cox's Bazar (North) Forest Division. This natural forest is one of the important watershed areas of the country and floristically composed of a number of tropical evergreen and semi evergreen tree species, especially Baittya-garjan, *Dipterocarpus costatus* and civit, *Swintonia floribunda*, but gradual conversion of the natural forests with exotic species is responsible for the genetic erosion of the native species from this remnant mature forest. This forest is important not only for renewable resources, but also as essential in conservation of native species, wildlife, and environment.

Table 1 *Tree species naturally found in Rajghat Beat of Fulchari Forest Range*

No.	Local Name	Scientific Name	Family
1	Boilam	*Anisoptera scapula* (Roxb.) Pierre	Dipterocarpaceae
2	Bot	*Ficus bengalensis* L.	Moraceae
3	Civit	*Swintonia floribunda* Griff.	Anacardiaceae
4	Dhaki Jam	*Syzygium grandis* (Wt.) Wall.	Myrtaceae
5	Dholi Jam	*Syzygium wallichii* (Wt.) Walp.	Myrtaceae
6	Gab	*Diospyros peregrina* (Gaertn.) Gurke.	Ebenaceae
7	Kalo Jam	*Syzygium cumini* (L.) Skeel	Myrtaceae
8	Kiabang	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae
9	Moos	*Pterospermum acerifolium* (L.) Willd.	Sterculiaceae
10	Puti Jam	*Syzygium fruticosum* (Roxb).	Myrtaceae
11	Sil Batna	*Castanopsis indica* (Roxb.) A. Dc.	Fagaceae
12	Baitta- Garjan	*Dipterocarpus costatus* Gaertn.	Dipterocarpaceae
13	Uri Am	*Mangifera sylvatica* Roxb.	Anacardiaceae

For biodiversity conservation and successful establishment of natural regeneration, an economically- and ecologically-sound management plan is desirable. Thus, this study was undertaken to assess its tree species composition, stand structure, natural regeneration, and qualitative and quantitative distribution of plant species, which may be useful in providing guidelines for sustainable management and conservation of this remnant natural forest.

Methods

Selection of the study area

The study was conducted in the Rajghat Forest Beat, Fulchari Range of Cox's Bazar Forest Division (North). The Rajghat Beat has a total forest area of 566.84 ha, of which only 227.89 ha comprises natural forest. The forest area of Rajghat Beat has a cover of mature trees and a substantial portion of the forest is gradually degrading. Besides this, the Forest Department has converted the degraded areas to mono-culture by planting short-rotation exotic species, like *Acacia auriculiformis, Acacia mangium* etc.

Sampling design for measurement of composition and structure of tree species

The study area was divided into five blocks, e.g., Bital, Keyamontola, Napitkhali, Rohittarsia, and Purnogram area. From each block 10 (ten) sample plots were taken by using systematic sampling method and a total of 50 sample plots of 50 m x 50 m in size were taken. From the short-rotation plantations, a total of 15 sample plots of 20 m x 20 m in size were taken (5 plots from each type). All the plots were well demarcated, their corners were marked with pegs and then all the plants, including seedlings, saplings, and trees of all species in each plot were identified and recorded.

Sampling design for regeneration study

For regeneration survey, one sample plot (5 m x 5 m) was laid out at the middle of each main sample plot (50 m x 50 m) in two different slopes (hill top and hill bottom). In each block same number of sample plots was taken for the tree species. Seedlings were identified, counted, and recorded on the data recording sheet. In case of plantations, 2 sample plots of 5 m x 5 m in size were taken for regeneration assessment. A total of 30 regeneration plots in the three different-aged plantation plots were surveyed. For assessing the effect of aspects of natural regeneration, a total of 20 regeneration plots 5 m x 5 m in size were surveyed (5 plots from each aspect), which were selected randomly from the natural forest area. The Density, Relative Density (RD %), Frequency, Relative Frequency (RF %), Abundance, Relative Abundance (RA %), Relative Dominance (RDo %), and Importance Value Index (IVI) of each species were calculated according to Curtis (1959), Whittaker (1975), Shukla & Chandel (1988), Moore & Chapman (1986), and Dallmeire *et al.* (1992).

Results and Discussion

Tree-species composition

A total of 13 tree species were recorded from the 12.5 ha sampled area of Rajghat Forest Beat in Fulchari Forest Range of Cox's Bazar (North) Forest Division (Table 1). Baitta-Garjan (*Dipterocarpus costatus*) is recorded as dominant (743 tree individuals) followed by Civit (*Swintonia floribunda*) as 71 tree individuals. Other important tree species are *Syzygium grandis, Mangifera sylvatica, Castanopsis indica*, and so forth.

Diameter-class distribution

Percentage distribution of individual tree species in different dbh classes of the Beat (Napitkhali, Bital, Keyamontola, Rohittarsia, and Purnogram block) is shown in Table 2. In all blocks, the percentage distribution of trees was highest (59.2 %) in diameter class 61-70 cm and lowest (3.2 %) in the 41-50 cm diameter class. The percentage distribution of *D. costatus* was highest in all blocks followed by *S. floribunda* (Table 2). Due to lack of normal age-class distribution (sapling, pole etc.), Rajghat Forest Beat had wide difference in

Table 2 *Percentage distribution of individual species in different dbh (cm) classes in five Blocks (Napitkhali, Bital, Keyamontola, Rohittarsia, and Purnogram) of Rajghat Beat.*

Blocks name	Species	Percentage distribution of dbh classes (cm)				Total (%) in the Block
		41-50	51-60	61-70	≥71	
Napitkhali	*S. floribunda*	-	1.14	6.29	-	7.43
	S. grandis	-	-	1.71	-	1.71
	D. costatus	3.43	28.57	52.57	5.71	90.29
	M. sylvatica	-	-	0.57	-	0.57
Bital	*A. scapula*	-	-	0.52	-	0.52
	S. floribunda	1.57	3.66	5.24	1.05	11.52
	S. grandis	-	1.05	-	-	1.05
	C. indica	-	-	0.52	-	0.52
	P. acerifolium	1.05	1.57	-	-	2.62
	C. indica	-	0.52	0.52	-	1.05
	D. costatus	3.14	28.80	47.12	-	79.06
	M. sylvatica	-	-	2.62	1.05	3.66
Keyamontola	*A. scapula*	-	-	0.57	-	0.57
	S. floribunda	1.14	0.57	13.14	-	14.86
	S. grandis	-	0.57	0.57	-	1.14
	S. wallichii	-	-	0.57	-	0.57
	C. brachiata	-	0.57	-	-	0.57
	C. indica	-	-	0.57	-	0.57
	D. costatus	3.43	33.71	38.86	4.00	80.00
	M. sylvatica	-	-	0.57	1.14	1.71
Rohittarsia	*A. scapula*	-	-	0.58	-	0.58
	S. floribunda	-	0.58	2.33	-	2.91
	S. grandis	0.58	-	0.58	0.58	1.74
	S. fruticosum	-	1.16	-	-	1.16
	C. indica	0.58	-	-	-	0.58
	D. costatus	1.16	33.72	52.33	2.91	90.12
	M. sylvatica	-	0.58	1.74	0.58	2.91
Purnogram	*A. scapula*	-	-	0.81	-	0.81
	F. bengalensis	-	-	0.81	-	0.81
	S. floribunda	-	-	1.63	-	1.63
	S. grandis	-	0.81	-	-	0.81
	S. wallichii	-	1.63	-	-	1.63
	S. cumini	-	0.81	-	-	0.81
	S. fruticosum	-	0.81	-	-	0.81
	C. indica	-	-	0.81	-	0.81
	D. costatus	-	29.27	60.16	-	89.43
	M. sylvatica	-	-	1.63	0.81	2.44
Total		**16.10**	**170.10**	**296**	**17.80**	**500**

percentage distribution of diameter classes. Distributions of tree species among dbh classes do not show a trend typical of most undisturbed tropical and temperate forests (Campbell *et al.* 1986). Nath *et al.,* (1997) described that, as the dbh increases, both the number of individual species and stems decreased, showing the successful recruitment of a few species which need proper silvicultural management systems to maintain a regular diameter distribution.

Height-class distribution

The vertical profile of a forest provides a representation of different forest structure. The percentage distribution of individual species in different height classes of the five blocks (Napitkhali, Bital, Keyamontola, Rohittarsia, and Purnogram) is shown in Figure 1.

It was observed that 47.6 % trees belong to height class 20-22 m; the lowest was reported in ≥ 29 m height class. In Napitkhali lowest percentage distribution (5.14 %) of trees was recorded in height class 26-29 m, but in Bital, Keyamontola, and Purnogram lowest percentage distribution of trees was found in ≥ 29 m height class. In all the five blocks, *D. costatus* was dominant in all the height classes, followed by *S. floribund*a, but the stratification of tree canopy was not conspicuous because of the absence of middle (pole) or lower strata (saplings).

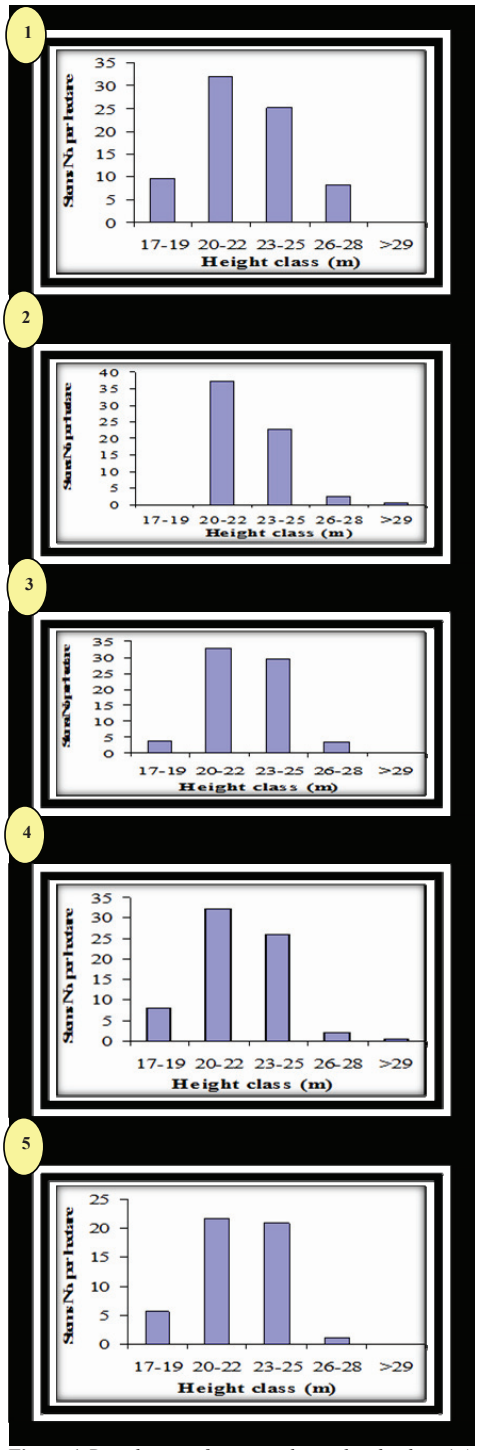

Figure 1 *Distribution of stem number in height class (m) in the studied blocks (1. Bital, 2. Keyamontola, 3. Napitkhali, 4. Rohittarsia, and 5. Purnogram) of Rajghat Forest Beat.*

Quantitative structure of tree vegetation

The quantitative structure of the tree vegetation was studied, based on the density, basal area, relative frequency, relative density, relative dominance, and importance value index.

Number of stems/ha (density)

Trees having ≥ 10 cm dbh is the commonest studied group of plants in species counts in plots of tropical rain forests (Shiva & Jantan 1998). In this study no tree species less than dbh 40 cm were recorded. A total of 907 stems were recorded in the 12.5 ha sampled area in five blocks. The density of individual stems in Bital, Keyamontola, Napitkhali, Rohittarsia, and Purnogram was 78, 73, 70, 69 and 70 stems ha^{-1} respectively. This indicates the poor density of tree species, compared to some other forests, e.g., Rahman *et al.* (2000) reported that the average density of individual stems in Chunati Wildlife Sanctuary was 459 stems ha^{-1}. Hossain *et al.* (1996) reported that the average density was 202-227 stems ha^{-1} at Bamu Reserve in Cox's Bazar Forest Division. Ahmed & Haque (1993) studied the natural forest of Ukhia Range in Cox's Bazar Forest Division and stated that 257 stems ha^{-1} were available.

Basal area and cylindrical volume/ha

The total basal area for all trees with ≥10 cm dbh was recorded as 1047.50 m^2 in the sample blocks and average basal area/ha was 83.95 m^2 (Table 3). Highest basal area was recorded for *D. costatus* (71.35 m^2ha^{-1}) followed by *S. floribunda* (7.26 m^2ha^{-1}) and *M. sylvatica* (2.25 m2 ha^{-1}). Lowest basal area was in *C. brachiata* and *P. acerifolium* (0.08 m^2 ha^{-1}) (Table 3), but the basal area is higher, e.g., Rahman *et al.* (2000) found the total basal area of all the tree species was 33.77 m^2ha^{-1} in Chunati wildlife sanctuary.

Nath *et al.* (1997) studied in Sitapahar Forest Reserve in Chittagong Hill Tracts (South Forest Division) and reported an average basal area of 53.5 m^2ha^{-1}. On average, the total cylindrical volume was recorded 733.64 m^3ha^{-1}. The highest cylindrical volume was for *D. costatus* (629.47 $m3ha^{-1}$) followed by *S. floribunda* (57.04 m^3ha^{-1}), *M. sylvatica* (17.50 m^3ha^{-1}) and *A. scapula* (6.91 m^3ha^{-1}). The lowest cylindrical volume was recorded for *S. fruticosum* (1.19 m^3ha^{-1}) (Table 3).

Relative frequency, relative density, relative dominance, relative abundance, and importance value index

The highest relative frequency was found for *D. costatus* (34.48 %), followed by *S. floribunda* (21.38 %) and *M. sylvatica* (10.34 %). Highest relative density was in *D. costatus* (82.01 %), followed by *S. floribunda* (7.84 %). Similarly, highest relative dominance was in *D. costatus* (84.99 %), followed by *S. floribunda* (8.64 %) and

Table 3 *Average height (m), dbh (cm), and number of stems/ha and cylindrical volume (m^3 ha^{-1}) in Rajghat Forest Beat.*

Sl. No.	Species	Average ht (m)	Average dbh (cm)	Average number of stem ha^{-1}	Basal Area (m^2ha^{-1})	Cylindrical volume (m^3ha^{-1})
1	*A. auriculiformis*	13.58	15.60	10	0.15	0.83
2	*A. scapula*	22.75	63.50	3	0.81	6.91
3	*F. bengalensis*	17.00	76.00	1	0.15	2.47
4	*S. floribunda*	19.93	63.79	28	7.26	57.04
5	*S. grandis*	20.95	54.55	4	0.75	6.26
6	*S. wallichii*	17.75	56.50	1	0.16	1.42
7	*A. hybrid*	14.92	16.90	6	0.11	0.64
8	*D. peregrine*	18.00	61.00	1	0.09	1.68
9	*S. cumini*	20.00	60.00	1	0.09	1.81
10	*C. brachiata*	19.00	58.00	1	0.08	1.61
11	*P. acerifolium*	19.00	58.00	1	0.08	1.61
12	*S. fruticosum*	17.25	52.50	1	0.21	1.19
13	*C. indica*	19.63	56.88	2	0.41	3.19
14	*D. costatus*	22.07	61.83	297	71.35	629.47
15	*M. sylvatica*	19.42	66.96	8	2.25	17.50
Total		**261.90**	**762.41**	**365**	**83.95**	**733.64**

Table 4 *Basal area (BA), Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo), Relative Abundance (RA), and Importance Value Index (IVI) of tree species in Rajghat Forest Beat.*

Sl. No	Species	Total BA (m^2)	BA (m^2ha^{-1})	RD (%)	RF (%)	RDo (%)	RA (%)	IVI
1	*A. auriculiformis*	1.83	0.15	2.65	5.52	0.17	8.70	8.34
2	*A. scapula*	10.13	0.81	0.88	3.45	0.97	4.64	5.30
3	*F. bengalensis*	1.81	0.15	0.11	0.69	0.17	2.90	0.97
4	*S. floribunda*	90.72	7.26	7.84	21.38	8.64	6.64	37.86
5	*S. grandis*	9.34	0.75	1.10	5.52	0.89	3.63	7.51
6	*S. wallichii*	2.00	0.16	0.22	1.38	0.19	2.90	1.79
7	*A. hybrid*	1.35	0.11	1.66	4.83	0.13	6.21	6.62
8	*D. peregrina*	1.17	0.09	0.11	0.69	0.11	2.90	0.91
9	*S. cumini*	1.13	0.09	0.11	0.69	0.11	2.90	0.91
10	*C. brachiata*	1.06	0.08	0.11	0.69	0.10	2.90	0.90
11	*P. acerifolium*	1.06	0.08	0.11	0.69	0.10	2.90	0.90
12	*S. fruticosum*	2.60	0.21	0.33	2.07	0.25	2.90	2.65
13	*C. indica*	5.08	0.41	0.55	3.45	0.48	2.90	4.48
14	*D. costatus*	891.90	71.35	82.01	34.48	84.99	43.10	201.48
15	*M. sylvatica*	28.16	2.25	2.21	10.34	2.68	3.88	15.23
Total		**1047.50**	**83.95**	**100**	**100**	**100**	**100**	**300**

M. sylvatica (2.68 %) (Table 4). Highest Importance Value Index (IVI) was found in *D. costatus* (201.48), followed by *S. floribunda* (37.86) and *M. sylvatica* (15.23). From the dominance of species in heterogeneous plant communities (Shukla & Chandal 1988), it can be concluded that in Rajghat Forest Beat, *D. costatus* is the dominant species, *S. floribunda* is the co-dominant species and others are intermediate and associated species.

Plantation establishment in Rajghat Beat

In Rajghat Beat, three types of plantation were established with fast growing exotic species. The plantations established as FRMP (Forestry Resource Management Project) in 1998 - 1999, Woodlot plantation in 2003- 2004 and Participatory Plantation Programmes in 2005-2006. The latter is a participatory approach involving the local people (Table 5). Highest number of stems/ha (1,717 ha^{-1}) was observed in participatory plantations followed by woodlot plantations (1,575 ha^{-1}), while in the FRMP it was the lowest (483 ha^{-1}).

The conversion of natural forests to short-rotation plantation leads to a change in the native forest ecosystem. For this reason, the natural forests, and the remaining natural ecosystems, must be protected and restored for their important ecological functions (Ansari 1989).

Table 5 *Height class (m) distribution of plantation tree species in FRMP, woodlot, and participatory plantation in Rajghat Forest Beat.*

Plantation type	Species	No. of individuals ha^{-1} in different height class (m)					Total stems ha^{-1}
		5 - 7	8 - 10	11 - 13	14 - 16	≥17	
FRMP	*A. auriculiformis*	-	25	67	183	67	342
(11-year plantation)	*A. hybrid*	-	0	17	33	33	83
	A. mangium	-	8	0	25	25	58
	Total	**-**	**33**	**84**	**241**	**125**	**483**
Woodlot	*A. auriculiformis*	142	325	400	117	-	984
(6-year plantation)	*A. hybrid*	33	42	217	108	-	400
	A. mangium	8	67	83	33	-	191
	Total	**183**	**434**	**700**	**258**	**-**	**1575**
Participatory	*A. auriculiformis*	100	525	375	42	-	1042
(4-year plantation)	*A. hybrid*	58	192	75	58	-	383
	A. mangium	42	100	142	8	-	292
	Total	**200**	**817**	**592**	**108**	**-**	**1717**

Table 6 *Number of seedlings ha^{-1}, Relative Density (RD), Relative Frequency (RF), Relative Abundance (RA) and Importance Value Index (IVI) of Regeneration tree species in the hill top of the Natural forest of Rajghat Beat.*

Sl. no.	Species	Seedlings ha^{-1}	RD (%)	RF (%)	RA (%)	IVI
1	*Acacia auriculiformis*	1493	13.11	6.02	13.83	32.14
2	*Emblica officinalis*	240	2.11	4.82	2.78	9.77
3	*Artocarpus chaplasha*	213	1.87	2.41	4.94	9.36
4	*Anisoptera scapula*	80	0.70	1.20	3.70	5.85
5	*Microcos paniculata*	240	2.11	2.41	5.56	10.36
6	*Swintonia floribunda*	1733	15.22	10.84	8.92	36.29
7	*Syzygium grandis*	773	6.79	8.43	5.11	20.57
8	*Schima wallichii*	533	4.68	8.43	3.53	16.76
9	*Diospyros peregrina*	53	0.47	2.41	1.23	4.06
10	*Vitex glabrata*	53	0.47	1.20	2.47	4.63
11	*Xanthoxylum rhesta*	27	0.23	1.20	1.23	2.42
12	*Vitex Pedancularis*	27	0.23	1.20	1.23	2.42
13	*Acacia hybrid*	133	1.17	2.41	3.09	6.49
14	*Elaeocarpus floribundus*	240	2.11	3.61	3.70	9.56
15	*Syzygium cumini*	27	0.23	1.20	1.23	2.42
16	*Carallia brachiata*	27	0.23	1.20	1.23	2.42
17	*Aporusa diocia*	27	0.23	1.20	1.23	2.42
18	*Actinodaphni angustifolia*	80	0.70	1.20	3.70	5.85
19	*Acacia mangium*	187	1.64	2.41	4.32	7.93
20	*Pterospermum acerifolium*	53	0.47	1.20	2.47	4.63
21	*Pterocarpus dalberdgioides*	27	0.23	1.20	1.23	1.63
22	*Castanopsis indica*	667	5.85	8.43	4.41	17.84
23	*Dipterocarpus costatus*	4080	35.83	18.07	12.59	67.22
24	*Cinnamomum cecidodaphne*	213	1.87	4.82	2.47	9.55
25	*Mangifera sylvatica*	160	1.41	2.41	3.70	8.36
Total		**11387**	**100**	**100**	**100**	**300**

Regeneration status in the natural forest areas of Rajghat Beat

The quantitative structure of naturally-regenerating tree species in the Rajghat Forest Beat was studied on the basis of the density, relative density, relative frequency, relative abundance, and Importance Value Index. A total of 25 naturally-regenerating tree species were recorded from the sampled area (Table 6). Natural regeneration of *Acacia auriculiformis, Acacia hybrid,* and *Acacia mangium* was found in other plots, because of seed dispersal from the adjacent *Acacia* plantations. Rajghat Beat is low hill (30-65 m) and the top of the hill was almost flat. For this reason, only two topographic positions (hill top and valley) were studied for regeneration. A total of 25 naturally-regenerating tree species were recorded on the hill top, with a total of 11,387 seedlings ha^{-1}, where the highest natural regeneration occurred by *D. costatus* (4,080 ha^{-1}), followed by *S. floribunda* (1,733 ha^{-1}) and *S. grandis* (773 ha^{-1}). Rai (1989) stated that, for a given species, a particular set of filtered light and

partial shade can support regeneration, which supports the present study. Ahmed *et al.* (1992) concluded that the natural regeneration increases as one moves up the hill, which also supports the present study. Tree cover, especially age of tree, have some effects on natural regeneration. Establishment of a new plantation on land previously occupied by natural forest will cause substantial changes in the plant community. The nature of the changes in the vegetation is influenced by many factors, but the most important of these are the degrees of difference between the tree species composition and physical structure of the plantation forest and those of the natural forest that is being replaced (Freedman 1989).

Conclusion

At present only 13 naturally-growing tree species are available in this forest, indicating that this remnant forest is not rich in plant diversity, but it contains some threatened tree species e.g., *Swintonia floribunda*, *Mangifera sylvatica*, and so forth. Though the natural regeneration is rich, the most alarming situation is that there is a continuous removal of young saplings from the forest. Saplings are used for fencing purposes in the farmer's crop field. Incendiary fire is occasionally caused by the local people for protecting their crop fields from wild animals (elephants, rodents, and so forth). This has encouraged the growth of grasses and weeds, which hamper seed germination and seedling growth. Cattle and goats graze in the areas, which causes damage to the seedlings and causes soil erosion. In order to maintain the complexity of this forest and its tree coverage, an economically-feasible and ecologically-sound management plan is desirable with minimum disturbance to the ecosystem, but tandem use of community-based natural-resources management can help to promote appropriate use of forest resources with social, economic, and environmental benefits. A regular diameter and height distribution should be maintained through protecting natural regeneration and by developing plantation programmes for native tree species in the forest area.

It can also be concluded that this investigation paves the way for further study to investigate particular reasons for variation in ground flora and regeneration in the Natural Forest of Rajghat Beat. Participatory forestry can play a vital role in protection of the natural forest, but monoculture plantation of *A. auriculiformis* is not an appropriate method for the conservation of biological diversity. *A. auriculiformis* spread in the plantation area, as well as in the adjacent natural forest, through seed dispersal and its higher survival percentage, growth rate, and capability of growing on the degraded land. Mixed-species plantation may be able to contribute to sustainable management, because monoculture plantations cannot provide the full range of goods and services of the natural forest. Mixed plantation can be appearing to extend the range of benefits from plantations, both for ecological and economic purposes. Thus, mixed plantations may contribute to the conservation of biological diversity at the level of the conservation of indigenous species in their original habitat.

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Chapter 5: An Evaluation of Endemism and Endemics in Bangladesh Flora

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Abstract

The endemic plants of Bangladesh are evaluated here on the basis of the study of angiosperm flora published in the literatures and on the basis of investigations. It is estimated that out of about 3563 species at least 25 species, including 2 varieties, are evaluated as endemic plants to Bangladesh. All the taxa are included under 24 genera and 18 families. Of the endemic taxa 5 species of 5 genera in 5 families fall under Liliopsida (Monocotyledon) and the remaining 20 species of 19 genera in 13 families included in Magnoliopsida (Dicotyledon). Except for only 7 tree species, all the others are either shrubs, climbers, annual, or perennial herbs. Almost all the taxa are terrestrial, but 1 is hemi-parasite and 8 are aquatic or amphibious. Of these taxa 13 are distributed in Chittagong and Chittagong Hill Tracts regions, 8 in Sylhet hilly regions, 1 in both Sylhet and Chittagong regions, and 3 taxa in the Central Plains (Dhaka-Mymensingh) of Bangladesh. Phytogeographically the Sylhet area is situated at the extreme west low margin of Khasia-Manipur Province and, Chittagong and the Chittagong Hill Tracts area is situated at the west boundary of South-Burma Province. This area is also situated at the western border line of the global Indo-Burma hotspot. The remaining lowland plain of Bangladesh (Mymensingh-Dhaka) is situated in the middle of Bengal Province in the Indian Floristic Region, situated further east of the said hotspot area. Geographically, the land of Bangladesh is mostly surrounded by India and Myanmar and is geologically much younger than those of the surrounding areas. Thus, in Bangladesh the endemic taxa are few, but the continuous surrounding land mass is one of the important world Floristic Regions, Sub–kingdoms, and Kingdoms, thus, shares many more pseudo-endemic taxa of both Eastern Himalayan and Indo-Burma hotspots as a whole. At the same time, the evaluated endemic taxa are assessed as the admixture of primitive (2 spp. of Magnoliidae; 1 sp. of Hamamelidae), transitional (9 spp. of Rosidae, 2 spp. of Arecidae and 2 spp. of Commelinidae), and advanced (8 spp. of Asteridae and 1 sp. of Zingiberidae) subclasses; indicating all the evolutionary stages of plants constituting the endemic flora of the country, which fall mostly in the Palaeotropic, but some are Holarctic also. Very little is known about the status of the endemic taxa of Bangladesh, but primarily almost all the endemic taxa have been evaluated as critically endangered, due to habitat loss or genetic causes. Furthermore, most of the species are yet to be either relocating the T*ype locality* or to be rediscovered both for biodiversity research and conservation purposes before extinction.

Keywords; e*ndemism, endemic plant taxa, Bangladesh flora*

Introduction

The taxa restricted in occurrence to a particular or definite small or large area are referred to as *endemics*, which may be continental, country, province, regional, or local. On the other hand, depending on the basis of evolutionary history, the endemics may again be palaeoendemics, neoendemics, or pseudoendemics. The endemism results from the failure of species to disseminate its prop gules, due to geographical or environmental barriers. For understanding endemics and endemism, evolutionary history, migration capacity, and ecological amplitude of the species need to be understood. Thus, understanding endemic species is a common study, when a flora is to be analyzed, after the introduction of the term endemics. Many countries have assessed endemic species of their own. Islands are known for high levels of endemism and, thus, endemic taxa (New Caledonia and Hawaii have about 95 %) than main lands (Takhtajan 1986). Almost all countries in South Asia have assessed their own endemic species, for example, Sri Lanka has about 25 % endemic species and Nepal has 5 % endemic species (Press *et al.* 2000).

Attempts have been made to assess the endemic species of British India, first by Chatterjee (1940) and then many researchers in present India (Bor 1960; Chatterjee 1962; Das & Deori 1983; Nayar 1980; Rao 1972; Sharma 1983). Ahmedullah and Nayar (1986) finally reported that about 33 % of the higher plants in India are endemic, but very little is known about endemism and endemic plant species of the present Bangladesh area. The first attempt was undertaken by Khan (2001), where he mentioned 8 species as endemic to Bangladesh, but in the same year Khan *et al.* (2001) identified a total of 16 endemic plants for the country. Finally, Hassan and Ahmed (2008) mentioned (without any list) 16 endemic taxa from Bangladesh (probably the same as in Khan's reports). After that no attempt was taken on this subject, but none have

attempted to discuss or evaluate the endemism and endemic flora of the country. Thus, this attempt has been undertaken to evaluate the flora of Bangladesh and assess the endemism and endemics of Bangladesh as far as possible.

Geographical location and physiography

Bangladesh is a continuous landmass situated in between 20°25'N and 26°38'N latitude and between 88°01'E to 92°40'E longitude, at the south-eastern boarder of India. It constitute an area of about 148,303 km^2, of which 7 % land is occupied by forests, 20 % is aquatic or inland water bodies, about 5 % is housing and the rest is arable (Ahmed *et al.* 2008b). All the southern part is bounded by the Bay of Bengal. Almost all of the land is geologically young with recent deposition of alluvial soil carried by three mighty rivers; the Ganga entered from west, the Brahmmaputra from the north, and the Meghna from north-east, which merge at the south-central region of Bangladesh, and end towards the horn of Bay of Bengal.

About 86 % of land is plain with some great basins intersected mostly north-south by hundreds of small rivers and canals. The remaining 14 % of land is hilly, placed at the north-east and east boundary, which is a continuously-connected land locked with Assam, Tripura, Meghalaya, Mizoram states of India, and very small strips in the south-east with Myanmar. The remaining western and part of the north-western border is also completely bounded by West Bengal state of India.

The land enjoys periodical monsoon under the Indo-Australian Climatic Province, with more or less subtropical and tropical environment. The annual temperature varies from 6^0C to 40^0C with an average of 30^0C. The annual rainfall varies from 1700 mm in the south-west to gradually 5,500 mm in the extreme north-east near to Cherapunjee of India, where the highest (12,000 mm) rainfall of the world occurs. The highest peak, located in Chittagong Hill Tracts, is about 1,300 m situated in the Myanmar border area. Climatically the whole of Bangladesh is divided into seven sub – regions, of which north-east, south-east, north-west, and central zones are very distinct (Choudhury 2008).

Geographically, Bangladesh is located at the southern base of the eastern Himalayan mountain range bounded, east-west by the great Khasia-Jainta hills in the north, and north-south by the Mishmii hills in the east. Almost all the land mass is plain between a meter below sea level in some inland basins and few small elevated strips of about 30 m above the mean sea level. About 50 % land is considered as flood level wet land during the monsoon. Physiognomically the whole of Bangladesh is almost sloping down from north to south and intersected with several hundreds of rivers and canals (Rashid 2008). The north-eastern hilly areas are a comparatively older land mass than the rest of the country.

Phytogeography of Bangladesh

To understand endemism and endemics phytogeographic analysis of the floral studies are to be established first, but there has been no research on the phytogeography of Bangladesh. This can be understood from the following studies of the flowering plant flora of Indian Region and, thus Bangladesh: the *Horus Bengalensis* (Roxburgh 1814) and *Flora Indica* (Roxburgh 1820-24; Roxburgh 1832), Flora of British India (Hooker 1872-1894), Bengal Plants (Prain 1903), Flora of Assam (Kanjilal *et al.* 1934-1940), Flora of Manipur (Singh *et al.* 2000), Flora of Meghalaya (Haridasan & Rao 1985, 1987), Flora of Tripura (Deb 1981,1983), Flora of Burma (Kurz 1877), and other adjacent regional Floras, along with the local Floras are very useful. Very recently the Encyclopedia of Flora and Fauna of Bangladesh (EFFB) has appeared, containing an exhaustive account of the flora of the country (Ahmed *et al.* 2008b).

The phytogeographical features of the area have been assessed mostly from the work of Clarke (1889). Hooker (1904) and Chatterjee (1940, 1962), but more details are provided by Good (1974) and Takhtajan (1986). According to Good, in context of the Worlds Floristic Units, Bangladesh falls mostly in the Indo-Malaysian Sub–kingdom of the great Palaeotropical Kingdom. Under this Sub–kingdom most of the plain land of Bangladesh falls in the Indian Region, bounded in the extreme east, but its hilly south-eastern part, mostly the Chittagong and Chittagong Hill Tracts areas, is included in the Continental South-East Asiatic Region. At the same time the north and north-eastern hilly areas of Sylhet are included in the flanking west part of the Sino-Japanese Region, which is in the Boreal Kingdom.

Takhtajan (1986) more or less follows Good's division with some modifications. Here also, most of the Bangladesh plain land is included within the Indo-Malaysian Sub–kingdom of the Palaeotropic Kingdom. In this Sub–kingdom it is placed in the Bengal Province, which is further bounded by the Decan Province in the south-west and the Upper Gangetic Plain Province in the north-west. The south-eastern and eastern hilly border of Bangladesh is bounded by south the Burmese Province of the Indo-China Region. Here, all its north-eastern hilly part is included in the Khasia-Manipur Province and most of the north western part is bordered by the the Eastern Himalayan Province of the Eastern Asiatic Region in the Boreal Sub–kingdom of Holarctic Kingdom (Figure 1a). Thus, Bangladesh is uniquely placed at the junction of two great Kingdoms and three great Sub–kingdoms spread over four Provinces. All these Kingdoms, Sub–kingdoms, and Provinces are

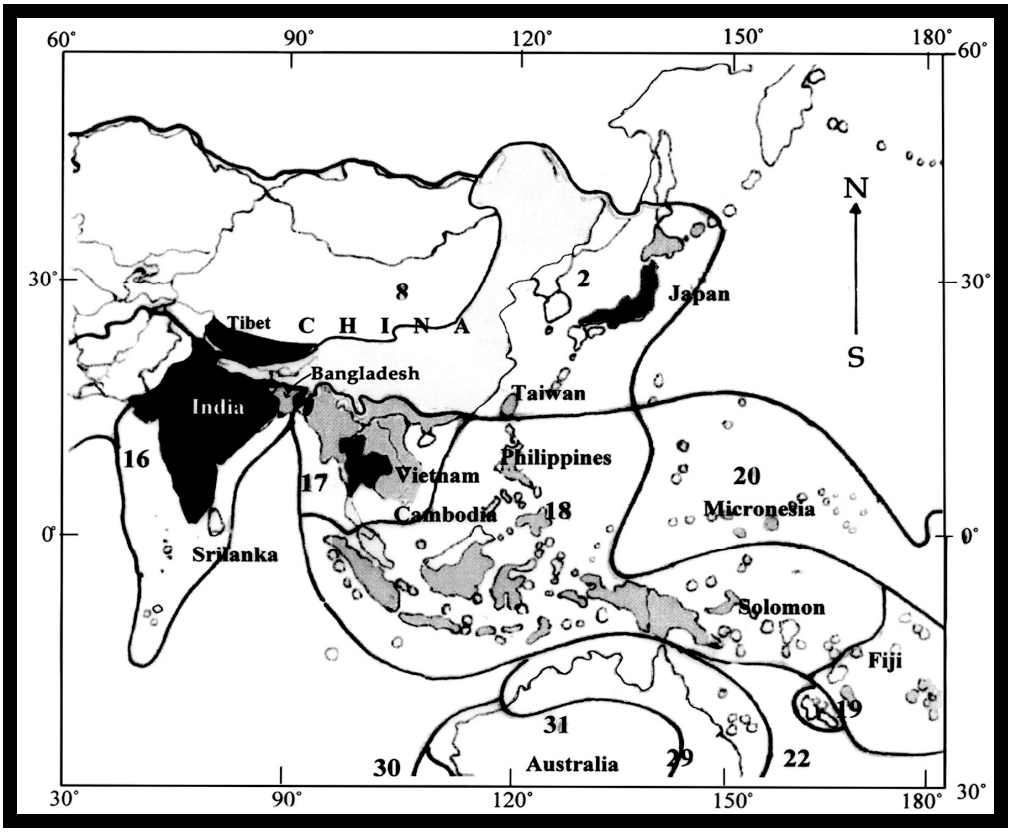

Figure 1a *Map showing the Eastern Asia, Australia, and part of Pacific Islands*; *showing the Phytogeograpic Regions in number (According to Takhtajan 1986).* ***Holarctic Kingdom****: 2- Eastern Asiatic Region; 8- Irano-Turanian Region;* ***Paleotropical Kingdom****: 16- Indian Region; 17-Indochinese Region; 18-Malasian Region; 19-Fijian Region; 20-Polynesian' Region; 22-Neocaledonian Region; 29-Northeast Australian Region; 30-Southwest Australian Region; 31-Central Australian Region* (redrawn from Takhtajan 1986).

unique in their floral spectrum, as well as endemic elements (family, genera, and species). So, it is the meeting place of so many diverse floral elements and represents the blending place for many unique diverse floras.

In the context of all these phytogeographic analyses it is observed that the most diverse area around Bangladesh is the north eastern region of India, which covers most of the south western and western mountainous region of Myanmar border of the Eastern Asiatic Region and the Indo-Chinese Region. Here, about 7,000 species have been recorded, of which about 2,500 species are considered endemic to this region (Yumnam 2008). Thus, a good number of endemic species and high biodiversity are to be expected in the flora of Bangladesh.

Flora and vegetation

After a long efforts of floristic studies, starting with Roxburgh (1814; 1820-24; 1832) to Hooker (1872-1894), Clarke (1889), Prain (1903), Heinig (1925), Cowan (1926), Raizada (1941), Datta and Mitra (1953), Khan 2001; Khan & Banu 1972; Khan & Halim 1987; Khan *et al.* 2001; Sinclair 1955 and, finally, Ahmed *et al.* (2008b) paved the major steps for understanding the flora of Bangladesh. Ahmed *et al.* (2008b) finally compiled almost all the taxa recorded so far in Bangladesh. In this compilation 3562 species, in 1379 genera and 199 families were recorded, of which about 25 % of taxa seem to be either very rare, scarce or have never been seen, or collected after the first record (Hassan & Ahmed 2008). At the same time more than half the type species, as specimens, are housed outside the country, mostly in CAL (Calcutta), the BM (British Museum), E (Edinburgh), or at K(Kew) herbaria. Thus, determination of species or identification of many critical species remains idle in the country's numerous herbaria. Furthermore, the actual location (i.e., *Type locality*) and its icon are also not available.

The major forest types in Bangladesh are tropical wet-evergreen and tropical semi-evergreen forests, covering most of the eastern hilly regions, with moist deciduous forests in the north-central

region, mangrove forests covering most of the southern coastal regions, and freshwater wetland forests or homestead forests and vegetation in other places. The most varied biodiversity is located in the north-eastern hilly regions than the plains of Bangladesh. This hill region supports about 2/3rd plant species of all Bangladesh, indicating a very rich biodiversity area (Rashid 2008).

Methods

For the evaluation and determination of endemic taxa and endemism of Bangladesh early authentic literature (Heinig 1925; Hooker 1872-1894; Kanjilal *et al.* 1934-1940; Prain 1903; Roxburgh 1814; Roxburgh 1820-24; Roxburgh 1832; Sinclair 1955) were consulted, along with the recent published flora of the neighbouring countries (Nepal, Sri Lanka, Pakistan, China, Malaysia, and India). A very recent and exhaustive compilation, the Encyclopedia of Bangladesh Flora and Fauna (Ahmed *et al.* 2008b), has also been consulted. Some local floristic and related literature (Alam 1988; Khan 2001; Khan *et al.* 2001), along with the specimens deposited in different herbaria at home and in abroad, have also been consulted. It is hoped that the efforts are more or less sufficient for the study.

The scattered information, along with the investigations, are assembled here to get all the materials required for the evaluation each endemic taxon. The assessed and evaluated endemic taxa are then enumerated alphabetically with the valid name, known synonym (s), taxonomic description, habitat and distribution, status and the relevant information.

Results and Discussion

From the critical study on the occurrence and distribution of the angiosperm flora of Bangladesh, there are at least 25 species, including 2 varieties, belonging to 24 genera in 18 families, endemic to Bangladesh. Of these, 5 taxa from 5 families belong to Liliopsida and the rest to Magnoliopsida. The ratio is about 1:5. All the genera are represented by single endemic species except Croton (2 spp.). The family Euphorbiaceae and Rubiaceae have the highest number (4 spp. each) of endemic species, followed by Cyperaceae (2 spp.). The other remaining families (Acanthaceae, Araceae, Arecaceae, Asteraceae, Fagaceae, Lauraceae, Lamiaceae, Loranthaceae Lythraceae, Marantaceae, Myristicaceae, Papilionaceae (Fabaceae), and Scrophulariaceae) have just one endemic genus. Of the listed species, 2 belong to Magnoliidae, 1 to Hamamelidae, 9 to Rosidae, and 8 to Asteridae sub–classes in the Class Magnoliopsida (Dicotyledon). On the other hand, 2 species belong to Arecidae, 2 to Commelinidae, and 1 to Zingiberidae sub–classes in the Class Liliopsida (Monocotyledon). An admixture of endemic taxa from primitive, transitional, and advanced sub–classes is revealed in this study, covering all the evolutionary stages of plants providing the country, but all taxa are Palaeotropic. All these evolutionary aspects indicate the age and area theory of Willis (1922) about the evolutionary history of plants. Bangladesh is comparatively younger in geographical age than the surrounding continuous landmasses of India and Myanmar. So, it is expected that the flora is mostly migratory in nature. Here, a detailed study should be done on the percentage of the migratory elements of these diverse phytogeographical origins.

So far about 3,563 species of angiosperm plants under 1,379 genera and 199 families have been enumerated from Bangladesh (Ahmed *et al.* 2008b). The estimated endemic taxa are fewer in number than any other country, which indicated a very low range of endemic plants (less than 1 %), but the endemic plants in the surrounding regions are very numerous (Ahmedullah & Nayar 1986; Bhargava 1983; Bor 1960; Chatterjee 1940; Das & Deori 1983; Deb 1958, 1981,1983; Dhar & Kachroo 1983; Haridasan & Rao 1985, 1987; Rao 1979). North-east India is an important Mega-diversity area, where the Indo-Burma Hotspots (Myers *et al.* 2000) comprise about 7.7 % of India's total geographic area, but support about 55 % of her total flora, of which 31.58 % (ca. 2526 sp.) are endemic (Yumnam 2008). Many of the endemic plants claimed by the Indian workers are also widely found in Bangladesh; for example, *Ficus religiosa* L., *F. benghalensis* L., *Aegle marmelos* (L.) Correa are considered as endemic to India, but these are also very common here in the wild. In that context, several hundred species of the surrounding countries would be accounted as *shared endemic* or pseudoendemic plants in Bangladesh.

Many species of *Citrus*, *Saccharum*, *Cicer,* and *Trichosanthes* in North-eastern India are considered as centers of origin, but they are mostly considered as native plants of Bangladesh, indicating an admixture of many phytogeographical elements, and a good degree of affinity of floral elements, with the surrounding countries.

When the distributional gradient of the enumerated endemic species is considered, almost all (except 3 spp.) are recorded in the eastern hilly regions only. Of the endemic taxa, 8 species are reported from the Sylhet area, which is attached to the Khasi-Jainta Province of Sino-Japanese Region; 13 species from Chittagong and Chittagong Hill Tract areas, which fall under the South-East Asian Province, and the remaining 3 species from the central plains, which fall under the Bengal Province of the great Indian Region.

Generally, the endemic species are perennials and have a very brief period of growth and are vulnerable to the changed environment. Their reproductive capacity and natural regeneration and

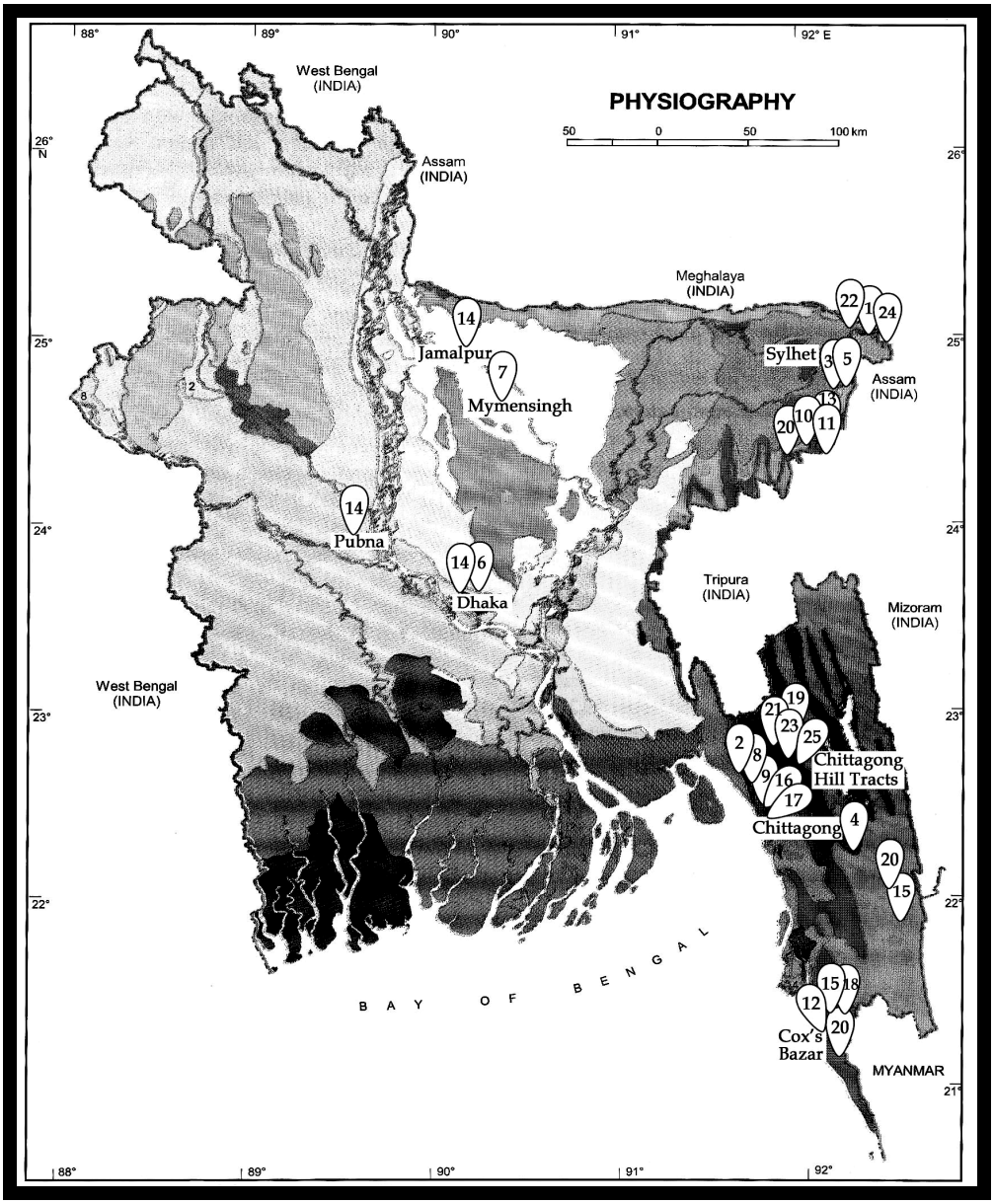

Figure 2 *Map of Bangladesh showing physiognomy and the distribution of the endemic plants of Bangladesh. The number in the bubble showing the type location of the species with the serial number enumerated in text.*

proliferation strategy is also reduced. Here, the recorded endemic species are very scarcely distributed; 7 of which are trees, 5 shrubs and the remaining either herbs or climbers. Many of those recorded *Type specimens* have been collected only once from the *Type locality* by the original authors, were recorded more than 100 years ago. After that no further record of specimens has yet been attempted or even targeted for rediscovery. Thus, it is not certain whether those endemic plants are yet available or still existing in their *Type locality* or nearby. It is further expected that almost all the taxa are critically endangered due to habitat loss or genetic causes. Otherwise, those species could be recorded any way by this time. Most of the species are known only through short descriptions by a few taxonomists. Now, the primary task is to relocate the species or rediscovered those from the area. If the taxa can be rediscovered, then the prime importance is to rehabilate the endemic species,

because they are the precious elements of the country and the world as a whole.

It was once thought that the land of Bangladesh is of recent geological origin, so the availability of endemic species might be nil. Only the Indian endemic species are being shared due to connectivity and continuous surrounding landmass. That is why the idea of endemic and endemism might remain unforced or undermined before 21st century. It was only due to Khan (Khan 2001; Khan *et al.* 2001), who first pointed out that Bangladesh also contains some endemic species. Khan (2001) first pointed out that Bangladesh has at least 8 endemic angiosperms. In the same year (Khan *et al.* 2001) published a Red Data Book of Vascular Plants of Bangladesh, where they clearly stated the 16 endemic plants of Bangladesh. Finally, Hassan and Ahmed (2008) pointed out the existence of at least 16 endemic species of flowering plants in Bangladesh, but without any list (probably the same taxa of Khan's enumeration). Out of 16 species claimed to be endemic by Khan *et al.*, three species, such as *Bulbophyllum roxburghii* (Lindl.) Reichb.f., *Butea listeri* (Prain) Blatter, and *Hedychium speciosum* Wall. *ex* Roxb. have found not to be truly endemic now; they can be considered as Pseudoendemics, because they are also claimed as endemic by the Indians (Singh *et al.* 2000). At the same time, some species recorded in EFFB (Ahmed *et al.* 2008b) as endemic to Bangladesh (e.g., *Hoya acuminata* (Wight) Benth *ex* Hook.f.) are also recorded from Meghalaya and other areas of India. In this investigation many of such anomalies have been filtered out. After judging different aspects of Bangladesh flora, 12 more species from this study, along with the 13 species previously (after deletion of 3 species), totalling 25 species are claimed to be true endemic species to Bangladesh. Of these species only 12 photography or illustration is available and are presented in figures 1-14. Finally the distributions of the species are presented in figure 2. Now, the prime task is to acquire the *Type species*, relocate the *Type locality*, along with the *Type specimens*, to provide the icon of the species in any form, before extinction. Otherwise, it will be difficult to identify and thus to undertake any further research on the endemic taxa so far reviewed. After that the conservation strategy must be framed for their survival. Furthermore, it is difficult to assess the extent of endemism, unless the detailed phytogeographic elements, along with the species and generic identity, and ecological condition are considered. All these aspects are still totally unknown to us.

Here is tentative but exhaustive information so far known about the endemic species of Bangladesh. This estimate may be changed and the information will be increased when target-oriented research is undertaken in the future.

Enumeration of endemic taxa

1. Carex caespitita Nees, in Wight, Contrb. Bot. Ind.: 127 (1834); Clarke in Hook Flora Brit. Ind. 6: 675 (1894). **[Cyperaceae]**

English name: Caespit sedge.
Local name: Daraglick.
Description: Stoloniferous perennial herb, rhizome usually woody, short, but sometimes the stem at base appears slender, decumbent, rooting in mud, culms solitary or rarely tufted, 30-70 cm, glabrous, trigonous; leaves linear, flat, margins near the base slightly recurved; spikes 4-10, lowest subsessile or erect on short peduncle, cylindric, dense and rigid; terminal male spike sometimes 10-5 cm, pale, slender, or shorter and thicker, purple-chestnut, female spikes often 2-3 x 1-2 cm, often 2-7 fascicled with 1 or 2 remote below, frequently with 1-6 rectangular divaricated short branches, styles 2-fid, utricles ovoid, compressed, irregularly few-nerved, smooth, not glandular, greyish with green margins, 1-4 nerved, suddenly narrowed into a minute entire beak.
Flowering and fruiting: September-February.
Habitat: Wet openings in forests, grassy slopes, riverbanks, and lakesides, up to an altitude of 400 m.
Recorded by: C. B. Clarke (1889) recorded this species from Sylhet district; since then no other plant has been collected from the area.
Distribution: In north-east part of Bangladesh (Sylhet district).
Uses: No significant economic value is reported.
Propagation: By seeds.
Type specimen location: At Kew (K!).
Illustration/photography: Not found.
Threats to the species: Not known.
Conservation measures:
Status: Data Deficient (DD).
Measures taken: None.
Measures proposed: Proper investigation is necessary to relocate the *Type locality* and to rediscover the species for its conservation.

2. Cissus sicyoides Roxb., Hort. Bengal. (1814). **[Vitaceae]**

English name: Sicyoid vine.
Local name: Shiklata.
Description: A herbaceous climber, hairless to sometime pubescent, with tendrils, leaves simple, variable, oblong to heart-shaped or ovate, pointed or obtuse at the apex, base almost truncate to cuneate, margin dentate, setose, inflorescence a cyme, commonly shorter than opposite leaf, flowers small, yellow-green, white or purple, fruit a berry, obovoid-globose, black.
Flowering and fruiting: Not on record.
Habitat: Primary forests of hilly areas.
Recorded by: This plant was recorded by (Roxburgh 1814) from Chittagong, since then there

has been no report of further collection of this species from any other part of the country.

Figure 3 Morphology of the endemic plant - *Cissus sicyoides* Roxb.

Distribution: In south-east part of Bangladesh (Chittagong district).
Uses: Not known.
Propagation: By Seed.
Type specimen location: At Kew (K).
Illustration/photography: Available (Figure 3).
Threats to the species: Habitat destruction.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: None.
Measures proposed: Extensive search should be made to rediscover the plant from its reported site and seeds collected for ex-situ conservation.

3. Cleistanthus oblongifolius (Roxb.) Muell. Arg. in DC., Prodr. 15(2): 506. (1866).
Synonyms: Nanopetalum myrianthum Hassk., Clutia oblongifolia Roxb., Fl. Ind. ed. Carey 3: 730. (1832) (as Cluytia); Wall., Cat. No. 7887. 1847. Cleistanthus chartaceus Muell. Arg. in DC., Prodr. 15(2): 507, (1866); Hook. f., in Fl. Brit. India 5: 275. (1887). **[Euphorbiaceae]**

English name: None.
Local name: Cleistangi.
Description: Trees, 5-10 m high; young shoots sericeous; branchlets velutinous or tomentellous, glabrous in age; leaves elliptic, oblong to oblong-elliptic, 8-22 x 3-8 cm, acute to obtuse at base and slightly decurrent to petioles, caudate or acuminate at apex, chartaceous to subcoriaceus, glabrous above, evanescently appressed-sericeous beneath; lateral nerves 5 - 10 per side; petioles 5-15 x 1-2.5 mm; stipules not seen; glomerules few-flowered, 7 -10 mm across, borne on main leafy branches and leafless or small-leaved branchlets (up to 10 cm long); bracts deltoid-ovate, ca 0.5 mm long, male flowers: sessile, glabrous; calyx tube ca 2 x 2.5 mm; sepals triangular, 2 x 1.5 mm; petals flabellate-unguiculate, 1 mm long; disc annular; stamens 3 mm long; column 1 mm long; filaments 1 mm long; anthers ellipsoid-oblong, 0.8 mm long; pistillode ovoid; female flowers: sessile, 4 mm across, glabrous; calyx tube 1 x 1.5 mm; sepals triangular, 2 x 1.5 mm; petals flabellate, 0.8 mm across; outer disc flat; inner disc subconical and covering the ovary; ovary trigonous, 1.5 mm across, villous when young, soon glabrous, shortly stipitate; styles 2 mm long, bifid, capsules subglobose, 10 x 14 mm, 3-lobed, somewhat depressed; stipe 3 -5 mm long.
Flowering and fruiting: February-July.
Habitat: In deciduous forests.
Recorded by: Sylhet, Collector's name illegible, s. n. (CAL, herb. acc. no. 400827); ibid., Wallich 7881 (K: photo!, K-WALL: microfiche!); ibid., Wallich 7887 (G-DC et K-WALL: microfiche!); ibid., Wallich 4896 (K-WALL: microfiche!). East Bengal, n. d., Griffith KD 4885 (CAL). HBC, King s. n. (DD), Wallich 7881 (CAL), and de Silva in Wallich 7881 (CAL).
Distribution: Sylhet district, at north-east part of Bangladesh. (One plant cultivated in Indian Botanic Garden, Howrah, India).
Uses: The tree yields timber.
Propagation: By seed.
Type specimen location: At Kew (K) and Indian National Botanical Garden, Hawrah (NBGI).
Illustration/photography: Not available.
Threat to the species: Habitat loss.
Conservation measures:

Status: Data Deficient (DD).
Measures taken: None.
Measures proposed: The plant should be rediscovered from the type location and then should be conserved.

4. Croton chittagongensis Chakrab & N. P. Balakr., in Proc. Indian Acad. Sci. (Plant Sci.) 92: 365, f. 2. (1983) & in Bull. Bot. Surv. India 34: 40. 1992 (publ. 1997). **[Euphorbiaceae]**

English name: Chittagong Croton.
Local name: Chittagong marichcha.
Description: Small trees; young shoots softly tomentose; branchlets glabrous; leaves (somewhat immature) oblong or obovate to oblanceolate, the largest 9 x 2.7 cm, acute or rounded at base, serrulate along margins, acute or obtuse at apex, membranous, glabrous, penninerved; lateral nerves 8-16 per side, faint; tertiary nerves obscure; basal

glands 2, sessile; the longest petiole 8 m long, glabrous; inflorescences up to 12 cm long; rachis sparsely puberulous; bracts subulate, 1-2.5 mm long; male flowers: pedicels 6-10 mm long, tomentellous; sepals 5, triangular or ovate-oblong, 2-2.5 x 1 mm, puberulous outside, lanate inside; petals 5, oblong-elliptic, 2-3 x 1 mm; stamens 10-12, 3- 4 mm long; anthers oblong; female flowers: pedicels 6-10 mm long, whitish-tomentellous; sepals 5 or 10, ovate to elliptic, 2-5 x 1-3 mm, sparsely whitish-pubescent outside; petals 5, filiform, 1 mm long; ovary obovoid, 4-5 mm across, unlobed, tomentellous; styles 5-6.5 mm long, connate below into a column (1 mm long), quadrifid above; fruits not seen.
Flowering and fruiting: May - June.
Habitat: Hill slopes in forest.
Recorded by: Chittagong Hill Tracts, Mainamukh, 9 May 1939, Dent 72 (DD).
Distribution: In south-east boarder of Bangladesh (Chittagong Hill Tracts).
Uses: Not known.
Propagation: By seed.
Type specimen location: At Indian National Botanical Garden, Hawrah (NBGI!).
Illustration/photography: Not available.
Threat to the species: Habitat loss.
Conservation measures:

Status: Endangered (EN).
Measures taken: No measure has been taken.
Measures proposed: Extensive research should be done to relocate the species from *Type locality*.

5. Croton chlorocalyx Mull. Arg. in Linnaea, 34: 109 (1865) & in DC., Prodr. 15(2): 590. (1866); Hook. f., in Fl. Brit. India 5: 394. (1887); Kanjilal *et al.*, Fl. Assam 4: 195. (1940); Chakrab. & N. P. Balakr. in Bull. Bot. Surv. India, 34: 41, f. 4. 1992 (publ. 1997). **[Euphorbiaceae]**

English name: Chloro Croton.
Local name: Lorok marichcha.
Description: Small trees; all parts (except very young shoots) glabrous; leaves elliptic to oblong-elliptic, 9.5-23 x 2-6 cm, cuneate or acute at base and decurrent to petioles, serrulate along margins, caudate at apex, membranous to thinly chartaceous, penninerved; lateral nerves slender, 6-14 per side, faint to prominent; tertiary nerves obscure to prominent above, conspicuous beneath, reticulate; basal glands 2, stipitate; petioles 0.3-2 cm long, channeled above, thickened and black at base; inflorescences 3-8 cm long; bracts deltoid, 0.5 mm long, male flowers: pedicels 4-5 mm long; sepals 5, ovate, 2-4 x 1-3 mm; petals 5, oblong-elliptic to spathulate, 2-3 x 1-1.5 mm; stamens 15-16, 3-3.5 mm long; anthers oblong, 0.8 mm long, female flowers; pedicels 1.5-2 mm long; sepals 5, elliptic to obovate, 8-15 x 4-7 mm, accrescent, glandular-serrulate along margins; petals 5, filiform; ovary campanulate,3 mm long, strongly 3-lobed with the lobes apically bilobulate, hollow towards apex, shortly stipitate; styles 5-6.5 mm long, connate at base into acolumn (2-3 mm long), quadrifid above, capsules not seen.
Flowering and fruiting: Period unknown.
Habitat: No data available.
Recorded by: From Sylhet, by N. Wallich 8001 (BM, CAL, G-DC, K-WALL- excluding right hand specimen belonging to *Trigonostemon*).
Distribution: In north-east part of Bangladesh (Sylhet district).
Uses: Not known.
Propagation: By seed.
Type specimen location: Indian National Botanical Garden (Hawrah (NBGI).
Illustration/photography: Not available.
Threat to the species: Probably habitat loss.
Conservation measures:

Status: Critically Endangere (CR).
Measures taken: Nothing known about its present existence, so, extensive research should be done to relocate the species from *Type locality*.
Measures proposed: After collection of seeds ex-situ or in-situ conservations to be needed.

6. Corypha taliera Roxb. in Pl. Coast Cor. 3: 51 (1819); Fl. Ind. 2: 174 (1832); Hook. f., in Fl. Br. India, 6: 428, (1892). **[Arecaceae]**

English name: Tali palm.
Local name: Tali.
Description: A medium-sized (about 10 m) menocarpic unarmed palm, looks very similar with palmyara palm, leaf base not split at base like palmyara, spinulate about 1 cm, leaf blade not deeply divided, about 2.5 m long from hastula to the tip of the middle sigments for up to 80 in number, middle segments usually bilobed at apices, lateral segments acuminate; inflorescence terminal erect, about 3 m, pyramidal, several horn like branches coming from the mouths of their respective spathes, ultimate flower-branches gradually shorter from about 80-40 cm long, flower bisexual, in dense clusters of 3-6, each 5 mm long, pale yellow calyx 2 mm long, lobes unequal, obtuse, hyaline, petals slightly incurved, 3 x 1 mm, fleshy, stamens about the length of petals, dorsifixed, fruits globose with short pedicellate, mesocarp fiberless, seeds 2.5 cm in dia., spherical; flowering in summer, fruits ripen after about a year.
Flowering and fruiting: The plant flowers in April 2009, fruit matured and seeded.
Habitat: In scrub jungle.
Recorded by: First recorded by Roxburgh (1814) in Bengal, then included Fl. Ind. (1855); also Hooker f. in Fl. Br. India (1894), and then (Khan *et al.* 2001).

Distribution: The last but one tree was recorded from Birvhum of W.B. in India, which was growing wild, but cut down in 1979 by the villagers suspected as ghost palmyara. The last one was discovered at Dhaka University Campus in wild (Khan *et al.* 2001). There is a record of plantation in Howrah Botanical Garden, India in 1981.
Uses: Botanical interest.
Propagation: Through seed.
Type specimen location: After fruiting the lone plant died. Many seedlings have been raised int the Botanical Garden, near Carzon Hall, Dhaka University, Dhaka.
Illustration/photography: Available (Figure 4).

Figure 4 Morphology of the endemic plant - *Corypha taliera* Roxb.

Threat to the species: Needs mass propagation through seeds, expected to be collected the germinated plantlets now available from collected seeds in 2010 from the last plant in the world.
Conservation measures:

Status: Extinct in Wild (EW), Planlets are now in *ex-situ condition.*
Measures taken: Plantlets are expected to be collected after germination.
Measures proposed: The plantlets are to be planted in-situ and ex-situ.

7. Cyperus pilosus Vahl var. polyantha C.B. Clarke, in Hook f., Fl. Brit. Ind. 6: 610 (1893); Prain, Bengal Pl., 2: 861(1903). **[Cyperaceae]**

English name: Fuzzy Flat Sedge.
Local name: Shokto khagra.

Description: Stoloniferous, tall, perennial herb, culms 1 to few, 40-100 cm x 4-8 mm, smooth or scabrid on angles below the inflorescense, shrply triquetrous, glabrous; leaves few to several, shorter than to equalling the culm, blade broadly linear, up to 40 cm x 6-10 mm, acute, flattish to plicate, soft to subrigid, scabrous on the margins, gradually acute at the apex, sheath 3-10 cm long, pale greenish to purplish-brown; involucral bracts 3-5, obliquely erect to spreading, the lower 2 very long, much surpassing the inflorescence, the longest up to 50 cm long; inflorescence simple to compound umbel, primary branches 3-8, up to 7 cm long, secondary branches up to 2 cm long, spikes oblong, 2-3 x 1-2 cm, rachis 1.5-3.0 cm long, nearly glabrous, spikelets 40-45 per spike, rather distant, spreading, linear-lanceolate to elliptic-oblong, 10-25 x 1-2 mm, flattened to sub–terete, chestnut-red, rachilla straight, wingless or nearly so, persistent, glumes 5-9 or more on the longest spikelets, ovate to broadly deltoid-ovate, 1.8-2.5 x 1.2-1.5 mm, acute, 5.7 nerved, pale brown tinged with reddish-brown, the margins whitish-hyaline, keel obtuse, green smooth, stamens 3, anthers 0.5-0.8 mm long, with short, smooth, reddish appendage of the connective, stigmas 3, nutlets broadly ellipsoid to obovoid, triquetrous, 1.0-1.4 x 0.6-0.7 mm, broadly stipitate, apiculate, maturing dark brown, smooth.
Flowering and fruiting: Throughout the year.
Habitat: Open wet places, grasslands, swamps, deciduous forest floors, and rice fields.
Recorded by: By C.B. Clarke (1894) and described in Hook.f. Fl Brit Ind.

Figure 5 Morphology of the endemic plant - *Cyperus pilosus* Vahl var.

Distribution: In north-middle region of Bangladesh (the greater district of Mymensingh).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K!).
Illustration/photography: Available (Figure 5).
Threats to the species: Not known.
Conservation measures:

Status: Data Deficient (DD).

Measures taken: None, *Type locality* is to be known and specimen should be collected or rediscovered.

Measures proposed: Proper investigation is necessary for undertaking future conservation strategy.

8. Dalbergia confertiflora Benth. var. ***listeri*** Thoth., in Bull. Bot. Surv. Ind. 17 (1-4): 66-67, Figure 4 (1975); Thoth. in Bot. Surv. India, 67. (1987). **[Papilionaceae]**

English name: Wild Sword Bean.
Local name: Jangli talwari shim.
Description: An extensive woody climber, branches black, lenticeolate; leaves imparipinnately compound, alternate, 9-11 cm long, leaflets 9, 2.0-3.8 x 1.5-2.0 cm, elliptic-oblong, entire, alternate, obtuse at the apex, rounded at the base, glabrous, petiolules 2 mm long; inflorescence of axillary to terminal panicles, 5-13 cm long, ferruginous tomentose, flowers dense and compactly arranged, 6-8 mm long, sessile or minutely pedicelled, bracts and bracteoles present, deciduous, calyx campanulate, 3-4 mm long, densely ferruginous tomentose, 5-toothed, petals 5, standard petal 5.0-6.5 mm long, obovate, clawed at the base, wing and keel petals oblong, stamens 9, monadelphous, staminal sheath 4-5 mm long, split open dorsally, filaments free above, ovary 5 mm long, stipitate, styles short, stigmas minute, 4-ovuled, fruit a pod, oblong, up to 12 cm long, shortly stalked, thinly coriaceous, rounded at the base, 1-2 seeded, faintly veined over the seeds, indehiscent.
Flowering and fruiting: February-August.
Habitat: Hill and beach forests.
Recorded by: Recorded by Thothathri in 1987 from Chittagong.
Distribution: In south-east part of Bangladesh (Chittagong district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: Indian National Botanical Garden, Hawrah (NBGI).
Illustration/photography: Available (Thothathri 1987).
Threats to the species: Habitat loss.
Conservation measures:

Status: Not Evaluated (NE).

Measures taken: No conservation measures taken.

Measures proposed: Both in-situ and ex-situ conservation measures should be undertaken.

9. Gymnostachyum listeri Prain. Beng. Pl. 2: 604 (1903); and J. As. Soc. Beng. 69: 171 (1905). **[Acanthaceae]**

English name: None.
Local name: Gymnotori.
Description: A small under shrub, leaves entire, acute to acuminate, secondary veins 12-14 pairs, puberulous on both surfaces, narrowing gradually to petiole, panicles lateral, mostly from leaf axiles, bracteate, small, linear, flowers solitary or clustered, bracts and bracteoles very small, sepals 5, deeply divided corolla puberulous, tube much narrow, stamens 2, nearly as long as corolla, carpel connate, 2-celled ovary, ovules many capsule 1.25 cm long, glabrous seeds, ovoid, compressed.
Flowering and fruiting: Not known.
Habitat: In rocky places.
*Recorded by:*Ahmed *et al.* 2008a; Khan *et al.* 2001; Prain 1903, 1905. This species has not been found since its type collection by Lister (No. 162) from Chittagong.
Distribution: Greater Chittagong district (Demagiri).
Uses: Not known.
Propagation: Probably by Seed.
Type specimen location: At Edinburg (E!).
Illustration/photography: Not found.
Threat to the species: Destruction of habitat.
Conservation measures:

Status: Endangered (EN).

Measures taken: None.

Measures proposed: Nothing known about its present existence. So extensive research should be done to relocate the species from *Type locality* and ex-situ/in-situ conservation is needed.

10. Gomphostemma salarkhaniana Khanam & Hassan, in Bangladesh J. Bot., 32 (1): 63-64, Figure 1 (2003); Khanam & Hassan, in Fl. Bangladesh: 58: 25 (2008). **[Lamiaceae]**

English name: None.
Local name: Khani-bormala.
Description: An erect herb, stem tetrangular, grooved, stellately brownish-tomentose; leaves petiolate 1-2 cm long, lamina 16-20 x 7-10 cm, ovate-lanceolate, obscurely serrate, acute, sparsely hairy on the upper surface, hairs simple and stellate, lower surface stellately brownish. tomentose but more densely concentrated on the midrib and nerves, bracts 1.1-1.2 x 0.5-0.5 cm, ovate to elliptic-ovate, broader than the calyx, stalked, stalk 0.2-0.4 cm long; inflorescence in lax axillary whorls, flowers pedicellate, calyx campanulate, 1-2 cm long, tube 0.5 cm long, teeth 0.7 cm long, sparsely hairy inside hairs simple and stellate,

corolla 2.4 cm long, light orange, hairy outside, upper lip hooded, lower lip spreading, stamens 2.5 cm long, slightly exerted, ovary 0.1 cm long, styles 2.4 cm long, gynobasic, slightly bifid at the tip, nutlet 1, 0.6 x 0.2 cm, drupaceous, dark brownish, oblong-terete, narrowed at the base, stalked 1 cm long.
Flowering and fruiting: September-December.
Habitat: Shady forest areas.
Recorded by: Collected by the authors from Sylhet.
Distribution: In north-east part of Bangladesh (Sylhet district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: Bangladesh National Herbarium.
Illustration/photography: Available in the original publication (Figure 6).

Figure 6 Morphology of the endemic plant - *Gomphostemma salarkhaniana* Khanam & Hassan.

Threats to the species: Apparently threatened.
Conservation measures:
Status: Not Evaluated (NE).
Measures taken: No conservation measures taken.
Measures proposed: Both ex-situ and in-situ conservation measures are needed.

11. Hedyotis thomsoni Hook. f., in Fl. Brit. Ind. 3: 63 (1880); Prain, Bengal Pl. I: 407 (1903). **[Rubiaceae]**
English name: None.
Local name: Soni papra.
Description: An annual herb, up to 16 cm tall, much-branches from the base, stem suberect, 4-angled; leaves stipulate, stipules membranous, bristly, petioles absent or very short, lamina narrowly linear, 1.5-2.6 x 0.2 cm, apex acute, base dilated, spreading and recurved, cymes terminal or axillary flowers short pedicelled, calyx teeth lanceolate, recurved, corolla very minute, glabrous, tubes and lobes short, capsules indehiscent, ridged, with persistent calyx, seeds numerous, small, angular, pitted.
Flowering and fruiting: August-December.
Habitat: Open areas beside rivers and lakes.
Recorded by: Recorded by Hooker and described in his Flora of British India in 1880.
Distribution: It seems to occur in bank of the river Meghna and Mahanudde in Middle-north and subsequently it has been collected from north-east part of Bangladesh (Sylhet district) as well.
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K).
Illustration/photography: Herbarium illustration available (Figure 7).

Figure 7 Morphology of the endemic plant - *Hedyotis thomsoni* Hook. f.

Threats to the species: Habitat destruction.
Conservation measures:
Status: VU (Vulnerable).
Measures taken: None.
Measures proposed: Both in-situ and ex-situ conservation measures are suggested.

12. Knema bengalensis W.J.J.O.de Wilde, in Blumea, 25 (2) : 413 (1979). **[Myristicaceae]**

English name: None.
Local name: Khudi barala.

Description: A handsome tree with finely striate bark, bright red resin oozes from injury, twigs suberect, young plants covered with stellate dendroid hairs, leaves ca 15-30 x 2.5-5.5 cm, oblong-lanceolate to lanceolate, gradually wide at or near above the middle, acute to acuminate, base subattenuate to rounded, midrib raised above, lateral veins 20-28 pairs; flowers unisexual, 10-20 flowered, peduncles 3-5 mm long, male flower pedicels about 10 mm long, bracteoles 2 mm long, perianth in bud 5-6 x 5 mm, tomentose, depressed obovoid, staminal disc 3.0-3.5 mm in diameter, flat to slightly concave, anthers 13-14, 0.6 mm subsessile, female flower and fruit not seen.
Flower and fruiting: December.
Habitat: Mixed evergreen forest.
Recorded by: Type collection was in 1957 (*Type locality* – Dulahazara in Cox's Bazar); after that a solitary tree was located at Upper Reju forest beat office in the same district in December, 1999 by Khan (2001), and also same way in Ahmed *et al.* (2008b).
Distribution: Extreme south-east part of Bangladesh (Cox 's Bazar district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Edinburgh (E!).
Illustration/photography: Drawing of a male plant twig in Khan *et al.* (2001) and one photograph of the same in Ahmed *et al.* (2008b) p. 241 (Figure 8).

Figure 8 Morphology of the endemic plant - *Knema bengalensis* de Wilde.

Threat to the species: Destruction of habitat.
Conservation measures:
Status: Vulnerable (VU).
Measures taken: No conservation measures taken.
Measures proposed: Female tree should be discovered and seeds to be collected for raising trees for propagation in both ex-situ and in-situ conservations.

It is to be seen the original paper of the author in Blumea. How this plant is escaped from the knowledge of previous workers? A photograph of Prof. Khan is attached in Ahmed et al. ((2008b)p. 241), indicated a living collection. I have crossed with some leaves collected for a project on elephant from Cox's Bazar in 2009, indicated more plants are there, where female plants are to be expected also if more attention is given.

13. Lagenandra gomezii (Schott) Bogner & N. Jacobsen, in Aqua Planta: 49 (1987); Karthikeyan *et al.,* Fl. Ind. Ser. 4: 10 (1989).
Synonym: Cryptocoryne gomezii Schott (1857) Rataj, in Ceskos. Acad. Ved. (1975). **[Araceae]**

English name: None.
Local name: Lagendragi.
Description: A small rhizomatous herb, leaves 4-6, c. 15 cm long, petiole is about twice the length of blade, blade about 6 x 3 cm, broadly elliptic or cordate, ¼ petiole base is sheathed, inflorescence about the size of leaf, about half peduncle, "Kettle" (the basal inflated part of spathe) is c. 1.5-2.0 cm long, basal with limited margin, basal part constricted, opening through a lateral vertical surface, pale inside the lower part, upper part red, stamens 40-50, in 5-6 spirals, pistils 6, their stigmas horizontal naked, spirally arranged, unilocular, ovules many.
Flowering and fruiting: Not available.
Habitat: Shady moist places.

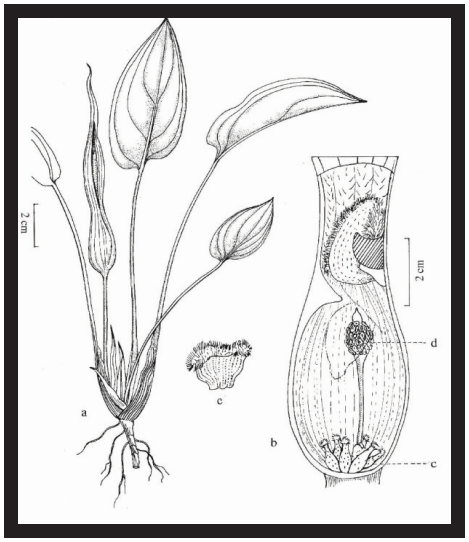

Figure 9 Morphology of the endemic plant - *Lagenandra gomezii* (Schott) Bogner & N. Jacobsen.

Recorded by: It was first described by Schott in 1857 based on a collection by Gomez 8958(K) from Sylhet, at Panchara in 1828 (Rataj 1975), then described again by Khan *et al.* (2001b), and in Ahmed *et al.* (2008b) in the same way as above.
Distribution: In North-east boarder of Bangladesh (Sylhet district).
Uses: Not known.
Propagation: Probably both by seeds and rhizome.
Type specimen location: At Kew (K).
Illustration/photography: Khan *et al.* (2001) (Figure 9).
Threat to the species: Habitat destruction.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: No measures taken.
Measures proposed: Extensive search should be taken to rediscover the plant and to collect the propagules for ex-situ and in-situ conservation.

14. Limnophila cana Griff., in Notul., 4: 98 (1847); Hook. f. in Fl. Br. Ind., 4: 269 (1884-85); Prain, Bengal Pl. 2: 569 (1903); Khan & Halim, in Aqua. Angiosperms, 50. (1987); Cook, in Aqua & Wetland Pl. Ind. (1996). **[Scrophulariaceae]**

English name: None.
Local name: Canakutra.
Description: An annual, aquatic submerged, prostrate-semiprostrate herb; giving out simple, erect, stout, hirsute branches, up to 25 cm or more high; leaves up to 2.5 x 1.5 cm, 3-6 neatly whorled, sessile, upper leaves elliptic or linear-oblong, serrulate, 3-5 veined, lower ones pinnatisect to lacerate, submerged with up to 12 leaves in a whorl; inflorescence a terminal or rarely axillary, errect leafy spike with opposite, almost imbricate bracts; flowers sessile, crowded, bracteoles absent, calyx tube up to 3 mm long, subulate, petals 10-14 mm long, violet, blue or purple colour, stamens 4, anther cells divergent, free, styles deflexed tip, stigmas 2-lamellate, capsules up to 3 mm long, enclosed in persistent calyx with 5 teeth, seeds numerous, c. 0.5 mm long, oblong to ellipsoid, brown, smooth.
Flowering and fruiting: September-December.
Habitat: Stagnant water.
Recorded by: Griffith (1847) from Dhaka.
Distribution: Khan *et al.,* (2001) and Ahmed *et al.* (2008b) also have been reported from Dhaka, Jamalpur, and Pubna districts and recorded as endemic.
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Bangladesh National Herbarium, Dhaka (DACB) and at Kew (K!).
Illustration/photography: Available in Ahmed *et al.* (2008b).
Threats to the species: Restricted occurrence.
Conservation measures:

Status: Not Evaluated (NE).
Measures taken: No measures taken.
Measures proposed: Status survey should be conducted for the species in the wild. Plants should be cultivated in tanks and reintroduced in natural habitat.

15. Lithocarpus acuminat*us* (Roxb.) Rehder, in J. Arn. Arbor 1 (2): 122 (1919); Camus, Les Chenes 3: 907 (1952-54); Alam & Khan, Bangladesh J. Pl. Tax. 4 (1): 60 (1997).
Synonym: Quercus acuminate Roxb. Fl. Ind. ed. 2,3: 636 (1832); Wight, Icon 1: t.221, figs. 6-9 (1840); Hook. f., in Fl. Br. Ind. 5: 607 (1888); Prain, Bengal Pl. 2: 740 (1903); Brandis, Ind. Trees: 630 (1906). **[Fagaceae]**

English name: Indian Batna.
Local name: Dholi batna, Kala batna, Kali batna, and Kanta Gola batna.
Description: A large, evergreen tree, young shoots villous, bark grey, leaves elliptic-lanceolate, 15-30 x 6-10 cm, entire, glabrous, shining on both surfaces, oblique towards the base, petioles c. 1.2 cm long, male spikes: 5-20 cm long, erect, dense-flowered, hairy, stout, flowers cream-coloured, female spikes up to 15 cm long, solitary, pubescent, cupsule c. 2.5 cm across, saucer-shaped, echinate with short sharp prickles, enclosing about one-fourth of the nut only, fruit a nut, ovate, smooth, brown.
Flowering and fruiting: January-November.
Habitat: Mixed and Evergreen forests.
Recorded by: It was recorded by Roxburgh from the specimen collected from Chittagong and described in his Flora Indica.
Distribution: From the south-east part of Bangladesh. In the evergreen hill forests of Chittagong (*Type locality*), Cox's Bazar districts, and the Chittagong Hill Tracts. So far this species has been collected from Chittagong region only. Alam and Khan (1997) published it as endemic plant.
Uses: Wood is moderately hard and suitable for making agricultural implements.
Propagation: By seeds.
Type specimen locaion: Chittagong; Roxburgh, Drawing No.2386, K!
Illustration/photography: Not available, probably the local name is misapplies to some allied species.
Threats to the species: Loss of habitat.
Conservation measures:

Status: Endangered (EN).
Measures taken: No conservation measures taken.
Measures proposed: Further botanical exploration for documenting its present status is necessary, conservation through both in-situ and ex-situ methods are suggested.

16. Litsea clarkei Prain, in Beng. Pl. 2: 676 (1903); Brandis, Indian Trees 5: (1906); (Khan *et al.* 2001), Red Data Book of Bangladesh: 83. **[Lauraceae]**

English name: None.
Local name: Charki haria.
Description: A small evergreen tree, branchlets glabrous, buds finely silky, petiole c.4 cm, slender, leaves up to 12 cm, alternate, elliptic, obtusely caudate- acuminate, regidly coriaceous, 3-nerved, two suprabasal nerves extending to near the apex, veins reticulate and prominent on both surfaces, inflorescence umbellate, male flower head in short axillary racemes on a common peduncle with small imbricating bracts, flowers silky, up to 6 in each head, perianth segment 4, deciduous, fruit unknown.
Flowering and fruiting: Unknown.
Habitat: Mixed forest.
Recorded by: Hooker 5: 154 mentioned the species under *Actinodaphne* from; Chittagong district (Sitakundo) which is then mentioned by Ahmed *et al.* 2008b; Brandis 1906; Khan *et al.* 2001; Prain 1903.
Distribution: In south-east part of Bangladesh (Chittagong district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K).
Illustration/photography: Not found.
Threat to the species: Habitat destruction.
Conservation measures:

Status: Critically Endangered (CR).
Measure taken: The species should be searched, and conservation measures should be taken.
Measures proposed: *Type locality* should be searched, and then the propagules should be collected for ex-situ conservation.

17. Myrioneuron clarkei Hook. f., in Fl. Brit. Ind. 3: 96 (1880); Prain, Bengal Pl. I.: 412 (1903); Khan *et al.*, Red Data Book of Bangladesh. 14(2001). **[Rubiaceae]**

English name: None.
Local name: Myronuron.
Description: A small erect shrub with spongy bark; leaves elliptic-lanceolate, much narrow, acuminate, petioles up to 3 cm long, nerves 12-15 pairs, slender, very obliquely arched, cymes corymbose, peduncles simple or branched, bracteoles much slender, flowers white, calyx teeth much slender, filiform, not rigid, stamens 5, adnate to corolla tube, carpel connate in two celled ovary, ovules many, stigma -2, linear-oblong, fruit ovoid, 2-celled, many seeded berry, seeds minute angular.
Flowering and fruiting: Not known.
Habitat: Moist primary forests.
Recorded by: It was reported by J. D. Hook (1880) from Chittagong, since then no report of collection of the species in Bangladesh is available.
Distribution: This species is available in some parts of South–east part of Bangladesh in the districts of Chittagong and Chittagong Hill Tracts.
Uses: Not known.
Propagation: By seeds.
Type specimen location: In Bangladesh National Herbarium, Dhaka (DACB) and at Kew (K).
Illustration/photography: Not available.
Threats to the species: Habitat loss.
Conservation measures:

Status: Endangered (EN).
Measures taken: None.
Measures proposed: Collection sites should be located for taking conservation and seeds should be collected and raised in nurseries.

18. Nothopegia acuminata J. Sinclair, in Bull. Bot. Soc. Bengal, 9(2): 90 (1956); Khan *et al.* Red Data Book of Bangladesh: 14 (2001). **[Anacardiaceae]**

English name: None.
Local name: Nishorti.
Description: A shrub, branches slender, glabrous, flexible; leaves simple, alternate, petiolate, elliptic-lanceolate, c. 15 x 3.5, entire, acuminate apex, base acute to obtuse, glabrous on both surfaces; inflorescence simple or branched, in short terminal and axillary, minute sparse pubescent; male flowers sessile, bracteolate, sepals 4 free, petals 4, free, white oblong, apex reflexed, many nerved, female flowers, and fruits not seen.

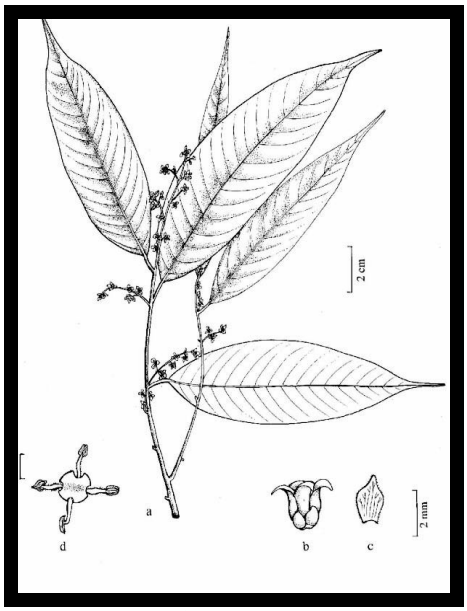

Figure 10 Morphology of the endemic plant - *Nothopegia acuminata* J. Sinclair.

Flowering and fruiting: March-April.

Habitat: In forest, near streams.
Recorded by: Sinclair (1955) reported from Cox's Bazar district (Kalatoli Chara); (Ahmed *et al.* 2008b; Khan *et al.* 2001). The plant should be rediscovered.
Distribution: In the extreme south-east corner of Bangladesh (Cox's Bazar district).
Uses: Not known.
Propagation: Probably by seed.
Type specimen location: At Edinburg (E?).
Illustration/photography: Khan *et al.* 2001(Figure 10).
Threat to the species: Destruction of habitat.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: No measure taken.
Measures proposed: The plant has not been collected since it was described from the *Type locality* by Sinclair. Extensive search to be taken to rediscover the plant and then would collect the propagules for in-situ and ex-situ conservation.

19. Ophiorrhiza villosa Roxb., in Fl. Ind. 2 : 546 (1824); Hook. f., in Fl. Br. Ind. 3:79 (1880); Prain, Bengal Pl. 1: 410 (1903). **[Rubiaceae]**

English name: None.
Local name: Pislagandhali.
Description: A perennial stout herb, up to 50 cm tall; leaves stipulate and petiolate, stipules ovate, villous, petioles up to 2 cm long, villous, lamina ovate-lanceolate, 3-10 x 1.5-5.0 cm, apex subacute, base acute, villous, lateral nerves 5-11 pairs, cymes terminal, subcapitate, dense-flowered, densely clothed with rusty pubescence, peduncles up to 6 cm long, villous; flowers subsessile, white or reddish, hypanthium 0.8-1.0 x 0.6-0.8 mm, obovoid, pubescent, calyx lobed 0.6-0.8 x 0.5-0.6 mm, ovate acute, pubescent, corolla up to 7 mm long, tubes 5-angular, ferruginous pubescent outside, villous at the throat, lobes 1-2 x 0.8-1.5 mm, ovate, acute, shortly keeled at back, filaments up to 3.5 mm long, adnate, styles up to 4 mm long, glabrous, stigma 2-lobed, villous, ovary obovoid, capsules 1.5-2.0 x 3.0-5.5 mm, hispid.
Flowering and fruiting: April-September.
Habitat: Moist shady places.
Recorded by: There is no record of the type collection of W. Roxburgh which was collected from Chittagong (Type) and Khagrachari. The plant is to be rediscovered.
Distribution : Distriuted in the eastern hilly area of Bangladesh (Khagrachari district, in Chittagong Hill Tracts).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K!).
Illustration/photography: Not found.
Threats to the species: Habitat destruction.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: None.
Measures proposed: The seeds should be collected for ex-situ conservation.

20. Phrynum imbricatum Roxb., in Fl. Ind. 1: 6 (1820); Hook. f. in Fl. Br. Ind. 6: 259 (1893); Prain, Bengal Pl. 2: 788 (1903); Khan *et al.* Red Data Book of Bangladesh: 97 (2001). **[Marantaceae]**

English name: None.
Local name: Pituli pata.
Description: An erect herb, rhizome creeping with petiole-like aerial stem, leaves 50-60 long, petiole and blade more or less equal, oblong acute, entire, inflorescence a spike, 7-10 cm long, oblong, from the side of the petiole, main bracts up to 4 cm ling, oblong, obtuse, mainly toothed to the obtuse tip, corolla segments shorter than the tube, while linear-oblong, as long as the bract, staminal lobes small, white, fruit a capsule, usually 3 seeded, rugose, oblong.
Flowering and fruiting: April-September.
Habitat: Deep shady wet situation along the stream.
*Recorded by:*Heinig 1925; Hooker 1872-1894; Khan *et al.* 2001; Prain 1903.
Distribution: In the eastern hilly region. Scarcely distributed in the hilly regions of Habiganj (Sylhet), and Chittagong and Chittagong Hill Tracks.
Uses: Not known.
Propagation: By rhizomes and seeds.
Type specimen location: At Kew (K).

Figure 11 Morphology of the endemic plant - *Phrynum imbricatum* Roxb.

Illustration/photography: Ahmed *et al.* 2008b; Khan *et al.* 2001 (Figure 11).
Threat to the species: Habitat destruction.
Conservation measures:

Status: Not Evaluated (NE).
Measures taken: No attempts have been taken for its collection and then conservation measures should be suggested.
Measures proposed: The creeping rootstock should be collected for ex-situ conservation.

21. Rotala simpliciuscula (Kurz) Koehne, in Bot. Jahrb. 1: 159 (1880); Cook, Boissiera 29: 100 (1979); Khanam, J. Pl. Taxon 3: 41 (1996).
Synonym: Ammannia simpliciuscula S. Kurz, J. Asiatic Soc. Bengal, 40 (2): 54 (1871); Hook. f., in Fl. Brit. Ind. 2: 568 (1879); Prain, Bengal Pl. 1: 363 (1903) **[Lythraceae]**

English name: None.
Local name: Shimghurni.
Description; Amphibious, annual, mat forming erect slender herb, stem decumbent; leaves 2.5-5 x 0.5-2 mm, decussate, narrowly oblong to obovate, obtuse or retuse at the apex, shortly petioled, bracts leafy; flowers solitary in axils of bracts, pedicellate, calyx tube 0.25-0.35 mm long, deltate at anthesis, shallowly triangular in fruit, petals absent, capsule 1.4 mm in diameter, 2 times longer than the calyx, opening by 3 valves, seeds c. 0.5 mm long, semi pyriform to hemispherical.
Flowering and fruiting: Not known.
Habitat: Marshy rice field or waste marshy places.

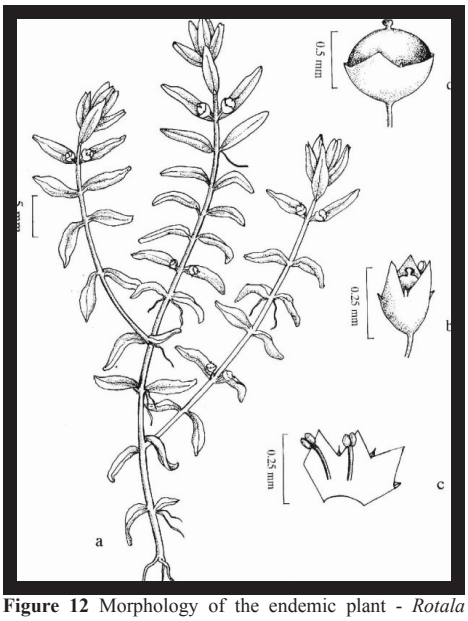

Figure 12 Morphology of the endemic plant - *Rotala simpliciuscula* (Kurz) Koehne.

Recorded by: The *Type specimen* was collected from Chittagong district by J. D. Hooker and T. Thomson (Kew) (Cook 1979). After that no other collection has been reported or rediscovered.
Distribution: In the south- east part of Bangladesh (Chittagong district).
Uses: Not known.
Propagation: By seed.
Type specimen location: At Kew (K).
Illustration/photography; Khan *et al.* 2001; Khanam 1996 (Figure 12).
Threat to the species: Habitat destruction.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: Immediate search should be made to relocate the species, and then conservation measures to be suggested.
Measures proposed: After seed collection, plants can be raised in amphibious situation.

22. Tarenna scandens (Roxb.) Good, in J. Bot., 64 (Suppl. 2): 11 (1926).
Synonym: Webera scandens Roxb. In Fl. Ind. 3 (1832). **[Rubiaceae]**

English name: None.
Local name: Gujer-kata.
Description: A scandent, glossy shrub, young shoots polished, especially the tender parts; leaves stipulate and petiolate, stipules triangular-lanceolate, petioles short, lamina oblong, 12-15 x 4-5 cm, entire, apex acuminate, base acute, glossy; inflorescence axillary cymes and in the forks of the

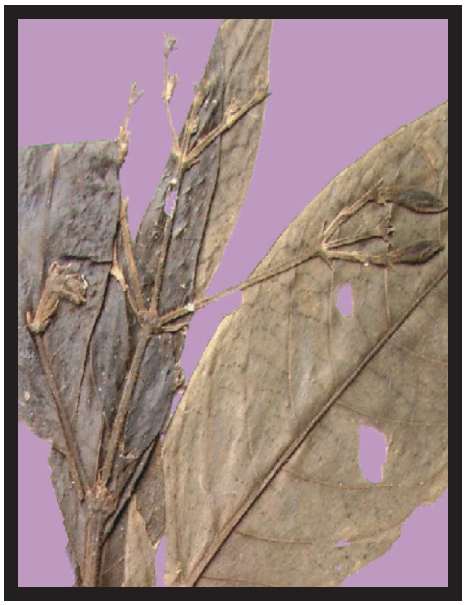
Figure 13 Morphology of the endemic plant - *Tarenna scandens* (Roxb.) Good.

branchlets, solitary, divisions generally bi-ternate, flowers large, funnel-shaped, fragrant, white, turning yellow at maturity, calyx sub–campanulate, corolla with a long slender tube, lobes segmented, obliquely oblong, anthers linear, sessile on the mouth of the tube, stigmas divided into 2 oval plates, styles as long as the corolla tube, fruits small, globose.
Flowering and fruiting: April - October.
Habitat: Shady slopes.
Recorded by: It was reported by Roxburgh (Roxburgh 1832) from Sylhet; after that no collection was made.
Distribution: In the north-east part of Bangladesh (Sylhet district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K).
Illustration/photography: Available (Figure 13).
Threats to the species: Habitat destruction.
Conservation measures:

Status: Endangered (EN).
Measures taken: None.
Measures proposed: Reported collection locality should be traced, then both in-situ and ex-situ conservation measures are to be adopted.

23. Taxillus thelocarpa (Hook. f.) M.K. Alam, in Bang. J. Bot., 14(1): 32 (1985); Alam, Fl. Bangladesh, 33:13 (1986); Khan *et al.* Red Data Book of Bangladesh: 87 (2001).
Synonym: Loranthus thelocarpus Hook. f., in Fl. Brit. India, 5: 211 (1886); Prain, Bengal. Pl. 2: 911 (1903); Brandis, Ind. Trees: 549 (1906); Scurrulla thelocarpa (Hook. f.) Danser, Bull. Jard. Bot. Buitenz. Ser. 3, 10(3): 353 (1929). **[Loranthaceae]**

English name: None.
Local name: Taxiladi.
Description: Hemiparasitic shrub on trees, branches stout, terete, sparsely lenticelate, bark grey, branchlets tomentose; leaves 3-7 x 2-3 cm, opposite, ovate, ovate-oblong or obtuse, entire, base rounded, glabrous, dark, brown, non-transparent above and finely rusty brawny tomentose beneath, rigidly coriaceous, veins mostly obscure, petiole 8-10 mm long; flowers in tomentose umbel, pedunculate; pedicel up to 5 mm long; bracts very minutes, calyx tube c. 2 mm long, corolla tetramerous, 13-14 mm long, fruits c. 4 mm long, clavate, contracted into the pedicel with an annular thickened base with pustule like tubercles.
Flowering and fruiting: October- December.
Habitat: Aerial parasite on branches of woody plants in forests.
Recorded by: Hooker and Thomson on 9/9/1851 from Kazke-hat (Kazir hat, (K-type); Bariardhala-Hazarikhil 19/10/1978 by Huq. *et al.* (H-3910), from Alam (1986).
Distribution: In the south-east part of Bangladesh, from Chittagong district, Sitakundo hill range-Kazirhat, Bariardhala and Hazarikhill.
Uses: Not known.
Propagation: Through seed.
Type specimen location: At Kew (K).
Illustration/photography: Ahmed *et al.* 2008b; Khan *et al.* 2001 (Figure 14).
Threat to the species: Needs old tree to be parasite, so old trees are vanishing quickly.
Conservation measures:

Status: Not Evaluated (NE).
Measures taken: Huq recorded from *Type locality*. So, in-situ and ex-situ conservation is suggested and further exploration to determine the distribution and status is needed.

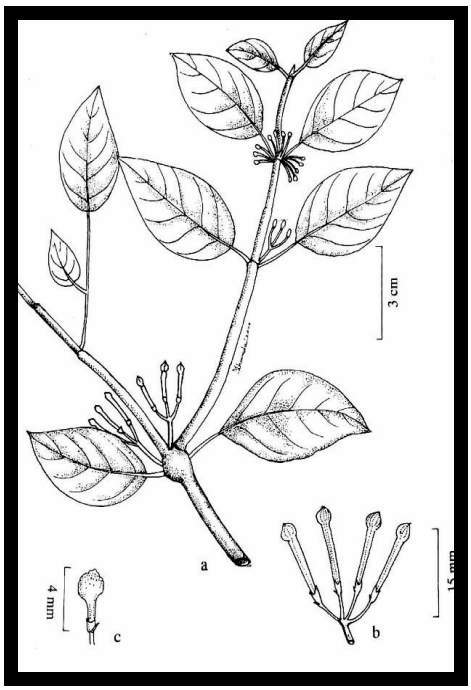

Figure 14 Morphology of the endemic plant - *Taxillus thelocarpa* (Hook. f.) Alam.

Measures proposed: Studies should be conducted on the dispersal of fruits to ensure natural regeneration.

24. Trigonostemon praetervisus Airy Shaw, in Kew Bull. 37: 121 (1982); N. P. Balakr. & Clarkrab. in Candollea, 46: 625 (1991).
[Euphorbiaceae]
English name: None.
Local name: Gonovis.
Description: Shrubs or trees; branches terete, 2-4 mm thick; young parts papilose, leaves oblong-elliptic, 8-16 x 1.5-4.5 cm, narrowly rounded and trinerved at base, entire and narrowly reflexed

along margins, acuminate at apex, chartaceous, glabrous; midrib slender, prominent; primary nerves (including basal ascending ones) 6-7 pairs, slender, arcuate-patent; nervules inconspicuous, subtransverse; petioles 5-15 mm long, glabrous, male inflorescences subtended by 2-4 leaves, with slender closely arranged divaricate branches; branchlets broadly spreading from each branch, each subtended by linear 2-3 mm long bract, flowers: many, only buds seen, small, not yet opened; pedicels 1-2 mm long, slender, sepals minute, ovate, scarcely 0.5 mm long, hyaline, pale, long pilose outside; petals ovate, 1-1.5 mm long, hyaline, pale, faded, contorted and hence bud apices subacute; disc annular, short; stamens 5; filaments short, nearly free, female flowers and fruits not seen.
Flowering and fruiting: Period unknown.
Habitat: Not known.
Recorded by: Wallich s. n. 8001 collected from Sylhet, No date, (K-Wall: photo! Holatypus, speciminibus Crotonis in parte sinistra plagulae exclusis), from Kew.
Distribution: In north-east part of Bangladesh (Sylhet district).
Uses: Not known.
Propagation: By seeds.
Type specimen location: At Kew (K-W).
Illustration/photography: Not found.
Threat to the species: Destruction of habitat.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: Nothing known about its present existence, so, extensive research should be done to relocate the species from *Type locality*, then ex-situ or in-situ conservations to be needed.
Measures proposed: Mature seeds should be collected for raising the plants to establish living germplasm bank.

25. Vernonia thomsoni Hook. f., in Fl. Brit. Ind. 3: 232 (1881); (Heinig 1925; Khan *et al.* 2001; Prain 1903) **[Asteraceae]**

English name: None.
Local name: Tomsivernon.
Description; A robust straggling undershrub, much branched with ribbed and grooved branches, younger part scaberulous; leaves up to 20 cm long and 7.5 cm broad, subsessile, lanceolate, serrate, acuminate, puberulous on the undersurface, membranous, heads 1.2 cm across on slender, pubescent pedicels, obconic, 10-15 flowered in short, axillary corymbs, involucral bracts recurved, glabrous, shining, outermost needle shaped, inner bracts up to 1.8 cm long, linear acuminate, achenes c. 3 mm long, glabrous, strongly 10 ribbed, pappus up to 8 mm long, very fine, white, persistent with very few outer hairs.
Flowering and fruiting: Not known.
Habitat: In open places, on the edge of semi-evergreen forest.
Recorded by: Hook (1881) reported from Chittagong (Sitakundo); (Heinig 1925; Khan *et al.* 2001; Prain 1903).
Distribution: In south-east part of Bangladesh (Chittagong district).
Uses: Not known.
Propagation: By seeds (achene).
Type specimen location: At Kew (K!).
Illustration/photography: Not found.
Threat to the species: Destruction of habitat.
Conservation measures:

Status: Critically Endangered (CR).
Measures taken: Nothing known about its present existence, so, extensive research should be done to relocate the species from *Type locality*, then ex-situ or in-situ conservations to be needed.
Measures proposed: Mature achenes should be collected for raising the plants to establish living germplasm bank.

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Chapter 6: Changing Trends in Biodiversity of the Mangroves of Bangladesh

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Abstract

This paper is about species diversity of flora and fauna in the natural and planted mangrove forests of Bangladesh. Changing trends in biodiversity over time have been highlighted. From exhaustive literature review and visual observations a number of plant and animal species are shown to have disappeared from the mangroves. Depletion of commercially-important species has also occurred, but barren shorelines have been planted with selected mangrove species and mesophytic species that provide habitats for various animals. Declining trends in major mangrove trees has been shown and the list of extinct, endangered, and vulnerable wildlife species presented. Biotic and abiotic factors affecting the richness of biodiversity in the coastal areas have been discussed and suggestions made to arrest further depletion of biodiversity.

Keywords; b*iodiversity, mangrove forests, depletion causes.*

Introduction

The floristic composition of the Sundarbans is rich compared to many other mangroves of the world. The forest is changing due to both natural and anthropogenic stressors. Mangrove plantation is also unique in the world. Bangladesh is the pioneer country in successful establishment of mangrove plantation. The world's largest afforestation programme was initiated in Bangladesh and, in this connection, species selection, nursery techniques, planting techniques, and management strategies were developed.

Under heterogeneous vegetation, there has been development of a diversified fauna, both terrestrial and aquatic. Faunal composition is not well recorded for that coastal areas, but seems to be gradually establishing on new land formations, but both plants and animals are under tremendous pressure from various stresses. The aim in this paper is to highlight the flora and fauna in the coastal environment, changes in species biodiversity, and reasons for depletion of biodiversity.

Species, genetics, and ecosystems are the main components of biodiversity. Due to lack of well-planned and long-term studies, information in relation to floral and faunal diversity needs to be generated for the mangroves of Bangladesh. Available information shows mainly species diversity. Regular and detailed studies on the existence and abundance of plants and animals are needed; even the old literature is not a sound basis for ascertaining the magnitude of deterioration of biodiversity and changes.

Methods

The coastal areas of Bangladesh lie between latitude 21^0 to 23^0 N and longitude 89^0 to 93^0 E. Erosion and sedimentation are the common characteristics of the coastal environment and greatly influenced by tides and downstream flow of the rivers. Mean tidal range varies from 2.2 to 4.0 m. Water salinity along the coast ranges from 3-27 ppt, depending on seasons and locations (Siddiqi & Khan 2004).

Most of the 710 km coastline is dominated by the deltaic deposits of the Ganges – Brahmaputra - Meghna rivers. The sediments from the Himalayas are transported and sorted by river flow and reworked by tidal and wind action, leading to extensive areas of accretion and erosion in the coastal lands (Saenger & Siddiqi 1993). Both natural forests and plantations exist along the shoreline of Bangladesh (Figure 1). The natural mangrove forests of Bangladesh include the Sundarbans and the Chokoria Sundarbans. The plantations have been developed on barren new accretion areas on the coastline and near shore islands during the last four decades (Siddiqi 2002).

The paper is based on literature review, interviews with the coastal population, and long observations by the author. Various relevant organizations were visited for survey of literatures. Moreover, information was also collected from browsing the internet. From the long experience of author since 1985, species biodiversity covering plants and animals has been discussed and attempts were made to project trends in biodiversity. For fauna, only mammals, birds, reptiles, and amphibians have been included. Trees having greater economic importance have been discussed with emphasis. No questionnaire was used for the purpose of the study. Area under study covers both natural and planted mangroves occurring in the shoreline and near shore–islands of Bangladesh (Figure 1).

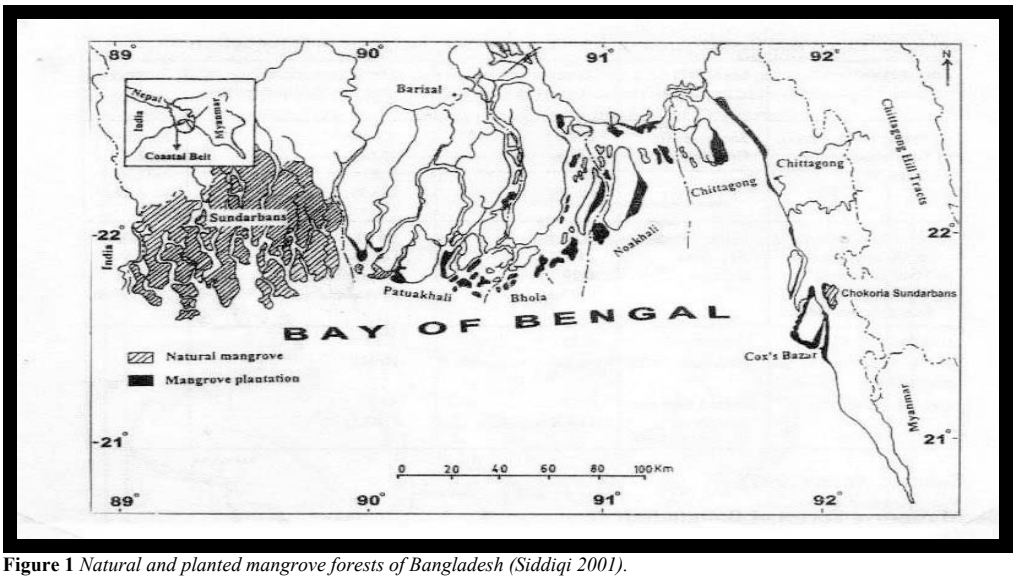

Figure 1 *Natural and planted mangrove forests of Bangladesh (Siddiqi 2001).*

Results and Discussion

Mangrove biodiversity

Flora of Sundarbans

The floristic composition of the Sundarbans is rich compared to many other mangroves of the world. Prain (1903) recorded 334 species, including mangrove and non-mangrove plants, belonging to 245 genera and 75 families for the Sundarbans and adjoining areas. Heining (1892) reported 70 species from 34 families for the entire Sundarbans (India and Bangladesh). Chaffey and Sandom (1984) presented a list of 66 mangrove species in Bangladesh Sundarbans from 37 families. Siddiqi (2001) mentioned that three more valuable tree species were likely to be present. *Heritiera fomes* and *Excoecaria agallocha* are the principal species. *H. fomes, H - fomes - E. agallocha, E. agallocha - H. fomes,* and *Ceriops decandra - E. agallocha* forest types cover 21.0 %, 29.7 %, 14.8 %, and 14.5 % of the area, respectively. The Sundarbans supports about 25 true margrave species with others mangrove associates. List of the valuable species with their uses is given in Table 1.

Flora of Chokoria Sundarbans

The Chokoria Sundarbans resembles the Sundarbans proper in floral composition, although it is located in the east, while the Sundarbans is in the extreme south–west of Bangladesh. Initial vegetation of the Chokoria Sundarbans included 53

Table 1 *Economically- important plants of the Sundarbans and their uses (Siddiqi 2001).*

Scientific Name	Vernacular name	Family	Type of plant	Main uses
Avicennia officinalis	Baen	Avicenniaceae	Tree	Fuel wood and anchor logs.
Bruguiera sexangula	Kankra	Rhizophoraceae	Tree	Furniture, bridge, and house construction.
Ceriops decandra	Goran	Rhizophoraceae	Shrub or small tree	Fuel wood, houses posts, and charcoal.
Cynometra ramiflora	Shingra	Leguminosae	Shrub or small tree	Fuel wood.
Excoecaria agallocha	Gewa	Euphorbiaceae	Tree	Matchsticks and boxes, newsprints, other papers.
Heritiera fomes	Sundri	Sterculiaceae	Tree	House construction, boat building, electric poles, hard boards, and fuel wood.
Lumnitzera racemosa	Kripa	Combretaceae	Small tree	Fuel wood and posts.
Nypa fruticans	Golpata	Palmae	Recumbent	Thatching for houses.
Phoenix paludosa	Hantal	Palmae	Thomy plam	Post and rafters for huts.
Sonneratia apetala	Keora	Sonneratiaceae	Tree	Packing boxes and construction material
Xylocarpus granatum	Dhundul	Malvaceae	Tree	Furniture.
Xylocarpus mekongensis	Passur	Malvaceae	Tree	Furniture; bridges, and house construction.

species belonging to 42 genera and 22 families (Cowan 1926). The forest was stunted, growing to an average height of 10 m. *Ceriops decandra* and *Avicennia officinalis* were the dominant species. Other frequently-occurring species were *Kandelia candel, Bruguiera* sp, *Aegialities rotundifolia, Heritiera fomes, Excoecaria agallocha, Sonneratia apetala, Phoenix paludosa,* and so forth... The Chokoria Sundarbans differs from the Sundarbans in the abundance of *Dalbergia spinosa* and by the presence of pure stands of *Aegialtlis rotundifolia*. A notable feature was the total absence of *Nypa fruticans,* but *Sonnertia griffithii* on muddy flats does not occur in the Sundarbans.

A survey by Karim and Khan (1980) showed some commercially-important species in a reasonably-good number, but, later, Siddiqi *et al.* (1994) found a very poor condition of flora in respect of diversity and abundance. Only 28 species covering herbs, shrubs, and trees were recorded. All the trees were cut; the Chokoria Sundarbans was virtually an open area. Although the Chokoria Sundarbans has been destroyed, the latest survey shows that still there is sporadic distribution of natural stands along the south-eastern part of the shore line down to Teknaf and nearby shore–islands (Siddiqi & Alam 2006).

Mangrove plantations

Mangrove afforestation on exposed coast land was initiated in 1966, with the goal to protect human life and property against frequent storm surges. Subsequently, wood production, land reclamation for agriculture and human settlement, employment opportunity, and so forth, became part of the objectives. Initially, all the commercial species available in the natural mangroves were tried. Considering the success, mono-specific plantations, either with *Sonneratia apetala* or *Avicennia officinalis,* were established. Up to 2005, about 150,000 ha were planted (Siddiqi 2008a), but only 45,000 ha of mangrove plantation is reported to exist now (Forest-Department 2010).

Due to rapid sedimentation, he forest floor in many areas has risen and the area became unsuitable for mangrove species. Those areas have been found suitable for mesophytic species. In many areas plantations of successful selected mesophytic species have been created (Siddiqi 2008a).

Faunal composition

The Sundarbans fauna is rich and varied, but in recent decades several important animals have become extinct from the area. Many more are endangered or in a vulnerable condition. Salter (1984) reported the occurrence of 32 mammal species, at least 186 birds, 35 reptiles, and eight amphibians, as quoted by Blower (1985), but various authors differed in the number of existing species (Sarker & Sarker 1988).

Changing trends in flora and fauna

The coastal region is a highly-dynamic ecosystem. Abiotic change in this ecosystem is rapid and causes dynamism in biotic components. Moreover, due to densely human population in the coastal areas, pressure on flora and fauna is considerably high in order to meet the needs of the growing population.

Change in Sundarbans flora

In 18th century, the total area of the Sundarbans was 16,700 km^2, which is now reduced to 10,000km^2 (62 % in Bangladesh and 38 % in India). *Heritiera fomes* is the climax species of the Sundarbans and it was a dominant species in the Calcutta region about 5,000 years ago (Blasco 1975). Now Indian Sundarbans no longer supports healthy population of *H. fomes* trees, which prefer less saline areas (Chandhuri & Choudhury 1994).

In Bangladesh, *H. fomes* constituted 73 % and *E. agallocha* 16 % of the growing stock (Forestal 1960). Chaffey and Sandom (1984) showed depletion of growing stock of *H. fomes* by 40 % and 45 % of *E. agalloche,* compared to the Forest Inventory in 1959. This might be the result of over-exploitation. Standing volume of *Sonneratia apetala* and *Avicennia officinalis* are much the same. *Bruguiera sexangula* decreased and *Xylocarpus mekongensis* increased by 100 % due to a moratorium on felling since 1989.

Stems (diameter > 15 cm) of *H. fomes, E. agallocha, A. officinalis, S. apetala* and others accounts for 73.6 %, 12.0 %, 1.8 %., 1.7 %, and 10.2 %, respectively, in 1996 (FRMP). The subsequent survey made by US Forest Service in 2009 revealed that the number of stems of the species was reduced to 59, 20.8, 0.4, 1.6, and 8.2 respectively (M.A. Latif, personal communication). The situation is alarming for *H. fomes,* which constitutes only 45.3 % of the poles in 2009 though the dominant species of the forest.

There is a decrease in canopy closure. In 1960, 78 % of the total area of the Sundarbans had a canopy closure of 75 % or more. In 1985, 65 % of the forest had a canopy closure of 70 % or more. Some species (*Rhizophora apiculata, Avicennia marina,* and *Ceriops tagal*) are available in the Indian Sundarbans, which do not occur in Bangladesh Sundarbans (Siddiqi 2001).

Change in Sundarbans fauna

Over the past 100 years, a good number of animals have disappeared from the Sundarbans and many more are endangered or in a vulnerable condition. Extinct, endangered, and vulnerable species from Sundarbans and adjacent areas are mentioned in Tables 2 and 3. Status of mammals, birds, reptiles, and amphibians in the Sundarbans and adjacent-

Table 2 *Extinct species from the Sundarbans and adjacent areas (Khan 2008; Sarker 2010).*

	Species name	Last observed
1.	Grey wolf, *Canis lupus*	1940
2.	Swamp deer, *Cervus duvaucel*	1950
3.	Hog deer, *Axis porcinus*	Beginning of 19th century
4.	Black buck, *Antilope cervicapra*	End of 19th century
5.	Buffalo, *Bubalus bubalis*	1940
6.	Javan rhinoceros, *Rhinoceros sondaicus*	1908
7.	King vulture, *Sarcogyps Calvus*	1950
8.	Greater adjutant, *Leptoptilos dubius*	1975
9.	Bengal florican, *Eupodotis bengalensis*	1975
10.	Mugger, *Crocodylus palustris*	Beginning of 19th century

area is also shown in Table 4.

Although the status of *Panthera tigris*, an endanger species, has been mentioned as rare for Bangladesh, the Sundarbans supports about 350-375 individuals of tigers (Sarker 2010).

Fauna of plantations and adjacent Areas

Before the establishment of plantations, the shoreline of Bangladesh was exposed and prone to cyclones and tidal surges. Following the raising of plantations, the area is more suitable for animals to live, but there is much natural and human pressure on the development of a stable ecosystem for flora and fauna. The coastline that being still less disturbed is inhabited by various animals from adjacent areas for a safer existence. From observations, the following animals were recorded at Char Kashem (Patuakhali District) and Char Kakri (Bhola District):

1. Grey musk shrew, *Suncus murinus*.
2. Rhesus macaque, *Macaca mulatta* (introduced).
3. Jackal, *Canis aureus*.
4. Smooth Indian otter, *Lutra perspicillata*.
5. Small Indian civet, *Viverrcula indica*.
6. Common mongoose, *Herpestes auropunctatus*.
7. Fishing cat, *Felis viverrina*.
8. Spotted deer, *Axis axis* (introduced).
9. Wild boar, *Sus scrofa*.
10. Lesser bandicoot rat, *Bendicota bengalensis*.
11. Bandicoot rat, *Bandicola indica*.
12. House mouse, *Mus musculus*.
13. Common house rat, *Rattus rattus*.
14. Bengal grey lizard, *Varanus bengalensis*.
15. Monitor lizard, *Varanus flaviscens*.

The plantations act as shelter for many animals,

Table 3 *Endangered/ vulnerable species of the Sundarbans with their global and local status. Codes: VU: Vulnerable, EN: Endangered, CR: Critically Endangered, UC: Uncommon, C: Common, R: Rare, RR: Rare Resident, RWV: Rare Winter Visitor (IUCN 2010).*

Animals	English Name	Scientific Name	Global Status	Local Status
Mammals				
1	Fishing cat	*Felis viverina*	VU	UC
2	Tiger	*Panthera tigris*	EN	R
3	Smooth-coated otter	*Lutrogale perspicillata*	VU	R
4	Ganges river dolphin	*Platanisa gangetica*	EN	UC
Birds				
1	Masked finfoot	*Heliopais personata*	VU	UC
2	White-rumped vulture	*Cypa bengalensis*	CR	RR
3	Greater spotted eagle	*Aquila changa*	VU	RWV
4	Lesser spotted eagle	*Aquila pomarina*	VU	RR
5	Pallas's fish eagle	*Haliaeetus leucoryphus*	VU	RR
6	Lesser adjutant	*Leptoptilos javanicus*	VU	RR
Reptiles				
1	River/mangrove terrapin	*Batagur baske*	CR	CR
2	Three-kedded tortoise	*Medanochelys tricarinata*	VU	EN
3	Asian giant softshell turtle	*Pelochelys cantorii*	EN	CR
4	Red-crowned roof turtle	*Kachuga kachuga*	CR	CR
5	Spotted pond turtle	*Geodemys hamitonii*	VU	EN
6	Boahniny river turtle	*Hardella thurjii*	VU	EN
7	Indian syed turtle	*Morenia petersi*	VU	C
8	Ganges softshell turtle	*Aspideretes gangeticus*	VU	C
9	Peacock softshell turtle	*Aspideretes hurum*	VU	C
10	Narrow-headed softshell turtle	*Chita indica*	EN	C
11	Green turtle	*Chelonia mydas*	EN	C
12	Olive Ridley turtle	*Lepidochelys olivacea*	VU	EN

Table 4 *Status of mammals, birds, reptiles, and amphibians in the Sundarbans and adjacent areas (Blower 1985; IUCN 2010; Sarker 2010; Siddiqi 2008b).*

Class	Total No of species in Bangladesh	Existing species in Sundarbans	Sundarbans share with Bangladesh (%)	Extinct species (No.)	Endangered Species (No)
Mammalia	125	32	25	6	5
Aves	630	186	30	3	6
Reptilia	150	35	23	1	12
Amphibia	20	8	40	-	-

some of which are plentiful. Deer (*Axis axis*) were introduced into the mangrove plantations of Char Kuri (Bhola), Sonarchar (Patuakhali), Nizumdeep (Noakhali), and Sitakundah (Chittagong); they flourished well. Apparently this may be encouraging. *Sonneratia apetala* is the pioneer tree species in the ecological succession. Because of the preferential browsing habit of deer, the development of a second rotation crop is hindered and, thereby, the sustainable management and continuation of the forest (Siddiqi *et al.* 1994). Some common birds are also plentiful in mangrove plantations and adjacent areas. They get shelter in remote areas and are reportedly increasing in population. In addition to migratory birds, many local birds live permanently in the coastal belt.

Chokoria Sundarbans

In the past, the forest supported moderately dense vegetation, but a check list for the inhabiting animals was never available. Following conversion of the forests to shrimp ponds, no wildlife species are there, except for some birds dependent on aquatic organisms. So, what is lost cannot be ascertained for want of literature.

Depletion of biodiversity

Various factors, both abiotic and biotic, affect sustainability and richness of existing floral and faunal diversity. Flora is affected first and this subsequently causes depletion of animal diversity. In many cases animals are also directly affected.

Abiotic factors

1. Reduced flow of fresh water from upstream and increasing level of salinity.
2. Discharge of sediments in coastal areas and rising of forest floor affecting periodic inundation of root system by brackish water. Sometimes root systems may be buried due to heavy deposition of silts.
3. Unpredictable erosion and accretion of coastal land.
4. Tectonic movement causing rising of western part of delta, alteration of river courses and reduction of freshwater flow.
5. Natural calamities, including cyclones and storm surges.

Biotic factors

1. Conversion of mangrove forests to shrimp ponds.
2. Conversion of mangrove plantation areas to salt pans.
3. Agricultural expansion and urbanization in mangrove land.
4. Over-exploitation of mangrove forest resource.
5. Lack of sustainable mangrove management programme.
6. Poor socio-economic condition of the people living adjacent to mangrove areas.
7. Unplanned fishing inside mangrove forest.
8. Cattle grazing in plantation areas.
9. Destruction of wildlife habitat.
10. Poaching and hunting of animals in the mangrove forests.

Limitations of the study

The paper is based on secondary information. It could be enriched with recent studies and original findings. Nevertheless, available information has been compiled and the paper may act as basis for future goal- oriented studies.

Conclusion

Some 60 % of the world's human populations live within 60 km of the sea and the social, economic, and environmental significance of the boundary between the land and the ocean is widely recognised (Brown 1997). In Bangladesh, being one of the most densely-populated countries, human pressure on the coastal environment is high. It is difficult to take protective measures against abiotic factors pressuring biodiversity, but, human pressure can be greatly reduced against the negative impact on biodiversity. So far the Bangladesh Forest Department alone is responsible for the management and conservation of biodiversity, but pressure from the coastal population is so high for agricultural expansion, fishing, cattle grazing, salt production, that, without the involvement of the coastal population, it is not possible to control destruction of forests and biodiversity. Thus, a programme should be developed for the management of biodiversity with the participation of coastal people.

Detailed studies need to be made to assess current coastal biodiversity, to understand the

magnitude of depletion, and prospects for improvement in the future. This will help the taking of necessary steps to ensure a stable state of floral and faunal diversity in the coastal ecosystems. Multiple use of coastal environment, with integrated management of the available resources has to be attempted for optimal economic benefit of the coastal population, and this will greatly help the conservation of biodiversity.

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Chapter 7: Present Status of Wetland Biodiversity - A Study in Sujanagar Upazila, Pabna, Bangladesh

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Abstract

This exploratory study was conducted over a period of three months; it was concentrated in three unions of Sujanagar Upazilla in Pabna district. The present state of wetland biodiversity is exacerbated due to a series of problems, including poverty, population growth, force from pressure groups, and construction of flood-control embankment, through inappropriate regulations of water flow (i.e., sluice gate). Many aquatic species, including fish and plants, are shown to be threatened and endangered due to siltation of beel, changing physical nature of wetlands, indiscriminate uses of chemicals, construction of embankment, and fishing of broods. Physical changes in watersheds and floodplains have drastically reduced the area and quality of wetlands. Flood-control embankments and water control structures have blocked fish migration routes. On the other hand, expanded irrigation of cultivated areas and expanding areas of winter–rice cultivation has reduced the water available for aquatic life to survive in the six-month dry season. Losses of tree cover and poor cultivation practices in watersheds have caused high rates of siltation in rivers and loss of floodplain wetlands. The wetland environment unites the inhabitants into a society, which has a definite shape, culture, and livelihood pattern. Over-exploitation of aquatic resources, destruction of habitats, unwise use of agrochemicals, land use conflict and conversion of land, and construction of embankment and sluice gates are the major threats to wetland biodiversity. Many fishermen are losing their profession due to loss of wetland biodiversity (i.e., lack of fish). People's active participation can secure wetland restoration. Participatory wetland resource management or initiatives might save wetland biodiversity and aquatic resources.

Keywords; *wetland; biodiversity; threatened; endangered; restoration.*

Introduction

Bangladesh is lying between $20^0$34' and $26^0$38' N latitude and 88^0 51' and 92^0 41' E longitude. The country has a total area of 147,570 km^2 with a population of about 150 million. The land can be classified as 79 % flood plains, 12.6 % hilly areas, and 8.3 % terrace soils. The catchment basin of the combined Ganges, Brahmaputra, and Meghna rivers covers more than 1.5 million km^2. Bangladesh holds colossal wetland areas and, indeed, during the rainy season, about half of the country could be classified as wetland. It is estimated that about 50 % or more of the land surface of Bangladesh is wetland, consisting of about 700 rivers, creeks, streams and other water bodies known locally as *haor*, *baor*, *beel* and *khal*. About 6.7 % of Bangladesh is always under water, 21 % is deeply flooded (more than 90 cm), and 35 % experiences shallow inundation (FAO 1988). The average discharge of water in Bangladesh delta in the flood season is more than five million cusec. The wetlands in Bangladesh encompass a wide verity of dynamic ecosystems ranging from mangrove forest (about 577100 ha), natural lakes, man-made reservoir (Kaptai lake), freshwater marshes (about 400 haors), oxbow lakes (about 54488 ha, locally known as *baors*), freshwater depressions (about 1,000 *beels*), fish ponds and tanks (about 147,000 ha), estuaries and seasonal inundated extensive floodplains (Akonda 1989; cited in Ali Khan 1993).

Under the Ramsar international wetland conservation treaty, wetlands are defined as *areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*. Wetland biodiversity is very rich in aquatic resources, including fish, plants, and other aquatic animals. Several distinct vegetation zones that are found in the wetland zones are submerged, free floating, rooted floating, and sedges and meadows zones.

The Asian Wetland Symposium of 1992 concluded: *wetlands are being lost and degraded rapidly in Asia, as well as in other regions, and many people are paying the cost, some with increased cost of living, and some with their lives.* In Bangladesh, Sujanagar Upazila of Pabna District is supporting a huge water body. This area is now a smouldering example, and known as a lost biodiversity unit, due to establishment of the Pabna Irrigation and Rural Development Project (PIRDP), and also establishment of the embankment of flood control by Bangladesh Water Development Board (BWDB). Flood-controlled dykes, sluice gates, and pump houses have been established with a view to protect flood water, as well as supplying the river water into the cropping area in a controlled and systematic way. After the green revolution, farmers

are still using chemical fertilisers, pesticides, herbicides, and other toxic substances to improve crop production to meet the growing needs. As a result, biodiversity in the study area has been misplaced and beneficial insects, birds and aquatic animals, useful for biodiversity conservation do not exist in that region. Fishermen groups are becoming more vulnerable by losing their profession and have been forced to change their profession. Conflict between fishermen, private leases, and government over water access was common throughout the period and was the subject of a number of court cases (Pokrant *et al.* 1997). Every professional group from all sectors, except agricultural day labourers, have migrated to the other places or shifted their profession.

Wetlands are playing an enormous role in rural livelihoods and environment. Wetlands serve a wide range of functions, including ecosystem balance, flood control, water purification, protection from natural disasters, sources of livelihood, regular flow of water, and habitat for wildlife, fish, aquatic plants and animals. Paddy cultivation and lowland agriculture are the main rural livelihood options in the area at Sujanagar Upazila under Pabna District. The fisheries and other food and non-food resources are traditionally regarded common property in Bangladesh (Ahmed 1997). All of the aquatic resources in the common water bodies are common property regardless, so there is need of special care for its proper management. In the light of above circumstances, the aim of the study is to acquire knowledge of the present status of wetland biodiversity at Sujanagar Upazila, Pabna, Bangladesh. The associated objectives of the study are to: (i) determine the plant and fish species in that area, (ii) explore the causes of the loss of wetland biodiversity, (iii) study perceptions of local people about the problems exists in the study area, and (iv) identify measures for the restoration of wetland biodiversity.

Methods

Study areas

Sujanagar, Pabna is located 23°55′ N and 89°26′ E. It has 36,136 households and total area 334.4 km². Only three unions from Sujanagra upazillas, Pabna were selected to conduct the study, based on the availability of water bodies/wetlands. Three unions (Dulai, Ahammadpur, and Raninagar) were randomly selected from the study area. The study areas were concentrated on 27 villages, of which 7 villages were in Dulai Union, 11 villages in Ahmmadpur Union, and 9 villages in Raninagr Union.

Demography

As of the 1991 Bangladesh census, Sujanagar has a population of 214,132. Males constitute are 51.86 % of the population, and females 48.14 %. Upazila's population over the age of 18 is 102,202. Sujanagar has an average literacy rate of 26.7 % (7+ years), and the national average of 32.4 % literate. The total populations of the surveyed area were 71,438 people of whom 35,497 were females, 35,491 males, 16,228 children, and 203 were disabled. According to family professions, 14,567 were farmers, 2,516 fishermen, 2,091 weavers (*tanti*), 1,124 tobacco labours, 876 businessmen, 233 teachers, 23 doctors, 578 van pullers, 1,333 services, 169 human hawller's drivers, and 2,091 others . Average income per capita per diem was Taka 200 (equivalent to US$ 2.5).

Fishermen's livelihood

Fishermen's livelihood depends mainly on fishing activities including fishing, fish processing, and fish marketing. For the preparation of fishing, they need capital for purchasing fishing implements and maintenance of the existing ones. Eight units of fishermen groups are living in the vicinity of water bodies; 1) Dulai Natun-para Mathsayjibi Shamity, 2) Char Gobindapur Khara-para Matshyajibi Shamity, 3) Char Dulai Matshyajibi Shamity, 4) Char Boalia Matshyajibi Shamity, 5) Syedpur Matshyajibi Shamity, 6) Rani Nagar Matshyajibi Shamity, 7) Badai Matshyajibi Shamity, and 8) Sharirvita Matshyajibi Shamity. The fishermen units each consist of about 30 members. Fishing was usually done once a day and preferably at night. Average duration of fishing was normally eight hours using local fishing implements. Fishing implements were country nets and other implements (dharma jal, jhaki jal, vashal jal, fansh jal, charo, and so forth). Due to lack of available fish, the yield was low (30 kg/day) and the average fishing yield/day was 600 kg in the study area, which gives about 108 000 kg of fish a year when fishing every second day.

Capital

The main source of capital is a loan from Mahajon or an NGO's credit. In case of the Mahajoni loan, they have to repay with high interest and within a short time. But in case of an NGO loan, they can wait for some time before repaying. The maximum loan is normally not enough for them, though NGO charges lower interest than Mahajon.

Marketing opportunity

The fishermen groups in the study area are using local markets for fish marketing. Individual fishermen often sell their fish in the local bazaar or to the community in the villages.

Ownership of fishing implements

The fishermen rely heavily on local /indigenous fishing equipment, including several types of nets,

traps, and others. Most equipment belongs to them, made by threads, bamboo, and other local resources**.**

Fishing practices

Fishermen in rural Bangladesh usually live in a community in the vicinity of water bodies. They cooperate closely among themselves in all sorts of social and livelihood activities. Most of the fishermen are primarily dependent on fishing. They use simple and traditional fishing equipment. For fishing in the inland waters the fishermen use non-motorised boats and traditional nets. The only touch of modern technology is the recent use of nylon nets. The practice of fishing may be an activity of an individual or a group of fishermen, but fishing equipment is normally owned by an individual and not by the group. The income from fishing is different, not only in accordance with the types of fishing practices, but also with the various seasons. The income level among the fishermen is differentially distributed. Thus, many fishermen have neither the possibility nor the capacity of improving their position. The life of fishermen in Bangladesh has changed gradually. Due to the decline of fishing grounds and fishery resources, members of the fishing communities have started to leave their traditional occupation in search of other jobs.

Sampling and data collection

A survey of the given areas was carried out over a period of three months from March to June 2010. A total of 70 semi-structured and open structured questionnaires were administered randomly to adult males and females. The participants were selected randomly, and completion of questionnaires was facilitated through 'face-to-face' communication tools. The questionnaire included socio-demographic variables and a set of open-ended questions related to perceptions of respondents towards the loss of wetland biodiversity (Box 1).

Box 1. *Questions presented to respondents to assess their perceptions of declining wetland biodiversity.*

1. What are the resources (fish, animals, and crops) available in your area and what is the present state of the wetlands?
2. What are the common problems in your area, especially for wetland issues and livelihood issues?
3. What are the major causes of wetland biodiversity loss in particular with fish resources and how will it is improved?
4. What can be done to involve women in wetland biodiversity conservation?
5. Which type of assistance do you need for appropriate wetland biodiversity management?

Data analyses

Data were analysed using SPSS Version 16.0 (SPSS, Chicago, IL, USA). In this study, perceptions were related to level of occupation. The significance level was set at $p < 0.05$. Differences between perceptions were tested using Pearson's chi-square (χ^2) test.

Results

Available wetland in the study areas

There were about 33 water bodies in the study area (Table 1). These water bodies include rivers, canals, beels, and burrow pits. The ownership of these water bodies/wetlands are of two types (khas and private). Lease systems prevail in the study area. Khas wetlands are managed by lease-delineating terms and conditions. Almost every water body has a connection point with others. All wetlands/ water bodies (including river, khal, beel, and canal) are silted and lacking from storing of water during the dry season.

Present status of wetland biodiversity

There are several species of fish, aquatic plants, and crops were identified across the study areas (Table 2). Five types of rice, 11 of vegetables, 3 of pulse, 2 of oils, and 2 of spices were recorded in the typical wetland and three types of cropping patterns (i.e., single cropping, double cropping, and multiple cropping) were observed across the study areas. The farmers were normally growing monocrops followed by single-, and to some degree, double-cropping patterns. As a result, a vast area remains uncultivated during floods and, even in summer, due to flood and drought, respectively. Common fish species are found in local varieties of chapila (*Gudusia chapra*), bhedha (*Nandus nandus*), baila (*Awaous grammepomus*), kajuli (*Ailia koila*), taki (*Channa punctata*), tengra (*Mystus bleekeri*), boal (*Wallago attu*), katol (*Catla catla*), batashi (*Neotrpius athrinoides*), mrigel (*Cirrhinus cirrhosus*), gojar (*Channa marulius*), baim (*Mastacembelus armatus*), tara baim (*Macrognathus aceuleatus*), shol (*Channa striata*), mola (*Amblypharyngodon mola*), chanda (*Parambassia ranga*), darkina (*Esomus danricus*), kakila (*Xenentodon cancila*), koi (*Pseudosphromenus cupanus*), punti (*Punitus sarana*), chela (*Salmostoma acinaces*), air (*Sperata aor*), gang tengra (*Gogangra viridescens*), magur (*Plotosus canjus*), gutum (*Lenidocenhalichthys guntea*), potka (*Cheledon Patoka*), gulsha (*Nangra nangra*), ritha (*Rita rita*), and kholisa (*Colisa fasciatus*). Common aquatic plants found in the wetland areas are: *Pistia stratiotes* (topapana), *Salvania natans(tetul pana), Potamogeton crispus* (keorali), *Aponogeton echinatus* (ghechu), *Nymphaea nouchali* (padma), *Trapa*

Table 1 *Available wetlands in the study area.*

	Name	Area (ha)	Legal	Own	Lease period	Union	Type	Connectivity
01	Atrai	20.28	K[1]	G[3]	N/A	Dulai, Ahmedpur, Rani Nagar	River	Isamoty River
02	Atrai Borpit	8.11	K	G	N/A	Dulai, Ahammadpur,	Borpit	No Connectivity
03	Jiel Gari	-	P[2]	P	N/A	Ahammadpur	Beel	Badai River
04	Boro Beel	-	K	L[4]	36 months	Rainagar, Hatkhali, Ahmmadpur	Beel	Badai River
05	Bara Sher Jola	1.29	P	P	N/A	Dulai	Segment of a beel	Badai River
06	Kajir Khapa	-	P	P	N/A	Ahmmadpur	Beel	
07	Birahim Pur Baor	-	P	P	N/A	Ahammadpur	Baor	No Connectivity
08	Chalkpatta (putigara)	84	P	P	N/A	Dulai	Beel	Badai River
09	Kata Jola	1.35	P	P	N/A	Dulai	Segment of a beel	Badai River
10	Gorar beel	128.3	K	L	36 months	Dulai	Beel	Badai River
11	Kana Pukur	-	K	NL[5]	N/A	Ahmmadpur	Pond	No connectivity
12	Kolmi gara	-	P	P	N/A	Ahammadpur	Beel	Badai River
13	Mati Kata	7.08	K	L	36 months	Dulai	Beel	Badai River
14	Loher Thali	7.35	K	L	36 months	Dulai	Beel	Badai River
15	Kui bila	2.18	K	L	36 months	Raninagr	Beel	Badai River
16	Bokchor	-	K	L	36 months	Raninagar	Beel	Badai River
17	Boksher Jola	2.47	K	L	36 months	Dulai	Segment of a beel	Badai River
18	Jiai Nodi	-	K	L	36 months	Raninagr	Segment of a beel	Badai River
19	Jomer Thali	4.47	K	L	36 months	Dulai	Beel	Badai River
20	Laxman Thakurer par	-	K	L	36 months	Raninagr	Beel	Badai River
21	Bostaler Jola	-	K	L	36 months	Raninagar	Segment of a beel	Badai River
22	Sona patila	7.07	K	L	36 months	Raningar	Beel	Badai River
23	Lochu Mollar Jola	-	K	NL	N/A	Raninagar	Segment of a beel	Badai River
24	Shuber Beel	-	K	NL	N/A	Raningar	Beel	Badai River
25	Dighir Beel	-	K	NL	N/A	Ahmmadpur, Raninagar	Beel	Badai River
26	Hiron Nodi	-	K	NL	N/A	Raninagar	Segment of a beel	Badai River
27	Are Pother Jola	-	K	NL	N/A	Raninagar	Segment of a beel	Badai river
28	Tepar Beel	-	P	P	N/A	Raninagar	Beel	Badai River
29	Icha Khalir Beel	-	P	P	N/A	Raninagar	Beel	Badai River
30	Shohi baj	3.08	K	L	36 months	Dulai	Beel	Badai River
31	Shanhai	-	P	NL	N/A	Ahmmadpur	Beel	Badai River
32	Nangla khali	9.17	K	NL	N/A	Ahammadpur	Beel	Boalia canal
33	Boalia Canal	-	K	NL	N/A	Ahammadpur	Canal	Dighir Beel

Note: [1] khas land; [2] prvate land; [3] governmental lands; [4] leases, and [5] non-leases.

maximowiczii (paniphal), *Phragmites kakra* (nal khagra), *Polygonum barbatum* (bishkatali), *Barringtonia acutangula* (hijal), *Pongamia pinnata* (koroch), *Ipomea fistolosa* (dhol kolmi), Alternathera sp. (Helencha) *Woffia arrhiza* (Guripana), *Nymphaea* sp. (Lili), bandhshola, motmoti, chechra grass, tuptupigrass, vadal grass, *Trapa natans, Vallisneria* sp., *Potamogeton* sp., *Enhydra* sp., *Utricularia* sp., and *Nymphaea* sp. The terrestrial vegetation includes *Tamarix* sp., *Acacia nilotica, Bombax ceiba, Ficus* sp., *Dendrocalamus* sp., *Melia azadirachta, Calamus* sp., *Borassus flabellifer, Phoenix sylvestris, Musa* sp., and *Ipornoea* sp.

Problems perceived in the study area

Poverty, natural disasters, pollutions, lack of water, and fish are the common features in the study area. All the respondents recognised that poverty is the top priority problem, followed by lack of fish, siltation of beels, chemical pollutions, lack of water, siltation of beel, and natural disasters (drought, flood, and cyclone) are the major problems (Table 3).

Table 2 *Cropping patterns in the wetland.*

	Description
Crop season	*3 seasons (Rabi, Kharif-1 and Kharif -2)*
Major crops	*Rice, vegetables, oil seeds, pulses, spices, wheat, and sugarcane.*
Vegetables	*Ladies finger (okra), cucumber, ridged gourd, bitter gourd, snake gourd, amaranth, brinjal, pumpkin, Indian spinach, taro, wax gourd, spinach, bottle gourd, yard-long bean, bean, tomato, potato, cauliflower, cabbage, kohlrabi, turnip, radish, and carrot.*
Spices	*Ginger, onion, turmeric, and chili.*
Field crops	*Rice, wheat, mustard, potato, and sugarcane.*
Vegetation and aquatic plants	*Kolmilata, water lily, lotus, shewla, dhol kolmi, dol, kuttar jihba, bhatshola, motmoti, hijol, chul shewla, chechre, bhadale, tupri, bil kahe, panifal, hizol tree, koros tree, and rakhal sitka*
Fish	*Sheat, climbing, fry, walking, magur, eel, cat, tatkini, mola, chanda, darika, kakila, mrigal,and kholisha.*
Commercial species	*Crab, tortoise, kasim, frog, and chip.*
Endangered/ threatened species	*Snail, jheenuk, lily, snake, crubs, frog, tepa fish, sharputi, meni, pabda, rani putul, magur, gojar, aeer, chapila, raik, mola, bash pata, batashi, boro ban, kali baush, chitol, foli, and rita.*

Loss of wetland biodiversity

Wetland biodiversity loss is occurring due to a number of factors, and no one is predominant. Threats to biodiversity are numerous and human activities are responsible for most of them. Over-population growth creates crucial threats to biodiversity by over-harvesting, clearing forests, interrupting natural processes, and converting of land for industrial uses. Everyone agreed that population growth is the main reason for wetland biodiversity loss (Table 4).

Conversion of land affects biodiversity for agricultural production, residential and commercial uses; 82.8 % respondents identified that conversion of land for agriculture also leads to wetland biodiversity loss. On the other hand, hunting is another reason of wetland biodiversity loss. Pressure groups have also played a role in accelerating the process of wetland biodiversity loss. Indiscriminate uses of chemicals were responsible for the issue. Construction (i.e., embankment) works created obstacles to enter web-tide water during monsoon, which leads to negative impacts on fisheries, aquatic resources, and agro biodiversity. Climate change is also responsible for wetland biodiversity loss (Table 4).

The number of fish species and volume of fish both are diminishing due to many factors, including lack of water, use of chemicals, fishing broods, use of current jal, lack of awareness, weak enforcement of fishing ACT, and construction of dam/embankment. All respondents mentioned that lack of water around the year is a core cause in diminishing local fish (Table 5). Many factors are diminishing local fish as compared to the past, including indiscriminate use of chemicals, fishing broods, catching of pregnant mother fish, lack of awareness, and use of current *jal* (fishing net), and creation of obstacles in the mouth of water bodies.

Measures for wetland biodiversity restoration

Biological diversity is essential for the survival and balancing of nature and humanity. It provides the basis for improvements of domesticated species maintains functions of ecosystem stores and cycles nutrients essentials for life. Now it is time to think about wetland biodiversity; and to take measures for wetland biodiversity restoration. Many people think differently. In the study 87.1 % of respondents agreed for re-excavation or digging of beels, canals, and other water bodies (Table 6). Other measures, including planting of local varieties, conserving aquatic resources, and declaration of fish sanctuary, were also mentioned by the respondents.

Role of women in wetland biodiversity restoration

It is now widespread known that women are the backbone of agricultural workforce (NRCWA 2004). Women's work is both wide ranging and multi-faceted throughout the year, and they perform multiple tasks in the sphere of agriculture. Women's indigenous knowledge and skills are vitally necessary for wetland biodiversity conservation and restoration; 95.7 % of respondents mentioned that women can play great roles in producing and preserving local seeds for wetland biodiversity conservation (Table 7). On the other hand, they can also play a vital role in creating family awareness, planting trees, and child

Table 3 *Problems in the study area.*

Problems	**Fishermen N (%)**	**Farmers N (%)**	**Women N (%)**	**Elite N (%)**	**All N (%)**
Lack of fish	20 (100)	18 (90)	20 (100)	8 (80)	66 (94.3)
Siltation of the beel	18 (90)	20 (100)	16 (80)	7 (70)	61 (87.1)
Lack of water round the year	17 (85)	16 (80)	19 (95)	10 (100)	62 (88.6)
Pollution by using chemicals	20 (100)	17 (85)	18 (90)	10 (100)	65 (92.9)
Disaster(Drought, flood, and cyclone)	20 (100)	15 (75)	10 (50)	5 (50)	50 (71.4)
Poverty	20 (100)	20 (100)	20 (100)	10 (100)	70 (100)

Table 4 *Causes of wetland biodiversity loss.*

Causes	Fishermen N (%)	Farmers N (%)	Women N (%)	Elite N (%)	All N (%)
Population growth	20 (100)	20 (100)	20 (100)	10 (100)	70 (100)
Climate change	19 (95)	17 (85)	11 (55)	7 (70)	54 (77.1)
Conversion of land for agriculture	20 (100)	10 (50)	18 (90)	10 (100)	58 (82.9)
Hunting of birds	15 (75)	11 (55)	10 (50)	8 (80)	44 (62.9)
Encroachment by pressure group	20 (100)	14 (70)	-	5 (50)	39 (55.7)
Indiscriminate uses of chemicals	20 (100)	12 (60)	17 (85)	10 (100)	59 (84.3)
Desertification	14 (70)	18 (90)	11 (55)	8 (80)	51 (72.9)
Embankment	20 (100)	10 (50)	9 (45)	7 (70)	46 (65.7)

Table 5 *Major causes for diminishing local fishes.*

Causes	Fishermen N (%)	Farmers N (%)	Women N (%)	Elite N (%)	All N (%)
Lack of water around the year	20 (100)	20 (100)	20 (100)	10 (100)	70 (100)
Fishing through drying of beel	19 (95)	15 (75)	16 (80)	6 (60)	56 (80)
Chemicals use in fishing	18 (90)	16 (80)	19 (95)	7 (70)	60 (85.7)
Fishing broods	20 (100)	20 (100)	19 (95)	8 (80)	67 (95.7)
Lack of awareness	15 (75)	15 (75)	11 (55)	7 (70)	48 (68.6)
Use of current jal	18 (90)	14 (70)	14 (70)	8 (80)	54 (77.1)
Fishing of mother fishes	20 (100)	18 (90)	17 (85)	9 (90)	64 (91.4)
Obstacle in entering water	19 (95)	14 (70)	10 (50)	6 (60)	49 (70)
Disobey the fishing ACT	14 (70)	10 (50)	-	7 (70)	31 (44.3)

Table 6 *Measures for wetland biodiversity restoration.*

Measures	Fishermen N (%)	Farmers N (%)	Women N (%)	Elite N (%)	All N (%)
Re-excavation of beel/water bodies	20 (100)	16 (80)	15 (75)	10 (100)	61 (87.1)
Planting of local variety	19 (95)	20 (100)	10 (50)	9 (90)	58 (82.9)
Conserving aquatic resources	20 (100)	20 (100)	10 (50)	10 (100)	60 (85.7)
Declaration fish sanctuary	15 (75)	15 (75)	-	5 (50)	35 (50)

education on wetland biodiversity.

Support need

Overall, 70 % of respondents mentioned that they need training in seed production and preservation, followed by cultivation, nursery, small trade, and training in modern technology including information systems (Table 8). Greater awareness is crucial for ensuring the sustainable management of wetlands. Everyone should have to play a role in conserving wetland biodiversity. Both coping with adaptation and improvement measures are required for wetland biodiversity conservation.

Discussion

Wetlands provide habitats for a variety of resident and migratory birds, and a large number of commercially important birds. Wetlands are the most fertile and productive ecosystems and important breeding grounds for birds and growing areas for fisheries. Millions of people depend on the wetland resources for their livelihoods, but, paradoxically, wetlands have been labelled as wastelands associated with disease and difficulty in management. Wetlands have therefore been ignored for ages. Numerous development interventions like constructing embankments, dams, hydraulic structures, roads, and so forth, have been going on since the 1960s for the country's economic development, particularly for increased agriculture production and improved road communication. The unplanned development interventions, as mentioned above, have led to a wide range of damage and extinction of the wetland ecology and resources causing significant negative impacts on the livelihoods. Bangladesh has traditionally been rich in fish stocks. The inland fisheries system is estimated to contribute almost 73 % of the total production and supplies 80 % of the country's animal protein requirements (Khan *et al.* 2009). According to Wood (1994), the experience with group access to water bodies has revealed the presence of other vested interest. Similar findings were found in the study area, many people have created fictitious groups in order to gain access to fishing rights.

Ahmed *et al.* (2008) reported that fisheries and agriculture are the two major livelihoods for local people living in and around wetlands, while other livelihood supports are provided by cattle grazing. Despite all these support to human livelihoods, many parts of the world have experienced loss or degradation of wetlands on a massive scale, because of agricultural use, urbanisation, and excessive exploitation by local population (Karim 1993)**.** In Bangladesh, where inland water bodies constitute nearly 50 % of total land area (Khan *et al.* 1994), wetlands are critical to

Table 7 *Role of women in wetland biodiversity restoration.*

Activity	Fishermen N (%)	Farmers N (%)	Women N (%)	Elite N (%)	All N (%)
Raising family awareness	20 (100)	10 (50)	15 (75)	8 (80)	53 (75.7)
Planting trees	15 (75)	20 (100)	10 (50)	7 (70)	52 (74.3)
Child education on biodiversity	10 (50)	11 (55)	5 (25)	9 (90)	35 (50)
Producing & preserving local seeds	20 (100)	19 (95)	18 (90)	10 (100)	67 (95.7)

Table 8 *Training required.*

Training	Fishermen N (%)	Farmers N (%)	Women N (%)	Elite N (%)	All N (%)
Training in cultivation	10 (50)	20 (100)	11 (55)	7 (70)	48 (68.6)
Training in nursery	8 (40)	15 (75)	16 (80)	8 (80)	47 (67.1)
Training in seed preservation	11 (55)	11 (55)	18 (90)	9 (90)	49 (70)
Training in modern technology	11 (55)	5 (25)	3 (15)	5 (50)	24 (34.3)
Training in small trade	10 (50)	9 (45)	5 (25)	6 (60)	30 (42.9)

economic development and environmental improvement. The major role of wetlands are nutrient retention/removal, support for food chains, fisheries production, habitat for wildlife, recreation, natural heritage values, biomass production, water transport, biodiversity preservation, and micro-climate stabilisation (Dugan 1990). The wetland environment unites the inhabitants into a society, which has a definite shape, culture, and livelihood pattern. Over-exploitation of aquatic resources, destruction of habitats, unwise use of agrochemicals, land use conflict and conversion of land, and construction of embankment and sluice gates are the major threats to wetland biodiversity. Recently, capture fish production has declined to about 50 %, with a negative trend of 1.24 %/year (Ahmed 1995). The popular and abundant local fish species have declined drastically due to the negative impact of wetland biodiversity loss.

Conclusion and Recommendations

Wetland biodiversity provides food, shelter, habitats, and services to a greater extent and it is crucial for the survival and balance of nature and human welfare. Wetland resources and diversity form the basis of Bangladesh economy. The country's fisheries and agriculture, along with a number of aquatic resources, are supporting community livelihoods. Wetlands can play vital role by providing support for floating agriculture during flood season. People's active participation can secure wetland restoration. Nishat (1993) pointed out that the degradation of wetlands in Bangladesh were mainly due to: increase of population and expansion of human habitats; expansion of agriculture, and subsequent conversion of wetlands through drainage into rice fields; flood control and irrigation project for enhancement of agricultural productivity. Similar observation was found in my study. Participatory wetland resource management or initiatives might save wetland biodiversity and aquatic resources. It is the critical time for wetland conservation and we need to undertake appropriate steps for its better management.

The pollution problems frequently initiate from use of pesticides, and overdose and untimely application of fertilizers, and from domestic wastes. All the rivers flowing through Bangladesh originate outside the country and these carry heavy loads of silt, sediments and other debris, including domestic, agrochemical and industrial wastes, from far-away places.

The following recommendations may consider for next steps planning:

Policy – level recommendations

1. public-private partnership co-management may restore wetland biodiversity and can reduce further degradation of wetland biodiversity,
2. the critical wetland zones need to be declared as fish sanctuaries,
3. enforcement of fishing Act,
4. need advocacy programme for wetland biodiversity restoration at national level, and
5. need to ensure community participation in wetlands management.

Research – level recommendation

The following study will help in the potential field of wetland biodiversity:

1. study of breeding status of endangered and threatened local fish species,
2. study of natural food availability for local fish species, and
3. study of impacts of agro-chemicals on aquatic resources.

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Chapter 8: Diversity of Finfish and Shellfish of the River Halda with Notes on Their Conservation

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Abstract

Biodiversity of fin-fish and shell-fish species in three sections of Halda River, Bangladesh were investigated for two years from January 2007 to December 2008. Proportion of average daily catch (in number) was used to obtain the diversity indices. Simpson index of diversity (D) (0.54 - 0.66), Shannon index (H) (0.25 - 0.32) (re-scaled), and Evenness (E) (0.27 - 0.35) were calculated for fin fishes and shell fishes for 3 sections covering 39 km of the river. A total of 1017 catch samples of 34 different types of gear were analysed. Species richness (S) was observed to be 92 (83 fin-fish, 9 prawn), belonging to 14 orders, 37 families, and 71 genera including 3 exotic species over the studied area. Maximum number of species were recorded under the family Cyprinidae (19 species) followed by the family Gobiidae (11 species). Fin-fish species richness (FSR) in this study was 83, which was higher than earlier records. The actual total fin-fish and shell- fish species richness including the previous records was found to be 120 (106 fin-fish, 14 prawn), which is much higher than some larger river systems of Asia. Species richness was higher downstream (71 and 83 species) then mid (67 and 72 species), and upstream (61 and 69 species) for the years 2007 and 2008 respectively. ANOVA showed no significant difference between the populations of two years ($F = 0.0025$, $df = 1$ and 47, $p > 0.05$) and among the populations of three sections ($F = 0.0008$, $df = 2$ and 47, $p > 0.05$).Three critically-endangered, nine endangered, and eight vulnerable fish species (as in IUCN 2000) were observed in the population. Strong dominance was observed for *Corica soborna* (55.1 %) followed by *Macrobrachium rosenbergii* (19.2 %), *Setipinna phasa* (11.8 %), *Glossogobius giuris* (6.9 %), and *Macrobrachium villosimanus* (2 %). Three exotic species comprised less than 0.001 % of the population. Suggestions are provided for protection, conservation, and sustainable yield of the fish population of Halda River.

Keywords; *finfish, shellfish, biodiversity, conservation, Halda river*

Introduction

The River Halda (22°54′ N and 91°48′ E to 22°24′ N and 91°53′ E) originates in the hilly streams of Khagrachari district and flows through the Fatickchari, Hathazari, and Rouzan of Chittagong districts covering 88 km and then meets the River Karnaphuly, which after traversing 20 km empties into the Bay of Bengal. Tidal influence reaches about 40 km upstream in the Halda River from its mouth. From immemorial time the River Halda has been the richest natural spawning ground of four species of Indian major carp (*Catla catla, Labeo rohita*, *Cirrhinus mrigala,* and *Labeo calbasu*). This is the only tidal river of Bangladesh from which naturally-produced fertilised eggs of major carps are collected and hatched in the mud-made scoop on the river bank and has long been the source of naturally-produced carp fry for country's pond culture (Azadi 1979; Azadi 1983; Azadi 2004; Patra & Azadi 1985a; Patra & Azadi 1985b). The river is also one of the major sources of brood and PL (post-larvae) of giant freshwater shrimp (*Macrobrachium rosenbergii*). A rich assemblage of marine, estuarine, riverine, floodplain, and migratory fin fish and shell fish inhabit Halda River. Besides fisheries there are multiple uses of this river i.e., irrigation, navigation, sand collection, and drinking water supply to the Chittagong city dwellers. The river is fed by several hilly streams starting from its origin, including 12 important tributaries located in the lower region (downstream) of this river, where four spawning grounds of major carps are situated (Azadi 2004).

During 1975-76 and 1982-1983, 12 major tributaries in the lower River Halda were blocked by sluice gates and 47 km embankment was made by the Bangladesh Water Development Board for irrigation and flood control. Since 1948 five major oxbow bends (spawning ground of major carps) of the river were lost, due to making the river straight by loop cutting by local people to protect their homesteads from destruction by severe erosion. The impact of this habitat alteration was observed in the severe decline in major carp fry production from 2470 kg in 1945 to 20 kg in 2004 (Khan & Azadi 2006).

Information and status of biodiversity of any aquatic or terrestrial bodies are essential for formulating proper management policy, but no detailed works were found on the biodiversity of Halda River, except a short study of fishes of Halda by Rainboth (1978) and some research on biodiversity of other inland waters of Bangladesh

Table 1 *Location and size of the study area.*

	Section 1 (S_1)	Section 2 (S_2)	Section 3 (S_3)	Total study area
Location	**Upstream**	**Midstream**	**Downstream**	**Halda River**
Length (km)	20	10	9	39
Area (m^2)	135	94.5	121.5	351
Average width (m)	67.5	94.5	135	
Distance from Sea (km)	45	35	26	65 (up to upstream)

(Azhar *et al.* 2007; Sarker *et al.* 2008; Zafar *et al.* 2007). Some research, however, on limnology, plankton ecology, management of spawning and spawn fishery and restoration of spawning habitats of major carps were done by different authors (Azadi 1979; Azadi 1983; Azadi 1985; Azadi 2004; Khan & Azadi 2006; Patra & Azadi 1984; Patra & Azadi 1985a; Patra & Azadi 1985b; Patra & Azadi 1987; Tsai *et al.* 1981). During 2007 the Bangladesh government has undertaken a project on the restoration of the natural breeding habitats of the Halda River emphasising only the spawn fishery of the river. This study was undertaken to know the diversity and abundance of fin fish and shell fish of the river Halda and to provide suggestions for their conservation.

Methods

Diversity and abundance of fin fish and shell fish of the River Halda were studied by fortnightly sampling and survey for two years from January 2007 to December 2008. The River area was divided into three sections i.e. upstream (S_1), midstream (S_2), and downstream (S_3) (Table 1, Figure 1) to see any differences and variation in the abundance and distribution of species among the different sections.

A total of 1017 catch samples were collected from 34 types of gear, including hand picking. All professional, subsistence, recreational, occasional and illegal fishing gears used by day and night in the study area were monitored. Catch composition in respect of species and numbers were recorded.

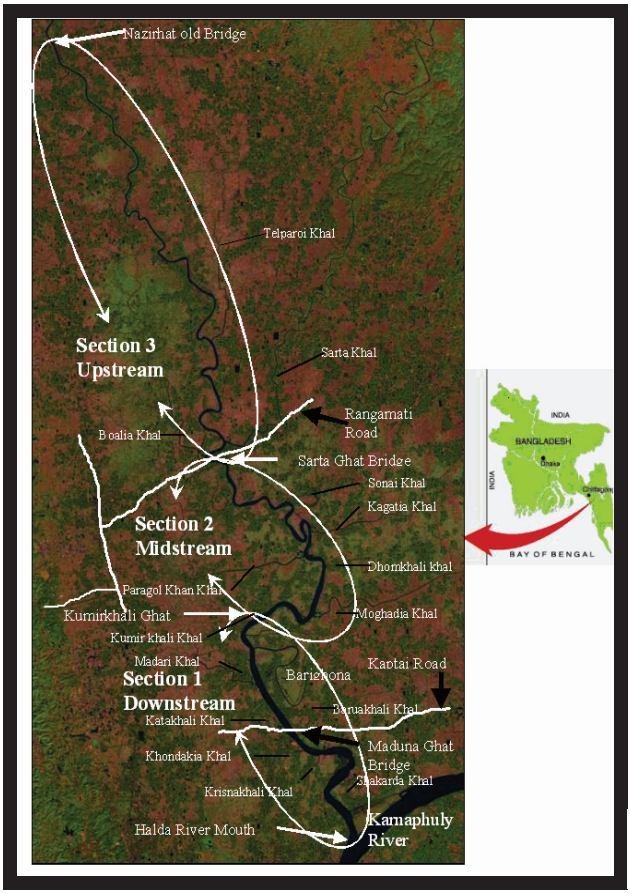

Figure 1 *River Halda showing the three sampling sections.*

Sum of average daily catch (in number of fish) by all gears were used for obtaining the proportion of different fish species. Abundance was estimated using the proportion of species (Table 2).

Table 2 *Population size and corresponding marks used to measure abundance.*

Size of population for an individual species	Mark	Abundance
More than 50 % of the population (½)	A++	Very common
More than 1 per 10 (1/10)	A+	Common
More than 1 per hundred (1/100)	A	Less common
More than 1 per thousand (1/1000)	B+	Moderate
More than 1 per 10 thousand (1/10000)	B	Few
More than 1 per 100 thousand (lakh) (1/100000)	C+	Very few
More than 1 per million (1/1000000)	C	Rare
More than 1 per 10 million (1/10000000)	D+	Very rare
Less than 1 per 10 million (1/100000000)	D	Very very rare

The total daily catch (Y_d) was obtained using the formula 1 of de Graff and Chinh (1992);

$$Y_d = \sum_g \overline{CPUE}_g \times \overline{f}_g \quad \text{---------- (1)}$$

Where, Y_d = total daily catch, $CPUE_g$ = daily mean catch per unit effort for gear, and f_g = mean effort (gears/day). Diversity was measured by the number of species (species richness-S), and by using the three indices, viz. Simpson (D) (Simpson 1949), Shannon (H), and species evenness (E) (Shannon & Weaver 1949; Wolda 1983) with the help of formulae 2 - 5:

Species richness (S) = Number of species in a given area----------(2)

Simpson index (D) = $\sum (Pi)^2$ ---------- (3)

Where *Pi*, is the proportion (n/N) of i^{th} species in the sample; *n*, is the total number of individual of a particular species and *N*, is the total number of individual of all species.

Shannon index (H) = - $\sum$ (Pi lnPi) ---------- (4)

Evenness (E) = H/ ln S ---------- (5)

Simpson index (D) (3) and Shannon index (H) (4) were rescaled from 0 to 1 (Odum 1980). ANOVA (three-way) was done to determine the variation in the population (%) of top ten species among three studied sections and between years (2007 and 2008). The *t* - test was done to find out the variation in Shannon index (H) (rescaled) between the three sections and between two years.

Results

Species composition and abundance in different sections

The species composition and abundances of fishery organisms (fin fishes and prawns) in different sections as well as in total study area for the year 2007 and 2008 (Table 3) shows that during the year 2007 there were 54 fin-fish species, and 7 species of prawn in upstream (S_1); 59 species of fin-fish and 8 species of prawn in midstream (S_2) and 63 species of fin fish and 8 species of prawn in downstream (S_3). In the year 2008 the species composition was found to be 60 fin-fish, and 9 prawns in upstream (S_1); 63 fin fish and 9 prawns in midstream (S_2) and 74 fin fish and 9 prawns in downstream (S_3). In the 39 km study area a total of 74 fin fishes and 8 prawn species were observed during 2007 whereas 80 fin fishes and 9 prawn species were observed during 2008. Thus, during two years of study a total of 92 fishery species were recorded, among which 83 fin fish and 9 were prawn, belonging to 14 orders, 37 families, and 71 genera, including 3 exotic fin fish species over the total area studied. Maximum number of species was recorded for the family Cyprinidae (19 species) followed by the family Gobiidae (11 species).

The proportion of different species in the population was uneven with a great difference from 0.00000004 (0.000004 %) to 0.55 (55 %). *Corica soborna* was the most dominant species in all the three locations. It constituted about 55 % of the total population. The population of the top ten species showed also remarkable differences (Table 4). ANOVA showed highly-significant differences between the populations of the top ten species ($F = 50.63$, $df = 9$ and 47, $p < 0.01$). *Corica soborna* (55.1 %), *Macrobrachium rosenbergii* (19.2 %), *Setipinna phasa* (11.8 %), *Glossogobius giuris* (6.9 %) and *Macrobrachium villosimanous* (2 %) were the most dominant species. Combined data for the two-year period showed that the remaining 82 species, other than the top ten, comprised only 1.7 % of the total population. Three exotic species *Aristichthys nobilis*, *Hypophthalmichthys molitrix,* and *Oreochromis niloticus* comprised only 0.001 % of the total population. *Anguilla bengalensis bengalensis* and *Moringua macrocephalus* were very rare in the population, with 0.000005 % and 0.000004 %, which was less than one individual/ten million of population.

Population structure on the basis of habitat preference

The population structure on the basis of habitat preference is shown in Table 5. Riverine fish showed the highest population, followed by freshwater riverine prawn, estuarine fin fish, and wide freshwater fin fish. There were only three

Table 3 *Species composition and abundance of different fishery species in the river Halda. [S_1=Section-1 (upstream), S_2=Section-2 (midstream), and S_3=Section-3 (downstream)](A++=Very common, A+ = Common, A = Less common, B+= Moderate, B = Few, C+ = Very few, C= Rare, D+ = Very rare, and D = Very very rare).*

Sl.	Species Name	S_1	S_2	S_3	S_1	S_2	S_3	Total study area	Total study area	Halda
			2007			2008		2007	2008	Combined (%)
1	*Anguilla bengalensis bengalensis*						D+		D	0.000005
2	*Moringua raitaborua*	C	C+	C+	C+			C+	C+	0.0027
3	*Moringua macrocephalus*						D+		D	0.000004
4	*Pisodonophis boro*	C+	C+	B	C	C+	C+	B	C+	0.008
5	*Corica soborna*	A++	A++	A++	A++	A+	A++	A++	A++	55.14
6	*Gudusia chapra*	B	B	B+	B+	B+	B+	B+	B+	0.35
7	*Tenualosa ilisha*	C+	C+	B	B	B	B+	B	B	0.047
8	*Setipinna phasa*	A	A	A+	A+	A	A+	A	A+	11.83
9	*Notopterus notopterus*					C	D+		C	0.00006
10	*Labeo ariza*	C		D+	D+		C	D+	C	0.00008
11	*Labeo calbasu*	C+	C	C	C+	C+	C+	C	C+	0.00101
12	*Labeo gonius*	C	C	C		D+		C	D	0.00014
13	*Labeo rohita*	C+	C+	C+	C+	C+	C+	C+	C+	0.00178
14	*Catla catla*	C+	C+	C+	C+	C+	C	C+	C+	0.00173
15	*Cirrhinus mrigala*	B	B	C+	C+	C+	C+	C+	C+	0.008
16	*Aristichthys nobilis*			C	C	C	C+	C	C	0.00061
17	*Hypophthalmichthys molitrix*			C			D+	D+	D+	0.00004
18	*Amblypharyngodon mola*	C+	C+	C+	C+	C+	C+	C+	C+	0.0059
19	*Chela laubuca*			C+	C	C	C	C+	C	0.00121
20	*Crossocheilus latius*		C+	C		C+	C+	C+	C+	0.0025
21	*Osteobrama cotio cotio*	C	C	C	C	C	C	C	C	0.00058
22	*Puntius sophore*	C+	B	B	B	B	C+	B	B	0.016
23	*Puntius ticto*	B+	B+	C+	C+	C+	C+	B	C+	0.035
24	*Puntius gelius*		B+		C+	B	B	B	B	0.021
25	*Puntius conchonius*		C+		C+		D+	C+	C	0.00084
26	*Rasbora rasbora*			C	C	C	C	C	C	0.00031
27	*Salmostoma bacaila*	B+	B+	B	B	B+	B+	B	B+	0.10
28	*Salmostoma phulo*	B+	B	B	B+	B	B	B	B	0.083
29	*Lepidocephalichthys guntea*	C			C		D+	C	C	0.00013
30	*Sperata aor*	B	B	B	B	C+	B	B	B	0.031
31	*Mystus cavasius*	B	C+	C	C+	B	C+	C+	C+	0.0059
32	*Mystus gulio*	C		C			D+	C	D+	0.00010
33	*Mystus vittatus*	D+			D+	D+	D+	D+	D+	0.000037
34	*Clarias batrachus*		D+			C		D	D+	0.00004
35	*Heteropneustes fossilis*				C	C+			C	0.00026
36	*Pangasius pangasius*	D+			C	C	C	D+	C	0.00023
37	*Ailia coila*	B	B	B	B	B	B	B	B	0.055
38	*Clupisoma garua*	C+	B	C+	C+	C+	C	C+	C+	0.0035
39	*Eutropiichthys murius*	C+	C+	C	C+	C+	C+	C+	C+	0.0022
40	*Eutropiichthys vacha*	B	C+	C+	C+	C+	C+	C+	C+	0.0061
41	*Neotropius atherinoides*	C	C		C	C	C	C	C	0.00049
42	*Ompok pabda*	B	C+	C	C+	C	C+	C+	C+	0.0020
43	*Wallago attu*	C+	C	D+	C+	C	D+	C	C	0.00068
44	*Oryzias dancena*	B+	B+	B	B+	B+	B+	B	B+	0.17
45	*Hyporhamphus limbatus*		C+	B	B	B+	B+	B	B+	0.10
46	*Xenentodon cancila*	C+	B	C	C+		D+	C+	C	0.0024
47	*Aplocheilus panchax*			D+			C+	D+	C+	0.00159
48	*Microphis cuncalus*	B	C+	B				B		0.008
49	*Chanda nama*	C	C+	C	C+	C	C	C+	C+	0.00103
50	*Parambassis ranga*		C	C	C+	C	C+	C	C+	0.0031
51	*Pseudambassis baculis*						C		C	0.00009
52	*Scatophagus argus*					C	D+		C	0.00014
53	*Johnius coitor*	B	C+	B	B	B+	C+	B	B	0.048

Sl.	Species Name	S_1	S_2	S_3	S_1	S_2	S_3	Total study area 2007	Total study area 2008	Halda Combined (%)
			2007			2008				
54	*Macrospinosa cuja*	B	C+	C+		C+		B	C+	0.0058
55	*Oreochromis niloticus niloticus*		C+			C	D+	C	C	0.00017
56	*Anabas testudineus*		D+			C	C	D+	C	0.00026
57	*Sillaginopsis panijus*	C+	B	B	C+	C	C+	B	C+	0.0077
58	*Glossogobius giuris*	A+	A	A+	B+	B+	B+	A+	B+	6.85
59	*Brachygobius nunus*	C+	C+	B	B+	B+	B	B	B+	0.10
60	*Apocryptes bato*	B+	B+	B+	B+	B+	B+	B+	B+	0.68
61	*Pseudapocryptes elongatus*		C	C			C	C	C	0.00027
62	*Parapocryptes serperaster*					C+	C		C+	0.00071
63	*Oxyurichthys microlepis*		C			B	C+	D+	C+	0.0046
64	*Taenioides cirratus*	B+	B	B+	B+	A	B+	B+	B+	0.56
65	*Odontamblyopus rubicundus*	C+		C+	C+	C+	C+	C+	C+	0.00187
66	*Ophieleotris aporos*	C	C+	C+	C	C+	C+	C+	C+	0.0039
67	*Stigmatogobius sadanundio*	C+	C	C+			C	C+	C	0.00199
68	*Periophthalmodon schlosseri*			C				C		0.00011
69	*Colisa fasciata*				C	C	C+		C	0.00042
70	*Trichogaster chuna*			C+	C	C+	C+	C+	C+	0.0032
71	*Polynemus paradiseus*		C+	D+	C	C	C	C	C	0.00064
72	*Channa orientalis*		B	C				C+		0.00139
73	*Channa punctatus*	C+	C+	C+	C+			C+	C	0.00181
74	*Channa striatus*		C	C	C	C	C	C	C	0.00030
75	*Opisthognathus nigromarginatus*						C		D+	0.000032
76	*Sicamugil cascasia*	C+	B	B	B	B	B	B	B	0.035
77	*Rhinomugil corsula*	C+	B	C+		C	D+	B	C	0.0057
78	*Platycephalus indicus*	B	B	B	C	D+	C	B	C	0.019
79	*Mastacembelus armatus*	C	C+	C	C+	C+	C+	C+	C+	0.0030
80	*Macrognathus pancalus*	D+			C+		C	D	C+	0.00115
81	*Macrognathus aculeatus*	D+		C	D+		D+	C	D+	0.00023
82	*Brachirus orientalis*	B	B	B	B	B	B	B	B	0.023
83	*Cynoglossus cynoglossus*	C+	B	B	C+	B	C+	B	C+	0.013
84	*Macrobrachium villosimanus*	A	A	B+	A	A	A	B+	A	1.99
85	*Macrobrachium rosenbergii*	A+	A+	A+	A+	A+	A	A+	A+	19.17
86	*Macrobrachium malcolmsonii*	B+	A	B+	B+	B+	B+	B+	B+	0.57
87	*Macrobrachium dolicodactylus*	A	B	B	B+	A	B+	B+	A	0.80
88	*Macrobrachium dayanus*	B+	B	B	B	B+	B	B	B+	0.12
89	*Macrobrachium rude*	C+	C+	C+	B	B+	B	C+	B	0.055
90	*Macrobrachium birmanicus*	B	B	B+	B	B	C+	B+	C+	0.054
91	*Macrobrachium mirabilis*		C+	C+	B+	A	A	C+	A	0.76
92	*Metapenaeus monoceros*				B	B	B+		B	0.042
	Total	**61**	**67**	**71**	**69**	**72**	**83**	**82**	**89**	**100**

truly riverine fish in the river Halda, contributing 55.2 % of total population and, except for *C. soborna*, the other two species contributed only 0.1 %. Estuarine fishes showed the third highest population (13.4 %), among which *S. phasa* constituted the major portion (11.8 %).

The percentages of population in respect of order and family are shown in Table 6. The highest percentage of population was found for the order Clupeiformes (67.4 %), followed by Decapoda (23.6 %) and Perciformes (8.3 %); 11 other orders contributed only 0.8 % of the total population.

Table 4 *Percentage of population of top ten species in different sections of the River Halda during the years 2007 and 2008.*

	Species Name	S_1 2007	S_2 2007	S_3 2007	S_1 2008	S_2 2008	S_3 2008	Total study area 2007	Total study area 2008	Total study area 2007 & 2008)
1	*Corica soborna*	50.40	61.89	53.15	52.91	43.45	64.58	54.03	55.59	55.14
2	*Macrobrachium rosenbergii*	17.19	25.80	16.52	22.09	37.92	8.31	17.58	20.09	19.17
3	*Setipinna phasa*	1.02	6.00	12.25	16.65	4.61	18.52	8.44	14.37	11.83
4	*Glossogobius giuris*	24.69	1.59	15.36	0.42	0.81	0.50	15.10	0.57	6.85
5	*Macrobrachium villosimanus*	1.96	1.16	0.23	4.17	3.17	2.10	1.20	3.27	1.99
6	*Macrobrachium dolicodactylus*	1.37	0.03	0.02	0.48	3.13	0.48	0.67	1.00	0.80
7	*Macrobrachium mirabilis*		0.003	0.01	0.34	1.35	1.94	0	1.28	0.76
8	*Apocryptes bato*	0.76	0.91	0.58	0.70	0.47	0.77	0.68	0.68	0.68
9	*Macrobrachium malcolmsonii*	0.77	1.07	0.19	0.38	0.95	0.63	0.62	0.62	0.57
10	*Taeniodes cirratus*	0.48	0.06	0.69	0.40	1.44	0.22	0.52	0.59	0.56
11	Others	1.36	1.48	1.00	1.45	2.69	1.96	1.16	1.95	1.65
	(Species no)	(51)	(57)	(61)	(59)	(62)	(73)	(72)	(79)	(82)

Table 5 *Number of species (S) and percentage of population structure by habitat preference in different sections (S_1, S_2, S_3) of the River Halda during the years 2007 and 2008.*

Habitat preference		S_1 2007	S_2 2007	S_3 2007	S_1 2008	S_2 2008	S_3 2008	Combined
Riverine fin fish	S	3	3	3	3	3	3	3
	%	50.4	62.0	53.2	53.0	43.5	64.7	55.2
Estuarine fin fish	S	20	20	22	16	20	22	26
	%	2.4	7.2	13.8	18.1	7.1	19.7	13.4
Wide freshwater fin fish	S	31	35	36	40	38	43	48
	%	25.6	2.6	15.8	1.2	2.2	1.8	7.8
Fresh water (exotic) fin fish	S		1	2	1	2	3	3
	%		0.001	0.001	0.001	0.001	0.001	0.0008
Catadromous migratory finfish	S						1	1
	%						0.00002	0.000005
Marine finfish	S						2	2
	%						0.0001	0.00004
Freshwater riverine prawn	S	7	8	8	8	8	8	8
	%	21.5	28.2	17.2	27.6	47.11	13.6	23.5
Marine and estuarine prawn	S				1	1	1	1
	%				0.02	0.02	0.14	0.04
Total	**S**	**61**	**67**	**71**	**69**	**72**	**83**	**92**
	%	**100**	**100**	**100**	**100**	**100**	**100**	**100**

The values of different diversity indices are shown in Table 7. Species richness (S) was higher in 2008 than 2007. Species numbers were more downstream (71 and 83 species) than midstream (67 and 72 species) and upstream (61 and 69 species) during the years 2007 and 2008, respectively. Evenness (E) was low in 3 sections with a highest value in midstream during 2008. Values of diversity indices, such as Simpson index of diversity (D) and Shannon diversity index (H) were moderate and highest values were observed midstream during 2008. In the two-year study, although the total species number was higher in 2008, species diversity decreased with the decrease of evenness, but variation of Shannon index (H) (rescaled) between the two study years was found to be insignificant ($t = 0.632$, $df = 2$, $p > 0.05$). ANOVA showed no significant difference between the populations of two years ($F = 0.0025$, $df = 1$ and 47, $p > 0.05$) and among the populations of three sections ($F = 0.0008$, $df = 2$ and 47, $p > 0.05$).

Discussion

Population density

During the two-year study period (2007 and 2008) highest density was recorded for the small clupeids, *C. soborna*, which varied in different proportion in the three sections of the River. Rainboth (1978) also reported highest dominance of *C. soborna* in the River Halda. Dominance of this small clupeid was also reported from the River Pagla

Table 6 *Percentage of population and number of species under different orders and families.*

Sl. No.	Fish Order	Fish Family (Species number)	Common English name	No. of Species	Halda Av (%)	Rank
1	Anguilliformes	Anguillidae (1) Moringuidae (2) Ophichthidae (1)	Eels	4	0.011	10
2	Clupeiformes	Clupeidae (3) Engraulidae (1)	Anchovies, Shades, and Herrings	4	67.36	1
3	Osteoglossiformes	Notopteridae (1)	Feather backs	1	0.0001	14
4	Cypriniformes	Cyprinidae (19) Cobitidae (1)	Carps, Minnows, Barbs, and Loaches	20	0.2801	4
5	Siluriformes	Bagridae (4) Clariidae (1) Heteropneustidae (1) Pangasiidae (1) Schilbeidae (5) Siluridae (2)	Catfishes	14	0.1080	6
6	Beloniformes	Adrianichthyidae (1) Hemiramphidae (1) Belonidae (1)	Gars and Halfbeaks	3	0.27	5
7	Cyprinodontiformes	Aplocheilidae (1)	Top minnows	1	0.0016	13
8	Syngnathiformes	Syngnathidae (1)	Pipe fishes	1	0.008	11
9	Perciformes	Ambassidae (3) Scatophagidae (1) Sciaenidae (2) Cichlidae (1) Anabantidae (1) Sillaginidae (1) Gobiidae (11) Osphronemidae (2) Polynemidae (1) Channidae (3) Opistognathidae (1)	Perches, Snakeheads, and Gobies	27	8.2810	3
10	Mugiliformes	Mugilidae (2)	Mullets	2	0.0405	7
11	Scorpaeniformes	Platycephalidae (1)	Scorpion fishes	1	0.019	9
12	Synbranchiformes	Mastacembelidae (3)	Spiny eels	3	0.0044	12
13	Pleuronectiformes	Soleidae (1) Cynoglossidae (1)	Flatfishes	2	0.036	8
14	Decapoda	Palaemonidae (8) Penaedae (1)	Prawns	9	23.575	2

Table 7 *Species richness (S), Simpson index (D), and Shannon index (H) (rescaled) of finfish and shellfish in the three sections [upstream (S_1), midstream (S_2), and downstream (S_3) of the River Halda.*

	2007				2008				Halda
	S_1	S_2	S_3	*Total area*	S_1	S_2	S_3	*Total area*	*Combined*
S	61	67	71	82	69	72	83	89	92
D	0.65	0.55	0.65	0.643	0.64	0.66	0.54	0.626	0.640
H	0.30	0.25	0.29	0.30	0.29	0.32	0.27	0.30	0.31
E	0.33	0.27	0.32	0.310	0.32	0.35	0.28	0.311	0.319

(Zafar *et al.* 2007) and Kaptai Reservoir (Azadi *et al.* 1992). The second-highest population density was observed for the freshwater giant shrimp, *M. rosenbergii*, proportionately varied in three different sections of the River. Hossain *et al.* (2007) recorded 38.9 % shrimp population in the River Naff, where molluscs and echinoderms were also included in the total population, but Hossain *et al.* (2007) studied the catch from only one gear (set-bag net) in comparison with the catch of 34 gears in this study. Species richness increased with the decrease of distance from river mouth. This showed close similarities with the findings of Raghavan *et al.* (2008) in the river Chalakudy, India.

Impact of sanctuary

During 2007 the declaration of sanctuary (Bangladesh Gazette, 2 July, 2007) of 20-km area from Sarta Ghat Bridge to Maduna Ghat Bridge at downstream (lower Halda) of the river showed its positive impact by increasing the number of fish species during 2008. This showed a close similarity

to the records of different researchers in the newly-established sanctuaries in the different water bodies of Bangladesh (Azhar *et al.* 2007; FAP 2005; Kadir *et al.* 1999; Worldfish-Center 2005). The recent (Bangladesh Gazette, 14 Oct. 2010) extension of earlier declared sanctuary area, however, from Sarta Ghat Bridge to Maduna Ghat Bridge (20 km) to whole fishing area from Nazirhat Old Bridge to Kalurghat Bridge (40 km) seemed to be unscientific and will be detrimental to the livelihood of the local fishermen community. In earlier Gazette Bangladesh Government (2 July, 2007) has declared six months (February to July) a closed season for fishing, which was sufficient to allow the brood fish to migrate easily to the spawning ground, situated between the Sarta Ghat Bridge and Maduna Ghat Bridge. It is also notable that, after declaration of 20-km fish sanctuary, Directorate of Fisheries is facing a great problem to rehabilitate more than 2000 fishermen dependent on fishing within the 20-km sanctuary area, so, it will be devastating on the whole, to be prevented from fishing in the entire Halda river, including a portion of Karnaphully River (Halda Mouth to Kalur Ghat Bridge). Five-months closed season for fishing, and the banning of the detrimental gill and enclosure nets used for major carp fishing and juvenile fishing, are sufficient to protect sustainable stocks of the major carp and other fish species.

Habitat preference

According to habitat preference amongst the 83 fin fish species, 26 fish species were estuarine, 55 were freshwater (Riverine 3, wide freshwater 48, exotic 3, catadromous migratory 1), and 2 were marine fish species. Among the 9 species of prawn, 8 were freshwater and one was marine. Rainboth (1978) reported 48 fin fish apecies and 8 prawn species from the floodplains of Halda and Ichamati Rivers, 23 fish species and 5 prawn species from the upland of Halda and Ichamati Rivers, and 65 fish species and 12 prawn species from the tidal section of the Halda River. Although in this study, fin-fish richness (83) was higher, but prawn species richness (9) was lower compared to Rainboth (1978), which might be due to more sampling areas and much more frequent sampling in three locations of Halda River in this study, whereas the higher number of prawn in earlier records, due to the inclusion of marine species from the market survey.

Threatened species

Of the 83 fin-fish species, 20 species were found to be threatened, where three belonged to the critically-endangered, nine endangered, and eight vulnerable categories according IUCN (2000). The three critically-endangered species were *P. pangasius*, *C. garua*, and *E. vacha*. The nine endangered species were *L. calbasu*, *L. gonius*, *C. laubuca*, *C. latius*, *O. cotio cotio*, *R. rasbora*, *O. pabda*, *S. argus*, and *M. armatus*. The eight vulnerable species were *A. bengalensis bengalensis*, *N. notopterus*, *P. ticto*, *S. aor*, *M. cavasius*, *C. nama*, *P. ranga*, and *C. orientalis*. In the present investigation, however, *S. aor* and *P. ticto* were few, *M. armatus*, *C. garua* and *E. vacha* were very few; other threatened species were rare, very rare or very, very rare. In this study six fin-fish species (*M. macrocephalus*, *L. ariza*, *O. dancena*, *P. elongates*, *O. aporos*, and *O. nigromarginatus*), which were moderate to very very rare, are newly reported from the river Halda, which were not found in the country report of IUCN (2000).

Status and abundance of species composition

Three exotic species (*A. nobilis*, *H. molitrix*, and *O. niloticus*) were found occasionally during May to October, when beels and ponds adjacent to the Halda were flooded. Occasional presence of these three exotic species was very poor and was not threatening for the native species. In some Indian water bodies indigenous fishes were reduced and replaced by the introduced exotic fish (Johal & Tandon 1993; Kar *et al.* 2006).

Among migratory species, *T. ilisha* and *J. coitor* were found throughout the year, whereas coastal *S. panijus*, *P. paradiseus,* and *P. serperaster* were not very common and marine *S. argus* was rare. Juveniles of anadromous migratory *M. cuja* were found in small mesh set-beg net and lift net along with other immature fishes. No adult *M. cuja* was found. Estuarine species *S. phasa* was one of the most commercially-important fishery species, which occupied 11.8 % (this study) of the total catch and was found throughout the year in downstream Halda river. The pelagic fish species *X. cancila* and *H. limbatus* are resident fish of Kaptai Lake (Ahmed & Hasan 1981; Hafizuddin *et al.* 1989) and were found in the Halda river after torrential rain and flood, when the spillway of Kaptai dam at upstream of Karnaphully River was opened to reduce high-water pressure.

Due to the tidal (estuarine) nature of the River Halda, an assemblage of riverine, floodplain, and marine organisms were found, with a great difference in abundance. This dissimilar abundance among the population of different species causes low fin-fish evenness. Some species, such as *C. soborna*, *S. phasa*, *G. giuris*, *A. bato*, and *T. cirratus*, were highly abundant. Most of the species were present with very low abundance. Some species, such as *A. bengalensis bengalensis*, *L. gonius*, *C. batrachus*, *P. pangasius*, and *M. pancalus* were represented by only a few specimens. Some marine fishes entered the estuary occasionally, which varied seasonally depending on tidal flow and lunar periodicity. Marine fish *O. nigromarginatus* was an occasional invader in the river. Fishes of floodplain origin was found in low abundance.

The actual number of Fin-fish species richness (FSR), including previous records (Rainboth 1978), totals 106 species, which is much higher when compared to some larger river systems of Asia, including Irrawady (79 species), Narmada (77 species), Sepik (55 species), and Chalakudy (98 species) (de Silva *et al.* 2007; Raghavan *et al.* 2008).

Exploitation

The CPUA (catch/unit area) in the river Halda was found to be 411.9 and 527.5 kg/ha/year for the years 2007 and 2008, respectively (Azadi & Alam 2011). There was no previous record of CPUA for the river Halda. In the river Meghna the CPUA (1369.6 kg/ha/year) was higher, but in the Padma the CPUA was lower (50.6 kg/ha/year) than the Halda (DOF 1992). Ali & Morris (1977) recorded an average CPUE of 4.2 kg/gear/day (for commercial gear only) in the Halda, which was 2.9 and 3.4 kg/gear/day for the years 2007 and 2008, respectively, in the Halda (Azadi & Alam 2011). Although there was a decline of CPUE in comparison to the previous data of Ali and Morris (1977), it was higher in 2008 then 2007, which might be due to the regulations and sanctuary declaration (over 20 km) during 2007. In Malaysia, fish production in four principal rivers [Rajang (Sarawak, 100 kg/ha/year), Baram (Sarawak, 142-169 kg/ha/year), Gombak (Selangor, 180 kg/ha/year), and Perak (Perak, 11.64 kg/ha/year) (Yap 1992)] were lower than the River Halda.

Conservation measures

Several man-made causes, such as five main loop cutting in the spawning ground of major carp (destruction of oxbow bend) to make the river straight to protect the homesteads from erosion, establishment of 12 sluice gates on 12 big tributaries in the lower Halda during 1976-1983 for irrigation and flood control, which blocked the local movement of fish, and 47-km embankment for flood control closed the heart of the river. Indiscriminate killing of fish by 34 gears, instead of 10 during 1978 (Chong 1979; Khan & Azadi 2006), over fishing and illegal fishing and non- selective fishing by the highly-detrimental enclosure and gill nets decreased fish production alarmingly, which was clearly reflected in the steady decline to the lowest (20 kg) major carp fry production during 2004 from 2470 kg during 1945 (Khan & Azadi 2006). Instead of such destruction of habitat, although commercial fish production decreased tremendously, species richness has yet not decreased, but their population density is not homogeneous, as indicated by different diversity indices. The following measures are suggested to sustain the biodiversity of Halda River:

1. newly-formed oxbow bend (loop) should not be destroyed,
2. most of the sluice gates are not in use and damaged, and should be withdrawn for easy movement of fish,
3. there should be quota and licensing system for fishing,
4. illegal and detrimental gears (i.e., mono-filament enclosure net and gill net, and so forth) should be banned,
5. four rivers (Sangu, Chand Khali, Sikal Baha and Karnaphully) connected to Halda River should also be protected for facilitating the migration of major carp to Halda River for breeding (declaration of closed season for fishing from March to July as per Bangladesh Gazette, 2 July, 2007 should be maintained in those rivers),
6. without treatment no industrial effluents should be drained to the river Halda, and one paper mill established recently near Nandirhat, P.S. Hathazari, should be asked to maintain the treatment plant and only treated water should be allowed to drain into the River Halda.
7. stocking programme should be undertaken for the commercial endangered species. Recently (during 2010, 2011), some major carp fingerlings and sub–adults of Halda origin were stocked in the River Halda, without following the recommendations of Khan and Azadi (2006),
8. there should be a regular vigilance team from the Fisheries department for monitoring all activities by the Government to restore the natural breeding habitat of the river, and
9. mass–awareness programme, through radio, television, and leaflets, should be undertaken to protect and conserve the endangered fishery species of the River Halda.

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Chapter 9: Breeding Ecology of the Bank Myna, *Acridotheres ginginianus* (Latham, 1790), in Chapai Nawabganj, Bangladesh

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Abstract

A study on breeding ecology of the bank myna, *Acridotheres ginginianus* (Latham, 1790), was conducted in Chapai Nawabganj district of Bangladesh between June 2007 and October 2009. The total population in the breeding colonies was estimated to be 4,452. The species mostly made holes in the eroded riverbanks and earth heap of brickfields during February to April and laid eggs during late April to early July. The incubation period was 15 to 19 days (mean 16.6 days ± 1.6, n = 15) and fledging period was 22 to 25 days (mean 23.6 days ± 1.0, n = 14) during the study. Hatching success was recorded as 80.7 % in 2009 and 79.1 % in 2008 and breeding success 61.5 % in 2009 and 61.1 % in 2008 (overall mean 61.4 %), according to the number of eggs laid.

Keywords; *population, breeding ecology, bank myna,* Acridotheres ginginianus*, Chapai Nawabganj.*

Introduction

The bank myna, *Acridotheres ginginianus* (Latham, 1790), is called *Gang-shalik*, *Ram-shalik* or *Shargi* in Bangladesh. The Family Sturnidae contains 148 species in 38 genera worldwide (Siddiqui *et al.* 2008), of which 40 species are present in the Oriental region (Inskipp *et al.* 1996). In the Indian sub–continent the Family comprises 18 species in 12 genera (Baker 1926; Grimmett *et al.* 1998). Bangladesh supports 12 species belonging to 5 genera (Khan 2010; Siddiqui *et al.* 2008).

The bank myna is one of the common birds of Bangladesh (Khan 1982), having grayish-blue feathers with orange orbital skin and prominent orange-yellow patch on wings during flight. It breeds in self-made holes in the broken banks of rivers and large ponds, steep slopes, brickfields, bridge cliffs, heaps of soil or hay, and roosts on trees and farm houses.

No information is available on the breeding biology of this species, but some papers are available on distribution and taxonomy (Grimmett *et al.* 1998; Harvey 1990; Husain 1979; Husain 2003; Inskipp *et al.* 1996; Khan 1982; Rashid 1967; Ripley 1982; Sarker & Sarker 1988; Sibley & Ahlquist 1991; Sibley & Monroe 1990; Sibley & Monroe 1993). The following research on the breeding biology of sturnids has been done in Bangladesh: common myna (*Acridotheres tristis)* and jungle myna (*A. fuscus*) (Rahman & Husain 1988), grey-headed myna (*Sturnus malabaricus*) (Khan 1976), common myna (Hamid 1970), and jungle myna (Rashid 1970), and in other countries: bank myna in India (Khera & Kalsi 1986; Lamba 1981), hill myna (*Gracula religiosa*) in Thailand (Archawranon 2003), Indian myna (*A. tristis*) in Australia (Counsilman 1974a; Counsilman 1974b), common myna and starling (*Sturnus vulgaris*) in Australia (Pell & Tidemann 1997a; Pell & Tidemann 1997b).

Birds play a significant role to control insects, disperse seeds, and pollinate flowers. The bank myna is mainly an insectivorous bird, but also eats other invertebrates and occasionally fruits from trees. It collects insects from cultivated lands, trees and ploughed soils. Knowing the breeding ecology of a species is essential for its role in nature and for its conservation. So an attempt was made to identify breeding habitats, breeding biology, and population size of the bank myna in the study area.

Study area

Chapai Nawabganj District (24º44´ N and 088º12´ E), an area of 1,744.33 km², is bounded by West Bengal of India on the north, south and west. Rajshahi and Naogaon Districts cover the east side. The District comprises five Upazillas: Chapai Nawabganj, Shibganj, Bholahat, Gomastapur, and Nachole. Part of the District lies in Barind Tract and consists of diaras and charland (sandbars develop in river beds). Main rivers of the area are the Ganges, Mahananda, Pagla, Maraganga, and the Punarbhaba. The description of these rivers may be found elsewhere (e.g., Baby 2003; Chowdhury 2003a; Chowdhury 2003b; Taru 2003). These rivers, especially their banks at some places, are important breeding grounds of bank myna.

The study area experiences a tropical monsoon climate, characterised by hot, humid summer and dry, mild cool winter. There are three distinct seasons in Bangladesh (former East Pakistan) (Ahmad 1968): (1) pre-monsoon (hot)- March to May, (2) monsoon (rainy season)- June to October, and (3) winter season (dry)- November to February.

Methods

Breeding colonies of bank myna were searched along the Rivers (Mahananda, Punarbhaba, and Pagla), adjacent roads and brickfields under Chapai Nawabganj District of Bangladesh (Figure 1) during June 2007 to October 2009. Motorised boats

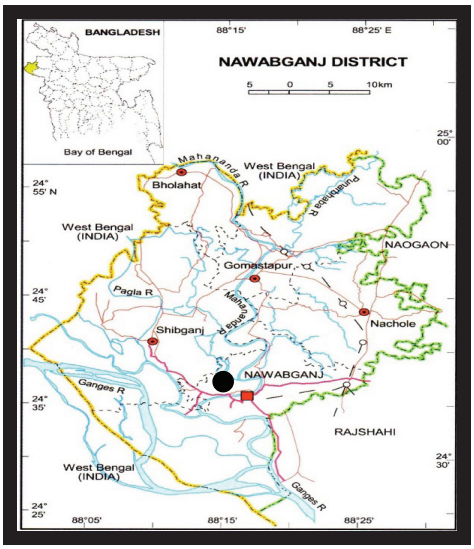

Figure 1 *Map of Chapai Nawabganj (black circle show the study areas). Source: National Encyclopedia of Bangladesh.*

were used to spot the breeding colonies of the bird. Later on, microbus and/or local transport were used to reach to the spots. Local assistants were engaged to collect information on the breeding spots, which we physically verified.

Population count

Population was estimated by transect methods through searching and counting active nests of the bank myna in the aforesaid areas, either on foot, boat, by boat or vehicle. The active nests were identified by seeing the pairs engaged in nest building and/or renovation.

Breeding biology

Twenty of 30 marked nests (e.g., Bar 1 [Barogharia 1], Bar 2, Bal 3 [Baliadanga 3] and so on) were visited on alternate mornings and afternoons to collect information about breeding biology (nest building, egg-laying, egg measurement, incubation, parental care, and feeding). Breeding biology was recorded in two sites: Baliadanga (24°37.238 N, 88°16.229 E) and Barogharia brickfields (24°36.237 N, 88°15.345 E).

Nest measurement

A long stick was pushed into the nest hole to measure the length of the tunnel. Circumference of the nest entrance was defined by a rope, which was then measured. In addition, five nests were dug out by *kodal* (spade) to get the actual shape of the nest tunnel. One long white paper was placed over the dug-out nest tunnel and sketched. Sketched paper drawn by marker was reduced to a suitable size by repeated photocopies.

Nesting materials

Observations on nesting materials were made by collecting them from damaged or broken nests (due to flooding) from Baliadanga, Nakkatitala, and Palsha brickfield sites.

Statistical analysis

Similar data were compared using either t-test or Mann-Whitney U-test depending on the nature of data. Relationships of two correlated samples were computed through Pearson's correlation coefficient. Statistical analysis was done using SPSS version 13.

Results and Discussion

Population

Twenty breeding sites were spotted in the study area, where 45 colonies were found (Table 1). Each

Table 1 *Breeding population of bank myna during July 2008.*

Sl. No.	Breeding site	No. of colony	No. of nest	Population
01	Kalupur	2	500	1,000
02	Chowdala	2	50	100
03	Ranibari Chandpur	3	60	120
04	Nayadiari	2	450	900
05	Fatepur	5	300	600
06	Mohipur	3	80	160
07	Sarjan	1	15	30
08	Poladanga	1	10	20
09	Raninagar	1	60	120
10	Nakkatitala	4	150	300
11	Moheshpur	1	60	120
12	Boliharpur	1	50	100
13	Baliadanga	1	150	300
14	Baroghoria brickfields	4	150	300
15	Palsha brickfields	1	15	30
16	Other brickfields	2	40	80
17	Mokarampur	1	10	20
18	Ramdasghat, Kazigram	1	20	40
19	Diyar	5	40	80
20	Pond banks (Ranibari, Nayadiary)	4	16	32
	Total	**45**	**2,226**	**4,452**
	Other		**274**	**548 = 5,000**

colony supported 10 to 500 pairs, whereas Baker (1926) reported from a dozen to 40 pairs. Two birds per nest or hole in 2,226 active nests gives a total of 4,452 birds and there might be some missing pairs whose nests could not be located. Thus, the total population of the species in the study area was estimated to be around 5,000.

Habitat analysis

Bank mynas come to breeding places and select nesting sites mostly near human habitations, where foods are available in the cultivated fields and homestead gardens. They nested in: (1) broken/steep riverbank, (2) soil heap or ditch-wall of brickfield, (3) holes in the culverts, (4) walls of man-made ditches, (5) water seeping holes of the walls along the rivers, (6) man-made soil heaps for use in other purposes, and (7) hay-heaps. The breeding habitat of the bank myna is riverbank, particularly under culverts and bridges (Rahman 2008); banks of the rivers, brick kilns, bridges (Feare & Craig 1998); banks of rivers, sides of disused brick kilns, ketch walls, and masonry bridges (Ali & Ripley 1983).

Sex recognition

Males and females look alike (Rahman 2008), in fact they are both monomorphic and monochromatic, but the male is slightly slimmer and smaller than the female.

Mating

Mating of bank mynas was observed on two mornings (0600 to 0800 h) in February 2009. It is a short ceremony when male and female sat closely for 2-3 minutes, male stretched his wings and soon jumped up in the air and mounted the female then bending his tail, brought his cloaca into the female and completed mating.

Breeding season

The breeding season of the bank myna spreads from February to July, during 2008 and 2009, but it varied in different parts of Chapai Nawabganj; for instance, at Baliadanga area, it was from December 2007 to July 2008. The breeding season may begin earlier depending on environmental conditions, such as heavy rainfall, flood, drought, temperature, and humidity, of which heavy rainfall and flood are most important. Heavy rainfall flooding the breeding areas made them unsuitable for nesting.

Bank myna breeds during March to August (Rahman 2008) and February to August (Hossain 2001) in Bangladesh; May to August (Ali 2002); mainly from April to June, but with occasional breeding activity from March to August (Feare & Craig 1998).

Nesting

Nest site selection

Prior to breeding season they aggregate at the breeding site. They make chirping noises during selection of nesting site and also show some antagonistic behaviour between pairs. Both sexes are involved in selecting suitable nesting sites. They either choose new or old sites for nesting and either choose old nests or make new nests. They took 7 to 15 days (mean10.4 ± 2.55 days, n = 10) to select old nests and 10 to 21 days (mean 15.5 ± 3.74 days, n = 10) to select new nest sites. The time taken in selecting new and old nesting sites by the bank mynas varied significantly ($t = 3.768$, $df = 9$, $p = 0.004$, 2-tailed). Sometimes one pair takes possession of the nest of another pair, resulting in conflict between pairs. A third and/or fourth pair may come forward to help settle the issue of possession of the genuine pair.

Nest building

Both male and female took part in nest building. After selecting a suitable new nesting site, the pair stood on the bank-nesting site for a long time. They pecked on the wall of steep bank and dug a hole there. They pushed their body into the hole and extended the hole with their beak. They removed soil from the nesting hole by their legs. The pair alternates in digging the hole. A pair took 20 to 38 days (mean 28 ± 5.42 days, n = 10) to build a new nest.

Some of the pairs repaired or renovated old nests instead of making new ones. They aggregated at the old nesting site and selected a suitable old nest for nesting, but it was not confirmed whether a pair selected their last year's nest or another. They usually repaired the old brood chamber and/or made it longer and made a new brood chamber. They took 10 to 18 days (mean 13.4 ± 2.55 days, n = 10) to repair/renovate an old nest. Time taken in building nests varied significantly between two nesting sites ($t = 8.018$, $df = 9$, $p = 0.000$, 2-tailed). Bank mynas continued nest building from morning till afternoon and returned to roosting site for the night. Daily nest building activities varied from 10.58 to 11.26 hours (mean 11.08 ± 0.28 hours, n = 5).

Bank myna took 10 to 15 days for nest building (Hossain 2001), while Feare and Craig (1998) studied captive birds and reported that the male excavates the nest and contributes straw and dry grass, but the female contributes the final stage.

Both male and female collected nesting materials [leaves of bamboo and shishu (*Dalbergia sisoo*), pieces of paper, pieces of polythene, straw, small sticks, and twigs] from the surrounds of the nesting area, when they hunted insects. They collected nesting materials 27 to 42 times in a day (mean 35, n = 3 days), usually more during the morning hours and gradually decreasing towards

mid-day and increase a little before the end of the day. Nesting materials of bank myna consisted of a pad of straw, feathers, and often pieces of sloughed snake skin and pieces of polythene in most cases (Feare & Craig 1998); a rough pad of grass, leaves and rubbish, but very often had one or more snake cast mixed in the nest (Baker 1926). They arranged nesting materials in the brood chamber, forming a cup-like structure (although some materials were scattered in the nest holes) for laying eggs.

Nest size

Shape, size, and length of the nest (tunnel) varied among the nests depending on the nesting place, it was more or less straight with a ridge in front of the brood chamber. The length was 49-172 cm (mean 106.3 ± 33.48 cm, n = 20), width 27-55 cm (mean 40.9 ± 7.15 cm), and diameter 9-18 cm (mean 13.2 ± 2.7 cm). Nest entrance is usually circular but oval, rectangular, conical and triangular shapes are also found (Figure 2). No significant relationships were found between length and width (r = 0.343, df = 18, $p > 0.05$), length and diameter (r = - 0.411, $p > 0.05$) and width and diameter (r = 0.166, $p > 0.05$) of the nests. Length of nesting hole in two nesting sites (Baliadanga and Nakkatitala) varied significantly (t = 3.877, $p = 0.004$, 2-tailed), but the width did not differ significantly (t = 2.157, $p = 0.059$, 2-tailed). Circumference of nesting hole in the two sites also varied significantly (t = 2.364, df = 9, $p = 0.042$, 2-tailed). No significant relationships were found between length and width of nest (r = 0.207, $p = 0.566$), length and diameter (r = - 0.410, $p = 0.239$) and width and diameter (r = 0.526, $p = 0.118$) at Baliadanga site; and length and width (r = 0.447, $p = 0.196$), length and diameter (r = 0.390, $p = 0.265$) and width and diameter (r = 0.494, df = 9, $p = 0.147$) at Nakkatitala. The variation in length of nest holes in two sites is due to the compactness of soils. The soils of Baliadanga site were softer than those of the Nakkatitala site and most of the nest holes of the Baliadanga site were old and renovated. This is also applicable to circumference of nesting hole. That is why; the length and circumference of nest holes were respectively longer and wider in Baliadanga (Table 2).

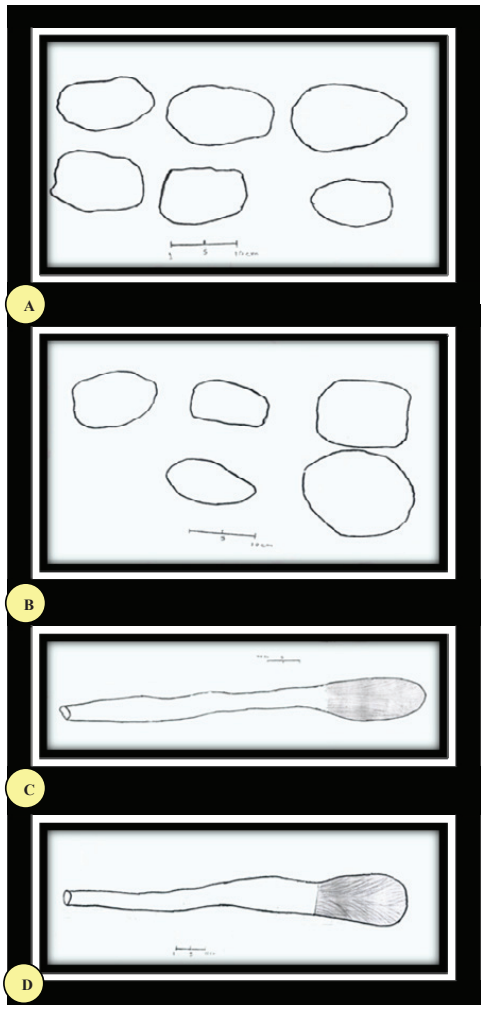

Figure 2 *Different shapes of nest entrance at different breeding sites (A and B); Shape and size of nest of Barogharia brickfield (C and D). Black sketch area shows the brood chamber.*

Table 2 *Nest size (cm) of bank myna in two sites (including brood chamber).*

Sl. No.	Baliadanga			Nakkatitala		
	Length	**Width**	**Diameter**	**Length**	**Width**	**Diameter**
01	87	44	12	49	32	16
02	155	45	10.5	70	38	14
03	160	41	12	70	27	12
04	172	50	11	135	45	18
05	117	37	14	83	42	15
06	105	51	10	85	35	14
07	120	47	14	96	43	12
08	90	55	18	110	36	15
09	115	36	8.5	87	33	13
10	145	35	9	75	46	16
Mean ± SD	**126.6 ± 29.75**	**44.1 ± 6.82**	**11.9 ± 2.84**	**86 ± 23.78**	**37.7 ± 6.22**	**14.5 ± 1.9**

Table 3 *Egg-laying sequence in 2009.*

Nest	Clutch size	1st	2nd	3rd	4th	5th	Remarks
BAR 2	5	28 March	29 Mar.	31 March	1 April	2 April	
BAR 3	3	12 April	13 April	14 April			
BAR 6	4	15 April	16 April	17 April	18 April		
BAR 7	3	11 April	12 April	14 April			One day interval
BAR 11	4	11 April	12 April	13 April	14 April		
BAR 13	4	16 April	17 April	18 April	19 April		
BAL 2	5	27 March	28 March	29 March	30 March	31 March	
BAL 3	3	19 March	20 March	22 March			One day interval
BAL 9	3	24 March	25 March	26 March			
BAL 12	4	23 March	24 March	26 March	27 March		One day interval

The average length of nest tunnel of bank myna is one metre long, but may be longer in softer soil (Feare & Craig 1998); is 6 feet (1.83 m) or even 7 feet (2.13 m) long in soft soil and 2 to 3 feet (0.61 to 0.91 m) in harder soil (Baker 1926).

Brood chamber

Structure of brood chamber (Figure 2) was different from any other portion of the nest and can be seen from outside. The average length of brood chamber was 29 ± 5.66 cm (range 20-35 cm, n = 5) and mean diameter 18.6 ± 1.67 (range 16-20 cm). Relationship between length and width of brood chamber did not differ significantly (r = 0.396, n = 5, p = 0.509). Horizontal earth tunnel ends in a brood chamber (Ali & Ripley 1983). It is 21 cm long and circumference 18 cm in diameter (Feare & Craig 1998).

Nesting height

Nesting height of the eroded bank from the base of the eroded place of breeding habitat varied depending on the height of the banks. The mean minimum and maximum heights were respectively 1.41 ± 0.79 m (range 0.91-3.66 m, n = 12) and 3.18 ± 1.19 m (range 1.22-4.88 m).

Egg

Bank myna laid eggs in the brood chamber after 2-4 days (mean 3 ± 0.82, n = 10 clutches) of the completion of nest building. Eggs were laid at night or early morning, because the eggs were found in the brood chamber the following morning. Eggs were laid daily except for the 3rd and 4th eggs, when they occasionally took a one-day interval (Table 3). Clutch size was 3-5 (mean 3.8 ± 0.79, n = 10), while the clutch size of bank myna were recorded to be 3-5 in Bangladesh (Rahman 2008) and 3 to 6, exceptionally 8 (Feare & Craig 1998).

Shape of the eggs is more or less oval, but somewhat pointed at the anterior end. Eggs are blue, which may become slightly paler during late incubation period. The length of eggs was 25.33-28.62 mm and breadth (at mid-point) 19.20-21.59 mm with an average dimension of 27.29×20.30 mm (n = 34) (Table 4). Dimension of eggs were 2.7×2.0 cm (Rahman 2008); 28.63×20.76 mm, range 28-30 × 20-22 mm (Hossain 2001); 24.2-29.8 × 18.3-22.1 mm (Feare & Craig 1998). The present measurement is close to the observations of the first two authors.

The average weight of eggs was 6.46 ± 0.33 g (range 5.95-6.89 g, n = 34), while Hossain (2001) mentioned 6.53 g (range 6.00 to 7.5 g), which is quite close to the present observation. Eggs lose weight from the first day of incubation till hatching and it was 1.15 ± 0.13 g (range 0.99-1.31 g, n = 5 eggs from 5 nests, i.e., 17.4 %, range 15.6-20.3 %). The average weight of egg was 6.58 ± 0.28 g (range 6.17-6.89 g) at the first day of laying and the average weight of eggs was 5.43 ± 0.26 g (range 5.15-5.64 g) before hatching. Loss of weight of eggs on first day and before incubation varied significantly (t = 19.522, df = 4, p = 0.0001).

Incubation

Incubation started as soon as the first egg was laid. They sat over the eggs covering them with abdominal feathers. The overall mean incubation period was 16.6 days (15-17 days mean 15.6 days in 2009, n = 38 eggs in 10 clutches and 18-19 days, mean 18.6 days in 2008, n = 18 eggs in 5 clutches) (Figure 3). It was interesting that the bank myna did not incubate eggs constantly; sometimes both parents left the nest for a while. The incubation period over two years varied significantly (Mann & Whitney U test = 0.0001, n = 15, p = 0.002, 2-tailed). The incubation period of bank myna varied from 11-16 days with an average of 13.38 days

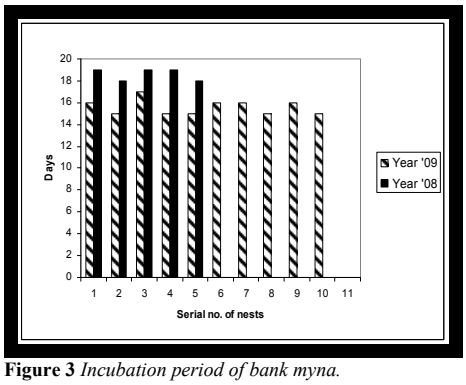

Figure 3 *Incubation period of bank myna.*

Table 4 *Dimensions of eggs (cm).*

Nest	Clutch size	Dimension of eggs					Mean Dimension/ clutch	Overall mean dimension
		1st	2nd	3rd	4th	5th		
1	3	28.09-20.52	28.62-20.66	27.99-21.12	-	-	28.23 - 20.76	
2	3	28.32-20.78	28.15-21.05	27.58-20.65	-	-	28.01 - 20.82	27.29 - 20.30
3	4	27.01-20.16	27.38-20.16	27.12-20.36	26.86-20.15	-	27.09 - 20.31	
4	3	28.32-20.76	27.38-20.32	28.01-20.05	-	-	27.90 - 2031	
5	3	28.01-20.32	28.32-20.62	28.06-21.01	-	-	28.13 - 20.81	
6	5	26.59-19.64	26.17-19.67	26.43-19.58	25.98-19.78	26.66-19.58	26.37 - 19.61	
7	4	26.32-20.12	26.64-20.31	26.91-20.78	27.12-20.22	-	26.75 - 20.03	
8	4	27.58-20.58	27.08-19.98	26.58-20.12	27.30-21.59	-	27.13 - 20.56	
9	5	26.61-19.54	26.12-19.80	26.53-19.21	25.69-19.20	25.33-19.66	26.05 - 19.48	

(Hossain 2001), and about 13 days (Feare & Craig 1998).

Hatching

The mean hatching success was 80.67 ± 18.63 in 2009 (range 50-100 %, n = 10 clutches containing 38 eggs) and 79.12 % in 2008 (range 50-100 %, n =10 clutches containing 32 eggs). Occasionally parents helped the hatchlings for coming out of the eggs by breaking the egg-shells. Number of eggs and hatchling of different nests varied significantly within same year (t = 3.207, df = 9, p = 0.011). Number of hatchlings over the two years did not vary significantly (Mann & Whitney U test = 30, n = 20, p = 0.089, 2-tailed). All the nestlings of the same nest hatched out between 24 and 72 hours with an average of 50.4 ± 17.7 hours, depending on the number of eggs hatched (2-4, mean 3 ± 0.67, n = 10 clutches) from a clutch and each egg hatched every 24 hours.

Brood size

One pair of bank myna produced only one brood in a breeding season. Brood size was 2-5 in 2009 and 2-3 in 2008 with an overall mean 2.71 (Figure 4). Brood size of 2008 and 2009 did not differ significantly (Mann & Whitney test, U = 30, n = 20, p = 0.089, 2-tailed). In 2009, 10 pairs were observed to see whether they laid a second clutch of eggs in a breeding season, but they did not.

Nestling

The newly-hatched nestling was small with closed eyes and the abdomen looked almost transparent. The body was reddish like flesh coloured. Beak and claws were soft. The opening of eyes was first marked by the appearance of a minute aperture on the naked skin covering the eyes. The eyes became visible during 5 to 6 days (mean 5.55 ± 0.51 days, n = 20 eggs of 10 clutches) after hatching.

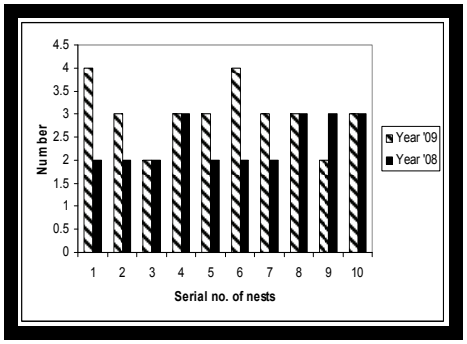

Figure 4 *Brood size of bank myna.*

Feeding

Though nestlings did not eat for the first 36-48 hours, the parents were busy collecting foods. They were totally dependent on parents for food. Both parents provided food for their nestlings, collecting from the surrounding area (agriculture field, open field, homestead vegetation, etc.). One of the parents completed feeding the nestlings and left the nest and the other entered. During feeding new hatchlings stayed inside the brood chamber, but 5-6 days later the hatchlings came out of the brood chamber and waited for food at the nest entrance, which indicated that they needed more food and wanted to see the world outside the nest. At that time there is a fair chance of the nestlings being eaten by predators.

Bank myna ate and fed to nestlings a variety of animal foods from insects to vertebrates (grasshoppers, prey mantis, *Gryllotalpa* sp., dragonfly, earthworms, snails and frogs) and ripe fruits (date [*Phoenix sylvestris*], neem [*Melia indica*] and mango [*Mangifera indica*]; of all,

insects were the major part. Bank myna mainly eats fruit, grain and insects, and is destructive of ripening crops of jowar, *Sorghum* (Ali & Ripley 1983), but important as insect pest control, for instance, larvae of a noctuid moth, *Ophiusmelicerte*, which is highly injurious of castor, *Ricinus* (Mason & Maxwell-Lefroy 1912). It also hunts insects disturbed by the feet of grazing cattle [*cf.* (Ali & Ripley 1983)].

Table 5 *Number of feeding visits of broods to nestling in different hours of the day.*

Time	Serial no. of nest					Mean
	3	*4*	*5*	*1*	*2*	
0600-0700	7	13	10	20	18	13.6
0700-0800	8	17	8	17	21	14.2
0800-0900	6	12	11	15	17	12.2
900-1000	7	16	10	17	18	13.6
1000-1100	4	13	12	14	10	10.6
1100-1200	1	10	9	12	18	12.2
1200-1300	7	9	8	14	16	10.8
1300-1400	6	8	8	11	10	8.6
1400-1500	5	4	7	8	6	6.0
1500-1600	3	7	11	5	7	6.6
1600-1700	3	3	8	5	6	5.0
1700-1800	7	8	10	11	7	8.6

Note: 1 = 10 days after hatching; 2 = 12 days after hatching; 3 = 4 days after hatching; 4, 5 = 6 days after hatching.

Feeding visits of parents varied nest to nest depending on the age of nestlings. Feeding frequency was 3-21 times per hour with an average of 10.6 (Table 5), but the frequency of visits was higher in the morning and lower during hot/warm (mid-day) hours. One brooding bird used to carry food in its beak 78 % of its visits to the nest-hole and the rest without food. Feeding visits to the same nest varied significantly for different hours of the day (nest 1: t = 9.116, df = 11, p = 0.0001, 2-tailed; nest 2: t = 7.863, p = 0.0001, 2-tailed; nest 3: t = 8.882, p = 0.0001, 2-tailed; nest 4: t = 7.928, p = 0.0001, 2-tailed, nest 5: t = 20.765, df = 11, nest 6: t = 20.765, p = 0.001, 2-tailed). Both parents kept the nest clean by removing faeces about 50 m from the nest.

Growth

Growth of nestlings of two nests was observed. The first nestling was the healthiest and strongest of all others in a nest. Nestlings were weighed on days 1, 5, 10, 15 and 20 (Table 6). The average weight of nestlings on the day of hatching was 6.15 ± 0.19 g (range 5.9-6.3 g, n = 6 nestlings of 2 nests). During eye opening (5-6 days old) the average weight of nestlings was 22.33 ± 2.33 g (range 20.6-26.1 g, n = 6 nestlings). At the age of 20 days, the average weight was 66.6 ± 1.31 g (range 65-68.4 g, n = 6 nestlings).

Fledging period

The overall fledging period was 23.57 ± 1.0 days, range 22-25 days, n = 14 fledging (23.2 ± 0.97 days in 2009, range 22-25 days, n = 9 and 24.2 ± 0.84 days in 2008, range 23-25 days, n = 5 fledging). The fledging period of two years did not vary significantly (Mann & Whitney test, U = 10.000, n = 14, p = 0.083).

Weight of nestling during fledging period

The average weight of was 73 ± 1 g (range 71.5 - 74.1 g, n = 6 nestling in 2 nests) during fledging period. Fledging weight of nestlings in two nests did not vary significantly (U = 1.000, n = 6, p = 0.100 to 0.658, Table 6).

Breeding success

The breeding success of bank myna was 61.5 % in 2009 (n = 10) and 61.11 % in 2008 (n = 3) and overall success was 61.41 % in relation to the total number of eggs laid and the number of hatchlings fledged. The breeding success of two years did not vary significantly (Mann & Whitney test, U = 9.500, n = 13, p = 0.342).

Conclusion

A study on the breeding ecology of bank myna, *Acridotheres ginginianus* (Latham, 1790), was carried out in Chapai Nawabganj District of Bangladesh during June 2007 to October 2009. Breeding biology was mainly observed at Baliadanga riverbank and Barogharia brickfield.

The total population in the breeding colonies was estimated to be 4,452. The species mostly made holes in the eroded riverbanks and earth heap of brickfields. Breeding season was February to July in 2009 and December to July in 2007-2008**.**

Table 6 *Growth of bank myna (weight in g).*

Age of hatchlings (day)	First nest				Second nest				Statistics		
	nestlings				*nestlings*						
	1st	2nd	3rd	Mean	1st	2nd	3rd	Mean	Mean (g)	U =	p =
One	6.3	6.1	5.9	6.1	6.4	6.2	6.0	6.2	6.2	3.0	0.513
Five	26.1	22.6	20.6	23.1	25.2	21.4	20.4	22.3	22.7	3.0	0.513
Ten	40.2	36.1	35.3	37.2	39.2	36.2	35.3	36.9	37.0	4.5	0.100
Fifteen	54.6	52.1	50.1	52.3	53.1	50.4	50.1	51.2	51.7	3.5	0.658
Twenty	68.4	66.2	66.4	67	67.2	66.4	65.0	66.2	66.6	3.5	0.658
Before fledging	**74.1**	**73.8**	**73.2**	**73.7**	**72.1**	**73.3**	**71.5**	**72.3**	**73.0**	**1.0**	**0.127**

They took 10 to 18 days (mean 13.4 days) for renovating old nests and 20-38 days (mean 28 days) for building new nest. Clutch size was 3-5. Average dimension and weight of the eggs were, respectively, 27.29 x 20.3 mm and 6.52 g.

The overall incubation period was 15-19 days with an average of 16.6 days (15-17 days, mean 15.5 days in 2009 and 18-19 days, mean 18.6 days in 2008). Hatching success was 80.67 % in 2009 and 79.12 % in 2008 in relation to the number of eggs laid. Overall fledging period was 23.49 days (22-25 days, mean 23.1 in 2009 and 24-25 days, mean 24.2 days in 2008). The breeding success was 61.41 % (61.15 % in 2009 and 61.11 % in 2008) in relation to the number of eggs laid.

Major threats to bank mynas are flood, children fun, predators and human for its meat. Villagers around nesting sites are very keen to protect this bird for its role in controlling insect pests.

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Chapter 10: Bird Parasites – Their Community Structure, Epidemiological Aspect, Interactions and Relationships with Host Phylogeny and Food Habits

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Abstract

Community structure of bird parasites, their epidemiological aspect, interactions and relationships with phylogeny and food habit of host were studied. 317 birds belonging to 5 species (3 sturnids, 1 pycnonotid, and 1 columbid) of 2 distant places differing in topography, landscape, land use, major vegetation, etc., of Bangladesh were autopsied over a period of 19 months. Eighteen clearly-distinguishable morphotypes were collected, of which 9 were identified up to species, 3 to genus and 6 only to the level of major taxa. Of the 18, 6 were ecto–parasites (all lice), 1 trematode, 4 cestodes, and 7 nematodes. The parasite fauna was at best moderately rich – the highest SR was 9 and the lowest 3. Similarly, the highest H´ value was only 2.18. Specificity was mostly narrow – 13, out of the 18 collected, were strictly host specific – the matter was more dominant in the case of ecto–parasites (5 out of the 6 were strictly host specific). The highest QS value between the parasite faunas of 2 hosts was only 54.60 % (in the case of *Acridotheres tristis* and *A. fuscus*). Having an absolutely different food habit (granivorous) and phylogenitic lineage, *Strepopedia chinensis* hosted a parasite fauna entirely different from those of the other hosts. The 2 host factors, phylogeny and food habit, were found to have almost equal influence on the composition of parasite communities. The moderate QS values indicate that factors other than these 2 also have important roles in shaping the parasite fauna of a host. Of the 257 hosts infected by endo–parasites, 58.8 %, 29.6 %, 10.9 %, 0.4 %, and 0.4 % carried single, double, triple, quadruple, and quintuple infections respectively. Among the multiple associations, significant correlations between parasites were obtained in only 7 cases, of which only one was negative.

Keywords; *Bird parasites, community structure, specificity, parasite interactions, host food habits, phylogeny, Bangladesh.*

Introduction

Ecologists have made significant progress in understanding infectious disease dynamics operating within populations, but less is known about the factors that influence patterns of parasite community diversity. Questions about parasite biodiversity can be addressed at two levels (Morand 2000). First, patterns of species diversification within specific parasite lineages can be examined using information on parasite phylogeny and factors that may influence parasite speciation or extinction (Poulin & Morand 2000). A second approach investigates host characteristics that best explain variation in parasite species-richness (PSR) (Morand 2000). This approach requires information on host characteristics, host phylogeny and parasite community diversity among multiple host species.

Host and parasites are, usually, phylogenetically related, i.e., related species and genera of parasites are often restricted to related species and genera of hosts (Kennedy 1975). As host species may inherit their pathogen communities from a common ancestor (shared by descent), so parasite species diversity may be more similar among closely-related hosts (Nunn *et al.* 2003). Thus, information on host phylogeny is required to identify independent evolutionary changes in parasite richness (Morand 2000; Poulin 1995).

Other than phylogenetic history of the host, many factors, including host specificity, parasite competition, and parameters of host biology, such as population size, habitat, diet, migration, and anti-parasitic defences(Esch *et al.* 1990; Simberloff & Moore 1997), and host body size (Poulin 1997) influence parasite communities. Besides those, factors like social interactions within populations (Anderson & May 1979; Anderson & May 1991), host density (Morand & Poulin 1998), host behaviour (Alexander 1974; Hart 1990; Moore 2002) and geographical range of the host (Bagge *et al.* 2004) also play important roles in shaping parasite communities in hosts.

Literature on bird parasites is enormous globally, but works on the present hosts (*Sturnus contra, Acridotheres tristis, A. fuscus, Pycnonotus cafer* and *Streptopelia chinensis*) are scanty in the Indian Sub–continent, particularly in Bangladesh. In Bangladesh only a few works have been done on ecto–parasites of birds by researchers, such as (Asmat & Choudhury 1995; Asmat & Kader 1990; Hari *et al.* 1981). Research on endo–parasites

(Akhtar 1987; Khanum 1997; Khanum & Jabbar 1997) were equally few and confined only to domesticated birds. Furthermore, all these studies of parasites were almost fully focused on taxonomic identification. Hence, this study was undertaken on both ecto– and endo–parasites.

The objectives in this research were by study the community structure of the parasites, their epidemiological aspect, interactions, and relationships with the phylogenies and food habits of bird hosts. For this, 5 bird species differing, to varying extent, in phylogeny and food habits were selected. They were collected from 2 localities differing in landscape, land use, rural/semi-urban nature, etc., and separated by a distance of about 160 kilometres.

Methods

Hosts selected

Of the 5 bird species autopsied, *Sturnus contra, Acridotheres tristis,* and *A. fuscus* belonged to the same family (Sturnidae: Passeriformes), *Pycnonotus cafer* to a different family (Pycnonotidae: Passeriformes), and *Streptopelia chinensis* to even a different order (Columbidae: Columbiformes). *S. contra*, *A. tristis,* and *A. fuscus* were predominantly insectivorous. However, *A. tristis* also included a good amount of human food items, such as rice, loaf, etc., consistent with their living near human habitation. *P. cafer* was predominantly a herbivore, eating also some insects. Being an absolute granivore, *S. chinensis* was entirely different from the above 4, as it was also phylogenetically.

The host animals were collected from two localities – a rural remote area of Chandpur (CP) district (riverine plain land) and the Chittagong University Campus (CUC) and the adjoining places (a mixed area of hilly and plain lands with rural, as well as somewhat semi-urban characteristics). A total of 317 specimens (33 *S. contra,* 34 *A. tristis,* 32 *A. fuscus,* 34 *P. cafer* and 30 *S. chinensis* from Chandpur, and 32 *S. contra,* 32 *A. tristis,* 30 *A. fuscus,* 30 *P. cafer* and 30 *S. chinensis* from CUC) were shot during June 2007 to February 2009.

Collection of parasites

The host birds were shot by an air gun. After shooting, all feathers of the host birds were removed from the body and examined very carefully by naked eye for collection of ecto–parasites. The viscera of the birds from CP were preserved in 6 % formaldehyde solution, whereas, samples from CUC were autopsied fresh. Food habit of host was determined by analysing the stomach contents by gravimetric method. Parasites were collected, fixed, preserved and cleared for study following Cable (1961).

Analysis of food habit of host

Food habits of the birds were analysed by the following formula (Lawlor 1980):

$$S_{ik} = \frac{\Sigma a_{ij}\, a_{kj}}{\sqrt{\Sigma a_{ij}^2\, a_{kj}^2}}$$

Where, a11 = value of one food item taken by one species and

a_{12}= value of the same food item taken by the other species in the comparison.

Identification

Identifications were mostly done following keys by (Adams *et al.* 2005; Ansari 1956; Hellenthal & Price 2003; Price 1977; Watt 1970) for ecto–parasites, and (Ellis 1969; Frantova 2001; Yamaguti 1961) for endo–parasites.

Community structures of parasites

Indices like Species Richness (SR), Shannon-Wiener Species Diversity Index (H´), Maximum Species Diversity (H_{max}), Community Dominance (DC), Evenness (E), and Quotient of Similarity (QS) were used (formulae in (Krebs 1972; Odum 1973).

Statistical analyses

As the data of the parasite fauna of any of the five host species, e.g., *S. contra*, of the two studied places, did not follow normal distribution; they were subjected to the non-parametric Mann-Whitney U Test. The test revealed that of the 25 cases (of parasite species or taxa), data of 22 belonged to the same populations. That means in each of those 22 cases there was no spatial difference between the data of CP and CUC. The three deviatory cases were of *Baruscapillaria carbonis* (of *S. contra*), *Menacanthus eurysternus* (of *A. tristis*), and *B. rudolphii* (of *P. cafer*), whose data of CP were significantly different from those of CUC. However, these 3 cases were regarded avoidable, and it was concluded that there was no spatial difference, generally, in the parasite fauna of any of the host species of the two studied places. So, the data of CP and CUC were merged for subsequent statistical analyses, which were done using the SPSS programme (version 16.0). For analyses, the parasite names were abbreviated, for example *Microtetrameres helix* as *M. h.* Association pattern of parasite species was first analysed by frequency of their occurrence in a host – separately for ecto– and endo–parasites. Multiple infection cases were further investigated only with the numerical data of endo–parasites, as that for ecto–parasites may not be fully reliable, because of their tiny size and hidden nature. The analyses done were simple and partial correlations, and multiple regressions.

Results

Community structure of the parasite fauna

In all, 18 parasite morphotypes were collected from the 5 bird species. Of them, 9 could be identified up to species level and 3 to genus. Six had still to be left at higher category level like Trematode-1, Ascarididae-1, Cestode-1, etc., for want of taxonomic keys. However, they are clearly distinguishable morphotypes representing species. Of the 18, six were ecto– (all lice) and 12 were endo–parasites. Host-wise the parasites were – *Menacanthus eurysternus* (abbreviated as *M e.*), *Sturnidoecus sturni* (*S.s.*), *Diplotriaenoides* sp. (*D.p.*), *Baruscapillaria carbonis* (*B.c.*), *Plicatolabia* sp.1 (*Pl.*1), *Plicatolabia* sp.2 (*Pl.*2), *Microtetrameres helix* (*M.h.*), Ascarididae-1 (Asc.), and Trematode-1 (Trem.) in *S. contra*; *M. eurysternus*, *B. carbonis*, *B. rudolphii* (*B. r.*), *Plicatolabia* sp.2 and Cestode-1 (Cest.1) in *A. tristis*; *M. eurysternus*, *Bruelia zohrae* (*B.z.*), *B. carbonis*, *B. rudolphii*, *Diplotriaenoides* sp., and Cestode-2 (Cest.2) in *A. fuscus*; *Myrsidea kathleenae* (*M. k.*), *B. carbonis*, *B. rudolphii* and Cestode-3 (Cest.3) in *P. cafer* and *Nitzschiella lativentris* (*N. l.*), *Columbicola turturis* (*C.t.*) and Cestode-4 (Cest.4) in *S. chinensis*. *M. eurysternus*, *S. sturni*, *B. zohrae*, *M. kathleenae*, *N. lativentris,* and *C. turturis* were ecto-parasites; the remaining 12 were endo-parasites – 1 trematode, 4 cestodes and 7 nematodes (*Diplotriaenoides* sp., *B. carbonis*, *B. rudolphii*, *Plicatolabia* sp.1, *Plicatolabia* sp.2, *M. helix,* and Ascarididae-1).

Five intra-community and 1 inter-community indices were analysed to study the community structure of the parasite fauna of the 5 bird species. They were SR, H′, H_{max}, E and DC among the intra-community indices, and QS for inter-community analysis (Table 1). The SR was determined with all parasites – both ecto– and endo–parasites. The remaining indices were calculated with the data of endo–parasites only, because quantitative data for ecto–parasites might not be fully reliable. The SR was highest (9) in *S. contra*, followed by 6, 5, 4, and 3 in *A. fuscus*, *A. tristis*, *P. cafer,* and *S. chinensis*, respectively (Table 1). The H′ values were invariably consistent, as theoretically expected, with the values of SR – H′ value highest in *S. contra* (2.18) and lowest in *P. cafer* (1.41). However, the values of E and DC did not uniformly follow the usual rule, e.g., the highest E was found in *A. fuscus,* not in *S. contra* (having highest SR and H′). Similarly, the DC values were also not uniformly consistent with H′ values, though such consistency was relatively more uniform in the case of DC than in the case of E (Table: 1). It should be mentioned here that the community structure indices could not be calculated in the case of *S. chinensis*, because this host had only one endo–parasite species.

The highest QS value was only 54.6 %, and the sequence of the values was as follows – 54.6 % (in *A. tristis* & *A. fuscus*) > 44.4 % (in *A. tristis* & *P. cafer*) > 42.9 % (in *S. contra* & *A. tristis*) > 40.0 % (in *S. contra* &*A. fuscus*) = 40.0 % (in *A. fuscus*& *P. cafer*) > 15.4 % (in *S. contra* &*P. cafer*) (Table: 1). The QS was 0 % in the case of comparison of parasite fauna of *S. chinensis* with that of any of the remaining 4 host species investigated, because *S. chinensis* had an entirely different parasite fauna.

Epidemiological aspect of the parasites

Although 3 epidemiological parameters - prevalence, intensity and abundance - were investigated, only prevalence has been considered here because it alone can be more representative of the extent of parasitism. The prevalence sequence of the parasites has been given below by host-species wise (Table 1).

- ***S. contra*****:** *M. eurysternus* > *S. sturni* > *Diplotriaenoides* sp. > *B. carbonis* > *Plicatolabia* sp.2 > *Plicatolabia* sp.1 > *M. helix* > Ascarididae-1 > Trematode-1.
- ***A. tristis*****:** *M. eurysternus* > *B. carbonis* > *B. rudolphii* > *Plicatolabia* sp.2 > Cestode-1.
- ***A. fuscus*****:** *M. eurysternus* > *B. zohrae* = *B. carbonis* > *Diplotriaenoides* sp. > *B. rudolphii* > Cestode -2.
- ***P. cafer*****:** *M. kathleenae* > *B. carbonis* > *B. rudolphii* > Cestode – 3.
- ***S. chinensis*****:** Cestode - 4 > *N. lativentris* > *C. turturis.*

So, the ecto–parasites were the more prevalent ones than the endo–parasites, and *M. eurysternus* was the most dominant ecto-parasite having highest prevalence value in 3 hosts (*S. contra, A. tristis,* and *A. fuscus*). Among the endo–parasites, *B. carbonis* had the highest prevalence in all but *S. chinensis* which had only one endo–parasite taxon.

Specificity

Of the 6 ecto-parasite species, only *M. eurysternus* had wide specificity – occurring in all 3 sturnid hosts (*S. contra, A, tristis,* and *A. fuscus*). The remaining 5 (*S. sturni*, *B. zohrae, M. kathleenae*, *C. turturis,* and *N. lativentris*) had strict specificity, each restricted to only one host species.

Among the helminths, Trematode-1, the only trematode collected, was strictly host-specific – infesting only *S. contra.* Of the 4 cestode taxa collected, each one had strict specificity – Cestode-1, Cestode-2, Cestode-3 and Cestode-4 infested only *A. tristis*, *A. fuscus, P. cafer,* and *S. chinensis*, respectively.

Specificity was rather wider in the nematodes. Of the 7 nematode taxa collected, 3 were strictly host-specific, 2 infested 2 host species, 1 infested 3, and 1 as many as 4 host species.

Table 1: *Epidemiological aspect and community structure indices of the parasite fauna of the five bird host species and the hosts' food habit analysis.*

Hosts	**Parasites**	**Prevalence**	**Community Structure Indices**		**Quotient of Similarity (QS) between**	%
S. contra	*S. s.*	83.08	SR (W.a.p.)	9	*A. t.* & *A. f.* (1)	54.6
Passeriformes	*M. e.*	84.62	SR (W.end.)	7	*A. t.* & *P. c.* (2)	44.4
Sturnidae	*Dp.*	46.15	H' (,,)	2.18	*S. c.* & *A. t.* (3)	42.9
	Asc.	3.08	H_{max}(,,)	2.81	*S. c* .& *A. f.* (4)	40.0
	Pl. 1	23.08	E (,,)	0.78	*A. f.* & *P. c.* (4)	40.0
	Pl. 2	26.15	DC (,,)	61.67%	*S. c.* & *P. c.* (6)	15.4
	M. h.	18.46			*S. ch.* & *S. c.*(7)	0
	B. c.	41.54			*S. ch.* & *A. t.*(7)	0
	Trem	1.54			*S. ch. & A. f.* (7)	0
A. tristis	*M. e.*	86.36	SR (W.a.p.)	5	*S. ch. & P. c.*(7)	0
Passeriformes	*Pl.* 2	27.27	SR (W.end.)	4		
Sturnidae	*B. c.*	51.52	H' (,,)	1.43		
	B. r.	33.33	H_{max}(,,)	2		
	Cest. 1	24.24	E (,,)	0.72		
			DC (,,)	90.46%		
A. fuscus	*M. e.*	48.39	SR (W.a.p.)	6		
Passeriformes	*B. z.*	38.71	SR(W.end.)	4		
Sturnidae	*B. c.*	38.71	H' (,,)	1.85		
	B. r.	25.81	H_{max}(,,)	2		
	Dp.	37.10	E (,,)	0.93		
	Cest. 2	27.42	DC (,,)	65.37%		
P. cafer	*M. k.*	70.31	SR (W.a.p.)	4		
Passeriformes	*B. c.*	54.69	SR (W.end.)	3		
Pycnonotidae	*B. r.*	43.75	H' (,,)	1.41		
	Cest. 3	31.25	H_{max}(,,)	1.58		
			E (,,)	0.89		
			DC (,,)	87.24%		
S. chinensis	*N. l.*	61.67	SR (W.a.p.)	3		
Columbiformes	*C. t.*	55.00				
Columbidae	Cest. 4	65.00				

Food Habit Analysis	**Hosts**				
Food Items	***S. c.***	***A. t.***	***A. f.***	***P. c.***	***S. ch.***
IBP (%)	88.20	55.37	77.53	6.03	0
F & S (%)	11.80	13.15	22.47	74.59	0
HFI (%)	0	31.48	0	0	0
Veg (%)	0	0	0	19.39	0
Pad (%)	0	0	0	0	83.49
Wheat (%)	0	0	0	0	8.36
Pul (%)	0	0	0	0	8.15

Similarity of food habits between

S. c. **& *A. f.* (1)**	***A. t.*** **& *A. f*** **(2)**	***S. c.*** **& *A. t.* (2)**	***A. f*** **. & *P. c.* (4)**	***A. t.*** **& *P. c.* (5)**	***S. c.*** **& *P. c.* (6)**	***S.ch.*** **& All (7)**
98%	87%	87%	36%	26%	20%	0%

Abbreviations used and explanations

A. f. – Acridotheres fuscus, A. t. – A. tristis, Asc. – Ascarididae-1, B. c. – Baruscapillaria carbonis, B. r. - B. rudolphii, B. z. – Bruelia zohrae, Cest.1 – Cestode-1, Cest.2 – Cestode-2, Cest.3 – Cestode-3, Cest.4 – Cestode-4, C. t. –Columbicola turturis, DC – Community Dominance, Dp. – Diplotriaenoides sp., E – Equitability or Evenness, F&S – Fruits and Seeds, H′ – Shannon Wiener Species Diversity, HFI – Human Food Items (loaf, rice, etc.), H_{max} – Maximum Species Diversity, IBP – Insect Body Parts, M. e. – Menacanthus eurysternus, M. h. – Microtetrameres helix, M. k. – Myrsidea kathleenae, N. l. – Nitzschiella lativentris, P – Prevalence, Pad – Paddy, P. c. – Pycnonotus cafer, Pl.1 –Plicatolabia sp.1, Pl 2 – Plicatolabia sp.2, Pul – Pulses, QS – Quotient of Similarity, S. c. – Sturnus contra, S. ch. – Streptopelia chinensis, SR – Species richness, S. s. – Sturnidoecus sturni, Trem. – Trematode-1, Veg – Vegetables, (W.a.p.) – with all parasites, (W.end.) – with endo–parasites. **--** *SR values are presented for all parasites and endo–parasites separately; H′, H_{max}, E, and DC values are presented for only endo–parasites; QS values are presented for all parasites. Numbers given in bracket represent the rank of similarity. H′, H_{max}, E and DC are not given for S. ch. because it contains only one endo–parasite.*

Host-wise, *S. contra* (SR = 9) harboured 5 strictly host-specific taxa; *S. chinensis* (SR = 3) had all its parasites strictly host-specific; *A. fuscus* (SR = 6) and *P. cafer* (SR = 4) each harboured 2 such parasite species, and *A. tristis* (SR = 5) had only 1. So, of the 18 parasite taxa collected, 13 (72 %) had strict host-specificity.

Association of species in the parasitic communities of the 5 bird hosts

Sturnus contra

Ecto–parasites

Of the 65 hosts autopsied, 7 were free of any ecto–parasite. Only 2 species parasitized this host either singly or together. Frequency of single infection was almost similar in both parasites – *M. eurysternus* (f = 4) and *S. sturni* (f = 3). Double infection by *M.e*. + *S.s.* was overwhelmingly dominant occurring in 51 out of 65 hosts autopsied (Table 3).

Endo–parasites

57 hosts out of the 65 autopsied were infected by 7 endo–parasite species. They occurred singly in 28 hosts. Other levels of infection were double (f = 14), triple (f = 13), quadruple (f = 1) and quintuple (f = 1) (Table 3).

Two-species-infections occurred in 8 combinations, of which *M.h.* & *Pl*. 1 (*M.h.Pl.*1**.** *Dp.* Asc.*Pl.*2 *B. c*. Trem. $^{r = 0.308,\ p = 0.017,\ df = 58}$), and *M.h. &B c*. (*M.h.B. c***.** *Dp.*Asc. *Pl.*1 *Pl.*2 Trem. $^{r = .263,\ p = 0.043,\ df = 58}$) only were significantly correlated. Partial correlation values have been given above, because partial is a better guide to relationship study, than simple correlation, as the effects of other co-occurring variables (parasite species in this case) are controlled in this analysis.

Three-species-infections occurred in 7 combinations, involving 6 parasite taxa (Table 3). Among them, the multiple regressions of the co-occurring parasite species (independent variables) was significant only on *M.h.* and *Pl.*1, that too in only one type of triple infection, - *M.h.* + *Pl.*1 + *B c.* The R^2 value was, however, very small (= 0 .073, $p = 0.036$, df = 2, 62) and (= 0.067, $p = 0.044$, df = 2, 62), in the cases of *M h.* and *Pl.* 1 (as dependent variables) respectively. Correlations were significant between *M.h.* and *Pl.*1, *M h*. and *B.c*., and Asc. and *B.c*., where the matter of variable interaction was evident, as exemplified below. It should be recalled here that 7 endo–parasite taxa were collected from *S. contra*.

- *M.h.Pl.*1 $^{r = 0.266^*,\ p = 0.032,\ N = 651}$
- *M.h.Pl.*1. *B. c.* $^{r = 0.228,\ p = 0.070,\ df = 62}$…….. 1.1
- *M.h.Pl.*1. *B. c. Dp.* $^{r = 0.223,\ p = 0.079,\ df = 61}$……. 1.2
- *M.h.Pl.*1. *B.c.Dp.* Asc. $^{r = 0.220,\ p = 0.086,\ df = 60}$... 1.3
- *M.h. Pl.*1.*B. c. Dp.*Asc. *Pl.*2 $^{r = 0.257^*,\ p = 0.046,\ df = 59}$……1.4
- *M.h.Pl.*1. *B. c. Dp*. Asc. *Pl.*2 Trem. $^{r = 0.308^*,\ p = 0.017,\ df = 58}$……1.5

  (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*).

The varying values of r in the above equations indicate the influence of the variables not controlled in the equations from 1.1 to 1.4 – *Dp*. Asc. *Pl.* 2 and Trem. in 1.1; Asc. *Pl.* 2 and Trem. in 1.2; *Pl.* 2 and Trem. in 1.3, and Trem. in 1.4. It is notable that the value of ^{r}*M.h. Pl.* 1 was highest when all the other endo–parasite variables of *S. contra* were controlled in the partial correlation (equation 1.5). The following two series of partial correlations also make evident the matter of factor interaction.

- *M.h.B.c.* $^{r = 0.230,\ p = 0.065,\ N = 65}$……..…..2
- *M.h.B.c..Dp.* $^{r = 0.248\ ^*,\ p = 0.048,\ df = 62}$……..…..2.1
- *M h. B.c.. Dp.*Asc. $^{r = 0.249^*,\ p = 0.049,\ df = 61}$……2.2
- *M.h. B.c..Dp.*Asc. *Pl.*1 $^{r = 0.196,\ p = 0.127,\ df = 60}$……..…..2.3
- *Mh. B.c.. Dp.*Asc. *Pl.*1 *Pl.*2 $^{r = 0.185,\ p = 0.152,\ df = 59}$……...2.4
- *M.h. B.c..Dp*. Asc. *Pl.*1 *Pl.*2 Trem. $^{r = 0.263^*,\ p = 0.043,\ df = 58}$……..…..2.5 (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*)
- Asc. *B c.* $^{r = 0.240,\ p = 0.054,\ N = 65}$……..…..3
- Asc. *B.c.. Dp.* $^{r = 0.237,\ p = 0.060,\ df = 62}$ ……3.1
- Asc. *B c.. Dp. M.h.* $^{r = 0.238,\ p = 0.060,\ df = 61}$……3.2
- Asc. *B.c.. Dp. M. h. Pl.*1 $^{r = 0.259,\ p = 0.042,\ df = 60}$……..…..3.3
- Asc. *B. c.. Dp. M. h. Pl.*1 *Pl.*2 $^{r = 0.262,\ p = 0.041,\ df = 59}$……...3.4
- Asc. *B.c.. Dp. M. h. Pl.*1 *Pl.*2 Trem. $^{r = 0.277,\ p = 0.032,\ df = 58}$……..…..3.5

  (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*).

Table 2 *Influence of hosts' phylogeny and food habits on the composition of their parasite fauna.*

Phylogenetic relationship		***Food habit similarity***			***Quotient of similarity (QS) of parasite fauna***		
Between hosts	Rank	Between hosts	% similarity	Rank	Hosts	% similarity	Rank
A. t. &. A. f.	1	*S. c. & A. f.*	98	1	*A. t. & A. f.*	54,60	1
S. c. &. A. t.	2	*A .t. & A. f.*	87	2	*A. t. & P. c.*	44,40	2
S. c. &. A. f.	2	*S. c. & A. t.*	87	2	*S. c. & A. t.*	42,90	3
S. c. &. P. c.	4	*A .t. & P. c.*	36	4	*S. c. & A. f.*	40,00	4
A. t. &. P. c.	4	*A. f. & P. c.*	26	5	*A. f. & P. c.*	40,00	4
A. f. &. P. c.	4	*S. c. & P. c.*	20	6	*S. c. & P. c.*	15,40	6
S. ch. &. S. c.	7	*S. ch. & S. c.*	0	7	*S. ch. & S. c.*	0	7
S. ch. &. A. t.	7	*S. ch. & A. t.*	0	7	*S. ch. & A. t.*	0	7
S. ch. &. A. f.	7	*S. ch. & A. f.*	0	7	*S. ch. & A. f.*	0	7
S. ch. &. P. c.	7	*S. ch. & P. c.*	0	7	*S. ch. & P. c.*	0	7

Comparison between QS of parasites and hosts' phylogeny					*Comparison between QS of parasites and hosts' food habit*			
Host	QS Rank	Ph. r.	Ph. s.	Pa	QS Rank	Fh. r.	Fh. s.	Pa.
A. t. &. A. f.	1	1	A. s.	1.0	1	2	R. m. s.	0.9
A. t. &. P. c.	2	4	R. l. s.	0.8	2	5	R. l. l. s.	0.7
S. c. &. A. t.	3	2	R. m. s.	0.9	3	2	R. m. s.	0.9
S. c. &. A. f.	4	2	R. l. s.	0.8	4	1	R. l. l. s.	0.7
A. f. &. P. c.	4	4	A. s.	1.0	4	4	A. s.	1.0
S. c. &. P. c.	6	4	R. l. s.	0.8	6	6	A. s.	1.0
				5.3				5.2

Abbreviations used and explanations

A. f. =Acridotheres fuscus, A. t. = A. tristis, P. c. = Pycnonotus cafer, S. c. =Sturnus contra, S. ch. = Streptopelia chinensis. Ph. r. = Ranking on phylogenetic similarity. Ph. s. = Similarity between phylogenetic ranking and QS ranking, A. s. = Absolutely similar (e.g., Phr. = 1 and QS = 1), R. m. s. = Relatively more similar (= a difference of only one in the values of the two rankings), R. l. s. = Relatively less similar (= a difference of only two in the values of the two rankings), R. l. l. s. = Relatively less similar (= a difference of only three in the values of the two rankings). F. h. r. = Food habit similarity ranking, F. h. s. = Similarity between food habit similarity rankings and QS rankings, Pa. = Point assigned: (1.0 for A.s., 0.9 for R.m.s., 0.8 for R.l.s, 0.7 for R.l.l.s).

Four-species-infection was obtained only once in the combination of *Dp*. + *M. h.* + *Pl*.2 +. *B.c.* (Table 3). All the 4 R^2 values were insignificant. That means the multiple effect of the remaining 3 variables (e.g., *M.h.* + *Pl*.2 + *B.c*.)on any dependent variable, *Dp*. in this case, was not statistically insignificant.

Like the 4-level infection, the 5- level one was also obtained only once as *Dp*. + *Pl*.1 + *Pl*.2 + *B. c*. + Trem.(Table 3). Here, the multiple regressions yielded some more significant results. The multiple effects of 4 co-occurring variables on each of *Pl*.1, *B. c*. and Trem. were significant. The R^2 values were 0.101 ($p = 0.033$), 0.135 ($p = 0.012$) and 0.204 ($p = 0.001$) respectively for *Pl*.1, *B. c.* and Trem. However, individually, the coefficient(s) of only *Pl*.2 and Trem.; of only *Pl*.1; of only Trem., and only of *Pl*.1 and *B.c.* were significant in the cases, of dependent variables *Pl*.1, *Pl*.2, *B.c*., and Trem., respectively. So, for verifications of the indications obtained from the coefficient of the above variables, the following partials were done.

- *Pl*.1 *Pl*.2.*Dp*. *B. c.*Trem. $^{r = -0.256*,\ p = 0.046,\ df = 60}$.....4

  (i.e., controlling the remaining 3 parasite variables of the association).
- *Pl*.1*Pl*.2. *Dp.B. c.*Trem. Asc.*M. h.* $^{r = -0.315*,\ p = 0.014,\ df = 58}$.....4.1

  (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*).
- *Pl*.1 Trem..*Dp.Pl*.2 *B. c* $^{r = 0.258*,\ p = 0.043,\ df = 60}$.....5
- *Pl*.1 Trem.. *Dp.Pl*.2 *B. c.M. h.*Asc. $^{r = 0.294*,\ p = 0.023,\ df = 58}$.....5.1

  (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*)
- *B.c.*Trem..*Dp.Pl*.1 *Pl*.2 $^{r = 0.374**,\ p = 0.003,\ df = 60}$.....6
- *B.c.*Trem.. *Dp.Pl.*1 *Pl*.2 *M. h.*Asc. $^{r = 0.437***,\ p = 0.001,\ df = 58}$.....6.1

  (i.e., controlling all the remaining 5 parasite taxa out of the 7 collected from *S. contra*).

The above partials also reveal the influence of uncontrolled variables in the equations – a matter termed here as factor interaction meaning the interaction among the co-occurring parasite species of the hosts.

Acridotheres tristis

Ecto–parasites

Sixty-six birds of this sturnid species were autopsied, of which 9 (13.6 %) were free of any ecto–parasite (Table 3). Only one species, *Menacanthus eurysternus*, was present in the remaining 57 birds.

Endo–parasites

Four endo–parasite species were collected from 53 birds, the others 13 (19.5 %) were free of any endo–parasite. Twenty-five birds had single-species-infection, 19 were infected by 2 and 9 by 3 parasite species. Double infection occurred in 6 combinations (Table 3), of which in only one case (*B.c.* + Cest.1) the two parasite species were significantly correlated ($r = 0.412$, $p = 0.001$, $N = 66$; *B. c.* Cest.1. *Pl*.2 *B. r.* $^{r = 0.413,\ p = 0.001,\ df = 62}$).

Triple infection occurred in 4 combinations (Table 3). In 2 (*Pl*.2 + *B.c.* + *B.r.,* and *Pl*.2 + *B.r.* + Cest.1) of them, the multiple effect of the co-inhabitants on any of the parasite species (dependent variable) was insignificant; i.e. all the 6 R^2 values were insignificant. On the other hand, R^2 for *B c.* and Cest.1 were both significant in the rest 2 multiple infection cases – *B.c.* + *B.r.* + Cest.1, and *Pl*.2 + *B.c.* + Cest.1, but the higher R^2 value for *B. c.* ($R^2 = 0.165$, $p = 0.001$, df = 2, 63) in the *B.c.* + *B.r.* + Cest.1 case than that for *B c.* ($R^2 = 0.148$, $p = 0.002$, df = 2, 63) in the other case (*Pl*.2 + *B.c.* + Cest.1) indicates that the multiple influences on the same dependent variable vary with the difference in the co-occurring parasite species – another example of factor interaction explained earlier. Among the endo–parasites harbouring *A. tristis*, however, only

one case of significant correlation was present, i.e., between *B. c.* and Cest.1 ($p = 0.001$).

Acridotheres fuscus

Ecto–parasites
Of the 62 birds autopsied, 20 were free of any ecto–parasite. Two parasite species were collected. *M. eurysternus* and *B. zohrae* occurred singly in 18 and 12 birds, respectively. Combined infection by the 2 species was present in 12 birds (Table 3).

Endo–parasites
Four endo–parasite species were present in *A. fuscus*. Thirteen birds (20.97 %) were free of any endo–parasite; 22 carried infection by single species, 23 had double infection, and only 4 bore triple infection (Table 3). Double infection occurred in 6 combinations, of which *Dp.* + *B.c.* was the most prevalent one having a frequency of 10. The remaining 5 combinations, with the frequency value in parenthesis, were *B.c.* + *B.r.* (1), *B.c.* + Cest.2 (4), *B.r.*+ Cest.2 (4), *B.r.* + *Dp.* (2), and *Dp.* + Cest.2 (2). Triple infection occurred in only 2 combinations – *B.c.* + *B. r.* + *Dp.* (1), and *B c.* + *Dp.* + Cest.2 (3). Simple and partial correlations, and multiple regressions analyses all revealed that there was no significant relationship between any 2 or among the endo–parasite species of *A. fuscus*.

Pycnonotus cafer

Ecto–parasites
Sixty-four birds of this species were autopsied; 19 were free of any ecto–parasitic infection. Only one species, *Myrsidea kathleenae*, parasitised the remaining 45 hosts (Table 3).

Endo–parasite
Five of the autopsied birds were free of any endo–parasite. Only 3 endo–parasite species harboured this host. Majority of the infected hosts bore single infection – *B. carbonis* had a frequency of 20, *B. rudolphii* 11, and Cest.3 harboured only 6. Multiple infection occurred in 2 levels – double infection in 20 birds, and triple infection in only 2 (Table 3). Double infection occurred in 3 combinations – *B.c.* + *B.r.* (f = 8), *B.c.* + Cest.3 (5), and *B.r.* + Cest.3 (7). Triple infection occurred in 2 birds in only 1 combination (*B. c.* + *B. r.* + Cest.3). As was found in the case of *A. fuscus*, correlation and regression analyses revealed that there was no significant relationship between, or among the endo–parasite species of *P. cafer.*

Streptopelia chinensis

This Columbiformes host had a poor parasite fauna, consisting of only 2 ecto–parasite and one endo–parasite species.

Table 3 *Parasite association – separately for endo–parasites and ecto–parasites.*

Association of endo–parasites	***S. c.***	***A. t.***	***A. f.***	***P. c.***	***S. ch.***	**Total**
0	8	13	13	5	21	60
Dp	10		5			15
Bc	8	12	5	20		45
Br		10	8	11		29
Pl1	4					4
Pl2	6	2				8
C1		1				1
C2			4			4
C3				6		6
C4					39	39
Dp + Pl1	3					3
Dp + Pl2	2					2
Dp + Bc	4		10			14
Mh + Pl1	1					1
Mh + Pl2	1					1
Mh + Bc	1					1
Mh + Dp	1					1
Pl1 + Bc	1					1
Pl2 + Bc		6				6
Pl2 + Br		3				3
Pl2 + C1		1				1
Bc + Br		1	1	8		10
Bc + C1		7				7
Br + C1		1				1
Bc + C2			4			4
Br + C2			4			4
Br + Dp			2			2
Dp + C2			2			2
Bc + C3				5		5
Br + C3				7		7
Mh + Pl1 + Bc	3					3
Dp + Pl1 + Bc	2					2
Dp + Pl2 + Bc	3					3
Dp + Mh + Pl2	2					2
Dp + Asc1 + Bc	1					1
Mh + Asc1 + Bc	1					1
Mh + Pl2 + Bc	1					1
Pl2 + Bc + Br		3				3
Bc + Br + C1		3				3
Pl2 + Br + C1		1				1
Pl2 + Bc + C1		2				2
Bc + Br + Dp			1			1
Bc + Dp + C2			3			3
Bc + Br + C3				2		2
Dp + Mh + Pl2 + Bc	1					1
Dp + Pl1 + Pl2 + Bc + Trem1	1					1
Total	**65**	**66**	**62**	**64**	**60**	**317**
Association of ecto–parasites	***S. c.***	***A. t.***	***A. f.***	***P. c.***	***S. ch.***	**Total**
0	7	9	20	19	20	75
Me	4	57	18			79
Ss	3					3
Bz			12			12
Mk				45		45
Nl					7	7
Ct					3	3
Ss + Me	51					51
Me + Bz			12			12
Nl + Ct					30	30
Total	**65**	**66**	**62**	**64**	**60**	**317**

Ecto–parasite
Of the 60 hosts autopsied, 20 (33.3 %) were free of any ecto–parasite species (Table 3). Among the infected hosts, 7 had only *Nitzschiella lativentris*, and 3 only *Columbicola turturis*. Infection by a combination of *N. lativentris* and *C. turturis* was the most prevalent one, occurring in 30 hosts.

Endo–parasite
Twenty-one birds (35 %) did not have any endo–parasite at all (Table 3). The remaining 39 hosts were infected by only 1 species, an unidentified cestode taxon, designated presently as only Cestode-4 – an apparently unusual finding in view of the absolutely granivorous food habit of the host.

Discussion

The parasite fauna was most diversified, among the present 5 bird host species, in *S. contra* (SR = 9, H´ = 2.18). These values were 5 and 1.43, 6 and 1.85, and 4 and 1.41 in *A. tristis*, *A. fuscus* and *P. cafer*, respectively (Table 1). Of those 4 host species, the first 3 belong to the same family; *A. tristis* and *A. fuscus* still further closer belonging to the same genus. *P. cafer* belongs to a different family of the same order as that of *S. contra*, *A. tristis,* and *A. fuscus. S. chinensis* had only 3 species (2 ecto– and 1 endo–parasite); hence, H´ and other related indices could not be calculated for this host.

S. contra was predominantly insectivorous; whereas, *A. tristis* and *A. fuscus*, though primarily insectivorous, had increasing amounts of plant materials in their diet (Table 1). On the other hand, *P. cafer* was predominantly a plant-eater, taking also a little percentage (6.03 %) of insects. The sequence of SR values of the parasite faunas of the sturnid hosts (*S. contra* > *A. fuscus* > *A. tristis*) and the low SR value (4) of *P. cafer* indicate the influence of animal food parts on the diversity of parasite faunas of hosts. The poor parasite fauna of *S. chinensis* similarly supports the above view regarding the influence of food items on the parasite species number of a bird host. It may be mentioned here that *S. chinensis* was absolutely a granivorous species, belonging even to a different order than the other 4 birds. In short, it appears that insects, as food items, play an important role in the formation of parasite fauna of a host. Apparently, however, an inexplicable matter was present in *S. contra* and *S. chinensis*. *S. contra* being a predominant insectivore was free of any cestode, whereas *S. chinensis*, being an absolute granivore, did have a cestode species of quite high prevalence. It should be mentioned here that cestodes complete their life cycle generally through the involvement of an intermediate host. This cestode-matter of *S. chinensis* appears to present an interesting problem for further study.

The phylogeny of host also has a role in the composition of its parasite fauna (Kennedy 1975; Klimpel *et al.* 2007). The importance of phylogeny of host and its food habit on the parasite fauna has been analysed by ranking the similarity in the phylogenies and food habits of 2 host species and then comparing each of those values with that of the QS between their parasite faunas. Table 2 indicates that the influence of those 2 host factors (phylogeny and food habit) on the composition of its parasite fauna is almost absolutely similar – the sums of points assigned to similarity in the rank of QS and that of phylogeny, and to similar matter between QS and food habits of hosts were 5.3 and 5.2, respectively (Table 2). The highest QS value, however, of only 54.6 % (Table 1) between the parasite faunas of *A. tristis* and *A. fuscus* strongly indicates that further factors are there influencing the composition of parasite fauna of a host. Factors, such as host body size (Poulin 1997), social interaction (Anderson & May 1979; Anderson & May 1991), host population density (Morand & Poulin 1998; Nunn *et al.* 2003), habitat diversity (Nunn *et al.* 2003),host geographical range (Bagge *et al.* 2004; Poulin & Morand 2004), host behaviour (Alexander 1974; Hart 1990; Moore 2002), latitude (Guernier *et al.* 2004; Nunn *et al.* 2005), host specificity, age, parasite competition, migration and anti-parasitic defences of host (Esch *et al.* 1990; Gregory *et al.* 1996; Kuris *et al.* 1980; Nunn *et al.* 2003; Poulin 1995; Poulin 1998; Simberloff & Moore 1997) also have influence on parasite fauna. In this study the influence of body size (including gut size) and plumage nature has been apparent in the highest SR of parasites of *S. contra* (9) and the lowest SR (4) of *P. cafer*, among the 4 passerine hosts.

Specificity
Of the 18 parasite taxa collected from the 5 host species, 13 (72 %) had strict host specificity. Of them, 5 were ecto–parasites and 8 were endo–parasites. It is interesting that 83 % of the ecto–parasites were strictly host-specific, compared to only 67 % of the endo–parasites. Living externally and having direct contact with the exterior, the ecto–parasites were likely to be more distributed among hosts. The contrary observation indicates the possible role of intricate physiological, biochemical, etc., matters behind this. The ecto–parasite *M. eurysternus* was present in all the 3 sturnid hosts autopsied. This is consistent with the earlier observation on its wide distribution among passerine hosts (Price 1975).

The 4 endo–parasite species, having wide specificity, all belong to the nematode group. Of them, *Plicatolabia* sp.2 and *Diplotriaenoides* sp. each parasitised 2 sturnid hosts – *S. contra* and *A. tristis* by the former, and *S. contra* and *A. fuscus* by the latter. *B. rudolphii* was still wider in its distribution – inhabiting *A. tristis*, *A. fuscus,* and *P. cafer*, i.e., involving birds of 2 families (Sturnidae

and Pycnonotidae). *B. carbonis* was, however, had the widest distribution occurring in 4 (*S. contra*, *A. tristis*, *A. fuscus,* and *P. cafer*) out of the 5 host species investigated. *B. carbonis* and *B. rudolphii* have earlier been reported (Barus & Sergeeva 1990; Frantova 2001) from different species of water fowl. The present hosts of *B. carbonis* and *B. rudolphii*, though are not water fowl, but are frequent visitors of marshy lands for feeding. Johnson *et al.*(2002) stated that dispersal limitation can be studied by exploring genetic structure of populations with varying degree of host specificity. They found relatively more sequence divergence in cytochrome oxidase I (COI) gene in lice parasites of wider specificity than that of lice of strict or less wide specificity. Work in this line is necessary to get an understanding of the varying degree of host specificity found in the present parasites.

Presently, 2 species of *Plicatolabia* were collected from *S. contra*. One of them, *Plicatolabia* sp.1, also occurred in *A. tristis*. The genus itself has so far been recorded only from a marine mammal of the manatee group (Yamaguti 1961). The present record of *Plicatolabia* spp. is thought to be an interesting finding, in the context of the above observation.

Association of species in the parasite communities

Association of parasites was studied only with the data of endo–parasites, because, for proper analyses of this aspect, quantitative data for ecto–parasites may not be fully reliable for their tiny size and hidden nature. Analyses of parasite association revealed multiple infections at a number of levels – double, triple, quadruple, and quintuple. Correlation and regression were used for the investigation of multiple infections. The matter has been presented in details in the results. The analyses showed that only a few relationships were significant – 6 such cases were present in *S. contra*, and only one in *A. tristis*. There was no significant relationship between any 2 parasite species of each of *A. fuscus* and *P. cafer*. Such analysis was not at all possible for *S. chinensis,* because only one endo–parasite taxon was present in this bird host.

The 6 significant relationships were between *M. helix* & *Plicatolabia* sp.1 (positive, $p = 0.017$), *M. helix* & *B. carbonis* (positive, $p = 0.043$), Ascarididae-1 & *B. carbonis* (positive, $p = 0.032$), *Plicatolabia* sp.1 & *Plicatolabia* sp.2 (negative, $p = 0.014$), *Plicatolabia*sp.1 & Trematode-1(positive, $p = 0.023$)**,** *B. carbonis* & Trematode-1 (positive, $p = 0.001$) in *S. contra*, and between *B. carbonis* & Cest-1 (positive, $p = 0.001$) in *A. tristis*. The relationships were positive in 5 cases, and negative in one (*Plicatolabia* sp.1 and *Plicatolabia* sp.2) in *S. contra*. In *A. tristis* the only significant relationship found was positive.

The negative correlation between *Plicatolabia* sp.1 and *Plicatolabia* sp.2 is understandable, because, both being taxa of the same genus and inhabiting same habitat (small intestine), there should naturally be competition between them. Other than *M. helix,* which inhabits posterior oesophagus, the other 6 mentioned above, inhabit the small intestine. The positive correlations between nematodes inhabiting same habitats offer interesting problems for further study. There must have been delicate aspects in these relationships, especially between *M. helix* (posterior oesophagial) and *Plicatolabia* sp.1 (small intestinal).

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Chapter 11: First Record of Land Molluscs *Macrochlamys lubrica*, *Girasia hookeri*, *Euaustenia cassida,* and *Sitala attegia* (Mollusca: Stylommatophora: Ariophantidae) from Bangladesh

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Abstract

A total of 4 terrestrial molluscs species under the family Ariophantidae, Order - Stylommatophora were collected, which are new records for Bangladesh. The information on the distribution and ecology, population density, and seasonal variation of *Macrochlamys lubrica*, *Girasia hookeri, Euaustenia cassida,* and *Sitala attegia* are provided in this paper. Population density was measured. Pearson correlation among meteorological factors of season (air temperature, rainfall and humidity) and molluscs population density were calculated.

Keywords; *land molluscs, first records, Ariophantidae*

Introduction

The molluscs are found in a wide range of habitats, from tropical to the polar seas, at altitudes exceeding 7000 m, such as the Himalayas, in flood plains, ponds, lakes, beels, baors, streams, paddy fields, forest beds, mud flats, mangroves, rivers, and the seas from pelagic to benthic depths. The land molluscs are adapted to all kinds of weather and dwell on ground habitats ranging from bushes, park gardens, vegetations and forests, particularly inhabiting those that offer sufficient shady and moist places. Malacologists, especially those who studied the land molluscs, unanimously accepted that land snails cause considerable damage to economic plants throughout the globe. Mead (1961) stressed that the problems presented by pestiferous snails would be with us for a long time to come and some of them are destined to be serious pests in the future.

Some researchers have worked on the systematics, abundance, breeding biology, and parasitological importance of some mollusc species from Bangladesh and India (Jahan 1993; Jahan *et al.* 2002; Jahan *et al.* 2003; Jahan & Raut 1994; Mannan & Khan 1990; Panigrahi & Raut 1992; Raut 1978; Raut 1979; Raut & Ghose 1981).

Methods

Study area

The north-eastern region includes the districts of Brahmanbaria, Comilla, Habiganj, Moulvibazar, Sylhet, and Sunamganj. This region covers a land area of 13,938.65 km^2 and is situated between 23°.2 to 25°.2′ N and 91°.7′ to 92°.41′E (Figure 1). Reserve forest, hills, haors, and beels are also included in this region.

Intensive surveys of population densities and seasonal variation of mollusc species in respect of climatic factors (temperature, humidity, and rainfall) of the north-eastern region of Bangladesh were carried over two years (2005-2007). From each of the localities, three quadrates of 1m^2 area each were taken in respect of summer, monsoon, and winter seasons. A total of 54 quadrates were selected for 3 localities: (1) 'BARD' annexe forest, Comilla, (2) Lawachara National Park of Moulvibazar district, and (3) Malnichara Tea Garden annexe forest of Sylhet district.

The collected snails were preserved in 70 % ethyl alcohol and then identified following (Gude 1914; Mitra *et al.* 2005) and confirmed from the Mollusca Division of the Zoological Survey of India, Kolkata. A sample of 200 adults of each species were randomly collected from the natural habitats of the north-eastern region of Bangladesh and their various morphometric measurements were taken with the help of a divider, scale, and slide callipers.

Results

A total of terrestrial mollusc species belonging to 4 genera of Ariophantidae family, Stylomamatophora order under class Gastropoda were recorded. The species were *Euaustenia cassida*, *Macrochlamys lubrica*, *Girasia hookeri,* and *Sitala attegia* found for the first time in Bangladesh. Pearson correlations among the climatic factors of different seasons and mollusc species population densities are presented in the Tables 1 and 2.

Diagnostic characters of *Macrochlamys lubrica*

***Genus: Macrochlamys* Benson, 1832.**
Species name: Macrochlamys lubrica Benson.
Synonyms: 1852. *Helix lubfica* Benson, Ann. *Mag, nat, Hist. (2) 10:349.*

Table 1 *Pearson's correlation among the climatic factors of different seasons and mollusc species population densities of Malnichara, Lawachara and BARD forest.*

Species	*S. attegia*			*E. cassida*		
Seasons	***Summer***	***Monsoon***	***Winter***	***Summer***	***Monsoon***	***Winter***
Habitats						
Malnichara	-	-	-	0.973	0.984	-0.656
Lawachara	-	-	-	-	-	-
Comilla BARD	0.875	0.940	- 0.795	-	-	-

Note: Population densities are not determined for Macrochlamys lubrica and Girasia hookeri.

Table 2 *Population densities of S. diplodon and S. castra.*

Species	*S. attegia*			*E. cassida*		
Seasons	***Summer***	***Monsoon***	***Winter***	***Summer***	***Monsoon***	***Winter***
Habitats						
Malnichara	-	-	-	0.16 ± 0.16	1.33 ± 0.33	-
Lawachara	-	-	-	-	-	-
Comilla BARD	0.83 ± 0.33	4.5 ± 0.5	-	-	-	-

Note: Population densities are not determined for Macrochlamys lubrica and Girasia hookeri.

1908. *Mocrochlamys lubrica,* Branford & Godwin-Austen, *Fauna of British India, Mollusca,* Testa cellidae and Zontidae 89.

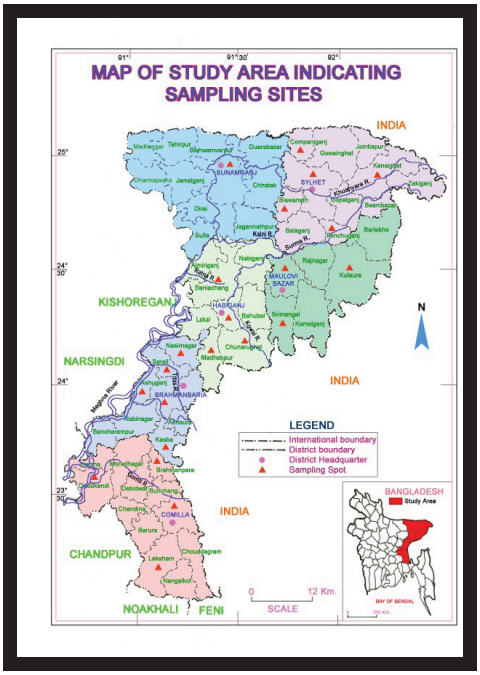

Figure 1 *Map of study area indicating sampling sites***.**

Description: Shell large, rather thin, depressed, perforate, smooth, and polished. yellowish to brownish with, finely microscopically striate; spire low, almost flat; whorls *5,* flatly convex above, the last much broad, rounded at the periphery, and blow, aperture spherical, broadly lunate peristome thin, arcuate above, calomella reflected above, basal margin slightly thickened inside. Distinct for its shining shell with flattened spire and broad last whorl (Figures 2a, 2b).

Figure 2a *Apertural view of Macrochlamys lubrica.*

Figure 2b *Apertural view of Macrochlamys lubrica.*

Size: Average length of shell, width, aperture length and width are 10.25 ± 0.35 mm and 18.5 ± 0.7mm, *7.5* ± 0.70 mm, and 7.25 ± 0.35 mm respectively.
Distribution: Sylhet district.
Elsewhere: India, West Bengal, Sikkim, and Meghalaya (Garo hills).
Habit: M. lubrica is nocturnal in habit. In the daytime hidden in the soil and litter near the base of

trees. They feed on tender leaves of plants, such as gourd, beans, marigold, lettuce, cabbage, and wild plants.
Habitat: Found in terrestrial habitat, kitchen garden, and bushes.
Population density: This species found sporadically during the study period.
Economic importance: Macrochlamys lubrica is a serious vegetable pest and has already established itself as a pest of mulberry plants in silk-growing regions of Bangladesh. It is frequently observed to graze upon the leaves of seedling and sapling of the rabi or winter crops.
Ecological role: M. lubrica plays a role as a vegetable pest in the food chain.

Diagnostic characters of *Girasia hookeri*

***Genus: Girasia* Gray, 1855.**
Species name: Girasia hookeri Gray.
Synonyms:
1855. *Girasia hookeri Gray, Cat.Pu1m.Brjt.Mus.p.6l.*
1872. *Helication (Hoplifis) theobaldi,* Godwin-Austen, P.ZS.p.517.
1875. *Helicayion shillongense*, Godwin-Austen, *J.A.S.B*.p.4.
1875. *Helication brunneum*, Godwin-Austen, *J.A.S.B*.p.5.
1891. *Girasia extranea* Cockerell, *A, M.N.H.(6) P.* 104.
1908. *Girasia hookeri* Blanford & Godwin-Austen, *Fauna of British India, Mollusca,* Testa cellidae and Zontidae p. 200.
Local name: Kukurjak (Sylhet).
Description: Shell oblong membranous and soft, with a thin olivaceous, epidermis curled up so as to form an incipient spire at one end, drawn out into a broad ribbon like stripe at the other. Animal varying from pale yellowish dull grey or pale brown to ochraceous or dark umber-brown sometimes spotted on mantle. The mantle-lobes completely cover the shell, at times leaving a small area exposed; they also cover a considerable portion of the animal in front of the shell (Figures 3a and 3b).
Size: Average body length and width are 61.00 ± 6.55 mm and 10.16 ± 0.76 mm respectively.
Distribution: Abundant in Comilla, Maulvibazar, Sylhet, Chittagong, and Chittagong Hill Tracts.
Elsewhere: India.
Habits: Hermaphrodite and herbivorous. Feeds on soft twigs or leaves of plants.
Habitat: Found in terrestrial habitat, kitchen garden, bushes, and leaves of large trees. During observation they were creeping on grass and crevices of bricks.
Population density: Found sporadically, so population density cannot be determined.
Economic importance: It is a vegetable pest.
Ecological role: The slugs play an important role in the terrestrial and arboreal ecosystems as herbivores.

Figure 3a *Whole view of Girasia hookeri.*

Figure 3b *Shell of Girasia hookeri.*

Diagnostic characters of *Euaustenia cassida*
***Genus: Euaustenia* Cockerell, 1891.**
Species: Euaustenia cassida Hutton, 1838.
Synonyms:
1838. *Euaustenia cassida* Hutton, *J. Asiat Soc, Beng*., 7:214.
1908. *Euaustenia cassida*: Blanford & Godwin-Austen, *Fauna of British India, Mollusca,* Testacellidae & Zonitidae: 150.
Description: Shell large, ovately depressed, very thin and fragile, imperforate, yellowish brown; decussately sculptured by raised oblique striate and very fine, close spiral lines both above and below; spire slightly convex, very slightly raised; whorls 4-4^{1}/2, convex, rapidly increasing in size, the last very broad and large, well rounded above and below; aperture strongly oblique, ovately lunate, peristome thin, upper margin remarkably arcuate, columellar margin curved, sinuate and reflected above forming a false perforation-like opening (Figures 4a and 4b).
Size: Average length of shell, width, shell aperture and width are 5.5 ± 1.41 mm, 8.75 ± 2.47 mm, and 4.75 ± 1.06 mm respectively.
Distribution: Moulvibazar and Sylhet district.

Figure 4a *Whole view of Euaustenia cassida.*

Figure 4b *Ventral view of Euaustenia cassida.*

Elsewhere: India: Western Himalaya, Himachal Pradesh, Kashmir, Punjab, and Uttaranchal.
Habit: They feed on decaying leaves and bark of trees. These snails are nocturnal. They are found active June to August. The remaining months of the year are spent in aestivation. During the monsoon found in daytime.
Habitat: Found in tree like as Jackfruit, Mehogoni, and Rakton Tree *(Lophopetolum fimbrianium)*. The snail can run fast.
Population density: E. cassida was highest (5.33/10 m^2) during the monsoon in Malnichara tea garden forest, Sylhet and minimum (0.33/10 m^2) summer in the same forest (Table 2).
Economic importance: It is a vegetable pest.
Ecological role: E. cassida plays an important role in the terrestrial and arboreal ecosystems as herbivores.

Diagnostic characters of *Sitala attegia*

***Genus: Sitala* H. Adams, 1865.**
1865. *Sitala* H. Adam, *Proc.zool.Soc.Lond.,* p.408.
Species name: Sitala attegia Benson.
Synonyms:
1959. *Helix attegia* Benson *Ann. Mag. Nat. Hist.,* (3): 184.
1908**.** *Sitala attegia* Blanford & Godwin-Austin, *Fauna of British India, Mollusca,* Testa cellidae &

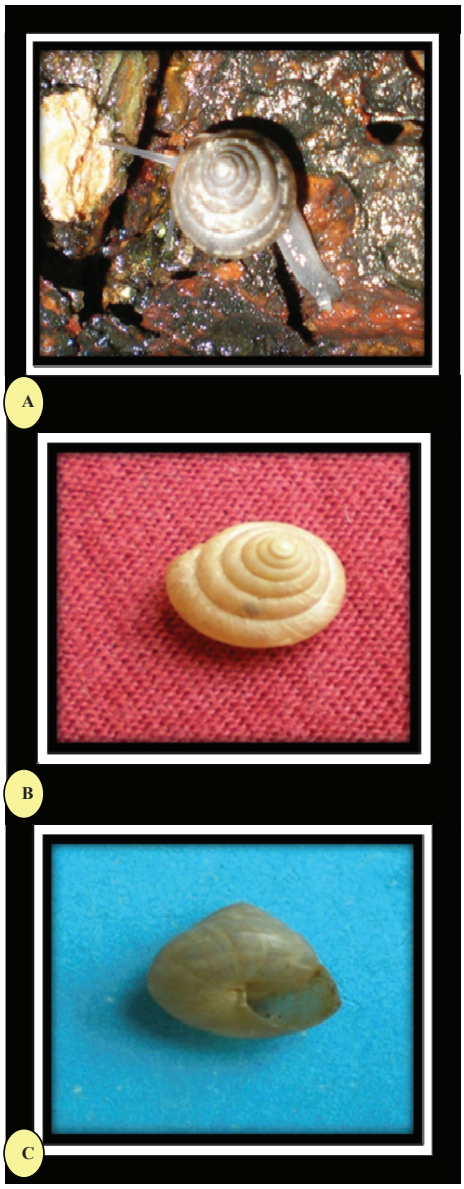

Figure 5 *Sitalia attegia, a: Dorsal view (Live), b: Dorsal view, c: Ventral view*

Zonitidae: 227.
Description: Shell rather small conoid, subtrochiform, very narrowly perforate, thin pale, yellowish translucent; decussately sculptured by oblique striate and raised spiral lines, both above and below, some of the spiral lines more prominent; spire conoidly raised, apex pointed; whorls 7-7.5 convex, gradually increasing, the last keeled at the periphery, rounded beneath; aperture oblique, sub–quadrately lunate, peristome thin, slightly arcuate

above, columellar margin vertical, broadly reflected above (Figures 5a, 5b, and 5c).

Size: Average length of shell, width, and shell aperture and width are 7.0 ± 5.81, 7.33 ± 6.08, and 2.66 ± 0.28 mm respectively.

Distribution: Comilla, Maulvibazar districts.

Elsewhere: India Andaman Inlands, Myanmar.

Habit: They feed on decaying leaves and tree bark. These snails are nocturnal. They are active June to August. The remaining months of the year are spent in aestivation. Occasionally, during the aestivation, they become active for a short period following a heavy shower.

Habitat: Found in terrestrial habitat, bushes twigs, and stem of large trees. During observation they are found on jackfruits (*Artocarpus heterophyllus*), teak tree *(Tectona grandis).* wood apple tree *(Aegle marmelous),* and bohera tree. They are also found on banana leaves.

Population density: During the study period, *S. attegia* was found highest (4.5 ± 0.5/10m^2)in monsoon; BARD annexe forest, Comilla District and lowest (0.83/10m^2) in the same forest.

Economic importance: It feeds on soft twigs and leaves of plants.

Ecological role: The snail plays an important role in the terrestrial and arboreal ecosystems as herbivores. Shell medium sized, depressed to turbinate; usually openly umbilcate, sculptured; more or less, circular, often variously, modified. Operculum calcareus or horny, many whorls, sometimes externally convex.

Discussion

Bangladesh, a land of rivers, numerous natural and artificial water reservoirs, and tropical evergreen rainforest with grasslands, offers suitable habitats for the land– and freshwater–dwelling mollusks, but a comprehensive account of the malacofauna of Bangladesh is lacking. In 1993, Jahan (1993) reported 23 (13 terrestrial and 10 fresh water) gastropod specimens belonging to 19 genera, 14 families and 4 orders, recorded from different localities of Bangladesh. Later, Jahan *et al.* (2003) reported sixteen molluscs species from Rajshahi university campus, Bangladesh, of which 14 species were also reported previously by Jahan (1993). Thus, Jahan (1993) and his associate workers (2003) recorded the presence of 14 species of land molluscs from the territory of Bangladesh for the first time a long time after publication of the Fauna of British India. These species were *viz*. *Cyclophorus auranticus* var. *pernobilis, C. aurora, Pterocyclus parvus*, (Cyclophoridae), *Achatina fulica* (Achatinidae), *Macrochlamys sequax*, *M. opiparus*, *M. indica, Girasia burtii* (Ariophantidae), *Glessula gemma* (Glessulidae), *Opeas gracile* (Subulinidae), *Rachis bengalensis* (Enidae), *Incillaria monticula* (Philomycidae), *Indosuccinea semiserica* (Succinidae), and *Semperula birmanica* (Veronicellidae).

In the present study 26 terrestrial mollusc species were recorded from the different localities of the study area. Of these 26 land molluscs *M. lubrica, G. hookeri, Girasia. crocea, Euaustenia cassida, Sitala attegia* (Ariophandae) *G. notigena* (Subulinidae), *G. gemma*, *S. diplodon, S. castra* (Helicarionidae), *C. delibrata* (Camaenidae), *I. plicata, Succinea daucina* (Succinidae), *Austenia gigas P. (E.) plectosoma* (Plectopilidae), *Pterocyclus parvus, Streptaxis pfeifferi* (Streptaxidae) *F. alte* (Veronicellidae), *C. theobaldinus*, *C. pearsoni, Chamalycaeus crenatus*, (Cyclophoridae), *A. fulica fulica*, *R. bengalensis, Lamellaxis (Allopeas) gracile* molluscs species were reported previously from the same area (Blandford & Godwin-Austen 1908; Gude 1914, 1921; Jahan 1993; Siddiqui *et al.* 2007).

The molluscs *M. lubrica, G. hookeri, Euaustenia cassida,* and *Sitala attegia* (Ariophandae) were recorded during this study for the first time from Bangladesh.

The Fauna of British India reported a total of 54 terrestrial and freshwater molluscs species from present Bangladesh territory (Blandford & Godwin-Austen 1908; Gude 1914, 1921; Preston 1915).

Though the presence of *M. hardwickii*, *Clausilia loxostoma, Alycaeus sylheticus, Amphidromus sinensis*, *Tiara (Melanoides*) *terebra,* and *T. (Mellanella) zonata* were reported in Fauna of British India from the study area, they were not encountered during this study. Moreover, *C. auranticus, C. aurora,* and *I. monticola* were reported by Jahan (1993), but could not be found during this study.

Most land snails are nocturnal. The shells of several terrestrial and aquatic molluscs are extremely alike, so that the eye fails to differentiate them externally. This might be one of the causes of such omissions. Moreover, to find the snails in their natural habitats throughout the country requires very extensive survey. Besides, these natural habitats are degrading day by day due to deforestation and development activities. Pollution from industries, agriculture and erosion has seriously threatened gastropod and mussel populations. As well as river siltation, impoundment and agriculture activities in haors, baors are also destroying the natural habitats of the malacofauna. Thus, it can be assumed that species previously reported, but not found now, may be extinct.

It is inevitable that the molluscan biodiversity of any habitat play various roles for the maintenance of sustainable ecosystem, food chain, and soil fertility. Accordingly, the molluscan biodiversity of Bangladesh deserves proper management. Management of biodiversity is the basis for its state in a given region; it can disclose the position of biodiversity, indicating the on-going trend of sustainability of local flora and fauna. It also helps us

to gain and understand sufficient knowledge of interdependences of species within ecosystem, economic, aesthetic, health, and culture impacts of the decrease or extinction of one species on others. Finally, it must be emphasised that extensive survey should be made throughout the country to explore and register the total malacofauna of Bangladesh, with their interrelationships to existing ecosystem components and underlying causes of their population reduction, so that the appropriate measures can be taken to keep sustainable molluscan biodiversity for the benefit of the country.

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Chapter 12: Conservation of Guava (*Psidium guajava*) Germplasm Using Wilt-resistant Rootstock of Poly Piara (*Pisidium cattleianum*)

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Abstract

Now-a-days guava plants are suffering seriously by wilt caused by *Fusarium oxysporum*. There is no effective control measure so far studied. Grafting on wilt resistant rootstocks may help to conserve germplasm and better production. Therefore, to overcome wilting problem in guava (*Pisidium guajava*) by producing wilt resistant plants through grafting procedure using Polypiara (*Pisidium cattleianum*) seedlings as rootstocks. Three separate experiments were conducted at the BAU Germplasm Centre, Fruit Tree Improvement Project (FTIP) and the Laboratories of the Department of Crop Botany and Plant Pathology, BAU, Mymensingh. Experiment I consisted of three varieties (Kazipiara, Swarupkathi and L 49), three grafting methods (Cleft, Veneer and Contact) and two types of scion (hard wood and soft wood) of guava. Different variety showed proportionate variation in the success, and survival of the graft as well as their growth parameters. The grafting methods and scion types also influenced significantly in the above parameters independently and combindly. The highest percentage of success (93.33 %), survival (95.70 %),and scion height and leaf number were observed in the grafting done through contact method. Hard wood scion contributed better grafting success (80.74 %) than the soft wood scion (62.22 %). In all cases, Kazipiara showed better performance than the other two varieties. Anatomical studies of the successful graft union (the 2nd experiment) showed that a rapid (60-80 days) and uniform union of scion and rootstock was formed in the veneer method with the clear indication of callus, cambium, xylem, and phloem tissue formation and intermingling. Cleft and contact methods of grafting also gave effective and uniform graft union, but required more time (100 and 100-120 days for cleft and contact methods, respectively) to complete the union process. In the 3rd experiment, inoculation of *Fusarium oxysporum* f. sp. *psidii* caused a significant variation in plant height and leaf and shoot formation in the seedlings of cvs. Kazipiara and Swarupkathi, whereas the resultant grafts on Polypiara and Polypiara seedlings were unaffected by the inoculation. Finally, inoculation produced leaf infection, caused leaf drop, root damage and ultimate death of the plants of Kazipiara and Swarupkathi, but no mortality was observed in the grafts on Polypiara and Polypiara seedlings. It was found that, Kazipiara was more susceptible to wilting, and Swarupkathi was comparatively less susceptible. The inherent potentiality of Polypiara i.e., absence of tannin cell in the cortex and scattered arrangement of vessels instead of radial arrangement (in cvs. Kazi and Swarupkathi) possible reasons provided resistance against wilt disease. Considering all these factors, contact grafting with physiologically mature scion may be recommended for use on Polypiara rootstocks to overcome the wilting problem in guava cultivation. Through this process conservation of all guava germplasm is possible.

Keywords; *guava,* Psidium guajava*,* Pisidium cattleianum*, Wilt, Fusarium oxysporum* f. sp. *psidii*.

Introduction

The ever increasing malnutrition problem together with the alarming rate of population growth in Bangladesh envisages the need to achieving accelerated productivity of both the field crops and garden crops. Although recently Bangladesh has got self-sufficiency in food crops. Increase in the production of garden crops i.e., fruits and vegetables are still far behind the country's present requirement. But for sound health and good physique, consumption of adequate fruit is essential. In Bangladesh, now only 35g of fruits is available for a person against the daily requirement of 85g (HRDP 1995a). This low consumption of fruits in association with protein and calorie deficiencies are the main reasons for wide spread malnutrition in the country. It is reported that 93 % people of Bangladesh have been suffering from vitamin C deficiency (Anon 1980). All such malnutrition problems could be reduced considerably through adequate consumption of fruits, especially fruits, which are rich in vitamin C and minerals like guava.

Guava (*Psidium guajava* L.), the apple of the tropics, is one of the most important and widely cultivated fruits of Bangladesh (Ullah *et al.* 1992). It claims to be the most important fruit in area and production after mango, banana, jackfruit,

pineapple, and melon. In Bangladesh, a good number of varieties, namely, Kazi, Swarupkathi, Mukundapuri, Syedi, Kanchanagar, BAU Guava 1, 2, 3, 4, 5, 6, 7, & 8; BARI guava 1, 2 & 3, and Allahabad are cultivated successfully. Now-a-days in guava cultivation, wilting is a serious problem. Almost all the guava varieties are suffering from this disease causing a great problem in guava cultivation (Meah & Mamun 1991). One of the main causes of guava wilt is *Fusarium,* for which no effective control measure is available. Through the grafting process of propagation, benefits of certain rootstocks could be obtained (Hartmann *et al.* 1997). There is a chance that, grafting with red varieties of guava could reduce the incidence to some extent (Darshana et al. 1991). Polypiara, a red variety of guava, now growing successfully in various parts of the country, is known as *Fusarium* wilt resistant. So, vegetative propagation of guava by grafting, using Polypiara as rootstocks could help in getting wilt resistant guava plants.

Success in grafting and subsequent growth and development of the successful grafts are dependent on a number of factors including variety, methods of grafting, scion and rootstock material, and environmental condition (Hartmann *et al.* 1997). The ultimate goal of the present study was to eliminate wilting problem in guava taking advantage of the rootstock. In view of the above fact, it was necessary to investigate the response of the resultant grafts against *Fusarium oxysporum.* Although, the etiology and varietals reactions of guava wilts were studied extensively (Meah 1992; Meah & Ansari 1994; Meah & Mamun 1991), the reactions of Polypiara was not been evaluated. Therefore, a number of experiments were undertaken in the present study to achieve the following objectives: (i) to observe the success of different grafting methods on guava varieties; (ii) to find out the best grafting materials, especially scion, to ensure higher graft success; (iii) to study anatomy of the graft union process; (iv) to determine the best and effective grafting method of guava through anatomical studies; and (v) to test the resistance of the resultant grafts against guava wilt disease.

Methods

Effects of variety, methods of grafting and scion type on the success, survival and subsequent growth of guava grafts:

A set of three experiments were conducted for the present study. In the studies, investigation on the effects of variety, methods of grafting and scion type on the success, survival and subsequent growth of guava grafts, and tolerance of the Polypiara i.e., the resultant grafts to *Fusarium* wilt were carried out at the BAU-Germplasm Centre of Fruit Tree Improvement Project (FTIP) of the Bangladesh Agricultural University, Mymensingh. The other experiment, anatomical studies of the graft union processes was carried out in the laboratory of the Department of Crop Botany, BAU, Mymensingh.

Experiment 1: The present experiment was carried out to find out an effective method of vegetative propagation of guava through grafting procedure as influenced by variety, methods, and scion type. This three factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment was consisted of different levels of each factor.

Treatments

Factor A: Variety	**Factor B: Methods of grafting (3)**
Kazipiara (V_1)	Cleft method (G_1)
Swarupkathi (V_2)	Veneer method (G_2)
L49 (V_3)	Contact method (G_3)

Factor C: Scion type (2)
i. Hard wood scion (H)
ii. Soft wood scion (S)

Thus, there were 18 treatment combinations. A total of 270 grafts ($18 \times 3 \times 5$-for each replication) were done in this experiment. Studies on growth technology of Veneer, Cleft, and Contact method were followed.

Experiment 2: Anatomical studies of the graft union process in guava:

For the anatomical studies, the experimental material was the excised grafts parts of the successful grafts, where union took place. Then the specimen was fixed in FAA solution followed by dehydration, infiltration, sectioning, and staining was done as per standard techniques.

Experiment 3: Tolerance of the resultant grafts (Desire variety on Polypiara) to* Fusarium *wilt:

Guava seedlings of about 1 year old of three varieties namely Kazipiara, Swarupkathi, and Polypiara and the grafted plants were used in the experiment. The seedlings of guava plant were inoculated with the spawn of *Fusarium oxysporum* sp. *psidii.* Inoculation was done in two methods namely mycelia block placement and soil inoculation with oat culture. The pot experiment was laid out following Randomized Complete Block Design (RCBD) with 3 replications. Thus the experiment comprised of -

Factor A: (Guava variety)
Kazipiara (V_1)
Swarupkathi (V_2)
Plant of Polypiara + Kazi/Swarupkathi (V_3)
Polypiara (V_4)

Factor B (Inoculation methods)

T_0 – no inoculation

T_1 – root inoculation (Mycelial block placement)

T_2 – soil inoculation (Oat culture)

Treatment Combination = $4 \times 3 = 12$

Total number of plant = $12 \times 3 \times 2$ (2 plants per replication) = 72.

For the convenience of data collection non-inoculation was considered as control and actually the differences between non-inoculated and inoculated were measured to get the response of *Fusarium* to the guava seedlings.

The soil was collected from the experiments site and was sterilized with formalin (200 ml 4 % Formalin per cft. soil). The treated soil was covered by polythene sheet for 72 hours without disturbance. After 72 hours, the polythene sheet was removed and the sterilized soil was exposed to air by 48 hours in order to remove excess vapour of formalin. The earthen pots were filled with the sterilized soil. A piece of broken earthen pot/brick was placed on the hole at the bottom of each pot to drain out excess water. A fertilizer dose of 20 g urea + 10 g MP +10g TSP + 3g $ZnSO_4$ was applied per pot before 7 days of planting.

Thirty six seedlings were transplanted in 36 pots. The rest 36 pots were given seedlings treated with mycelial block. Watering, insecticide spraying, weeding etc. were done from time to time.

Isolation of* Fusarium oxysporum *f. sp.* psidii *from diseased guava plants

The affected plant parts (roots and stems) of guava plant were collected from the experiment site. The affected plant parts were cut into small pieces (of 2 to 3 cm) and after washing they were surface sterilized 1: 1000 Mercuric Chloride solution. The pieces were dipped in the solution for 1 minute. The pieces were then washed thoroughly with sterile water thrice.

After surface sterilization, each piece was splitted longitudinally by sterilized secateurs. Five pieces of inocula (diseased specimen) were placed in acidified PDA plates aseptically. During plating excess water adhering with the inoculation was drained off by touching the inoculum at the edges of the Petri dish. The plates were incubated at room temperature (20 ± 2^0C.). Daily observations were made for growth of pathogen from the inocula. Pathogen was identified following the key outlined by Aycock (1966) and Barnett (1960).

Pure culture of the fungus

Inocula of *F. oxysporum* f. sp. *psidii* growing on PDA media were transferred aseptically to the fresh PDA plates and sub–cultures of the pure inocula were also prepared. After 3-7 days, the fungus grew out of the inocula, which were transferred to fresh PDA plates when colony of *F. oxysporum* f. sp. *psidii* was established. Then the Petri dishes were kept under dark condition covering with brown paper.

Inoculation through mycelial block culture (Root inoculation)

Six holes of 2 cm diameter were made on each poly-bag containing guava seedlings. Roots were exposed through the holes with the help of a hiddle and the tips of the roots were pruned off slightly to facilitate fungal infection. Then prepared mycelial blocks (Plate 3.7) were applied to the roots through the exposed holes. The inoculated seedlings were then transplanted to the pot. After 15 days of transplanting, 10 days old oat culture of *F. oxysporum* f. sp. *psidii* was mixed with soils around the rhizosphere of 1 year old guava seedling in the pot. Soil in the pot was kept moist.

Results and Discussion

Experiment 1: Effects of variety, methods of grafting and scion type on the success, survival and subsequent growth of guava grafts.

Days to bud breaking

Bud breaking is an indication of grafting success. The numbers of days for initiation of bud in the grafts as influenced by variety, methods of grafting and scion type are presented in Table 1. Varieties showed significant effect ($p < 00.5$) on the bud breaking in guava grafts (Table 1). Minimum time (23.90 days) for bud breaking was required in Kazipiara while in Swarupkathi maximum time (26.12 days) was required to bud sprouting, which was statistically similar to that (25.67 days) of L 49. The less time requirement to bud break for grafts of Kazipiara might be due to the inherent potentiality of the plants of Kazipiara as it was observed from faster and vigorous growth of the variety. The average time taken for sprouting of the grafts was significantly influenced by the grafting methods (Table 1). The earliest bud sprouting (23.61 day) was recorded in veneer grafting, while cleft method took relatively more time (26.84 days) for bud sprout. In veneer grafting the rootstocks are not severed from the top portion at the initial stage of graft union but it is done (cut off) in the cleft grafting method. So, the earlier bud break as well as the graft union in the veneer method might be due to keeping the rootstock as a functional plant, (it is cut off after having successful grafts), which might help in the auxin synthesis and translocation to the union portion that (auxin) helps in the callus formation and differentiation of parenchymatous cells as well as formation of the cambium and vascular bundle as was stated by Hartman *et al.* (1997). Regarding bud break, the scion type showed significant effect on sprouting of different

Table 1 *Effect of variety, methods, and scion type on the days to bud breaking in guava grafts.*

Treatment	Variety			Methods of grafting		Scion type	
	V_1	V_2	V_3	G_1	G_2	H	S
Days to bud break	23.9	26.12	25.67	26.84	23.61	23.34	27.12
LSD (0.05)			1.541		1.258		1.258
LSD (0.01)			NS		1.689		1.689

V_1: Kazipiara, V_2: Swarupkathi, V_3: L49, G_1: Cleft, G_2: Veneer, H: Hard, S: Soft

grafts done in different methods (Table 1). The earliest bud break was found (23.34 days) in hard wood scion grafts while, soft wood scion grafts required more time (27.12 days) to bud sprout. The hard wood scions are physiologically mature and have more reserved food materials, which possibly attributed to faster callus formation and union of the scion that lead to earlier bud break. Hartman *et al*. (1997) gave the same opinion while stating the biology of grafting.

The interaction effects of variety and methods of grafting, varieties and scion type and methods of grafting and scion type did not effect significantly on the sprouting of grafts. Both the three factors viz. variety, methods of grafting, and scion type did not influence bud breaking significantly. However, Kazi variety showed earliest bud break (20.34 days) in combination with hard wood scion when done through veneer method and Swarupkthi required the longest time (31.96 days) in case of soft wood scion when done through cleft method (Table 2). It was also found that the time required for sprouting was not uniform throughout the experiment, which might be due to the variation in varietal performances, differences in the performances of grafting techniques followed and variation in the age of scion.

Table 2 *Combined effect of variety, methods, and scion type on the bud breaking in guava graft.*

Treatment	Days to bud breaking			
	G_1		G_2	
	H	S	H	S
V_1	22.47	27.22	20.34	25.58
V_2	24.97	32.96	22.49	25.02
V_3	26.86	27.54	22.85	25.40
LSD (0.05)				3.081
LSD (0.01)				4.137

V_1: Kazipiara, V_2: Swarupkathi, V_3: L49, G_1: Cleft, G_2: Veneer, H: Hard, S: Soft

In case of contact grafting the scion shoots are not separated before the completion of graft union. So, it is not possible to find out whether the grafts unite successfully or not before the separation of the scion shoots from the mother plant. For that reason, the parameter bud break, was observed and analysed only in the grafts done through veneer and cleft grafting methods.

Success in grafting

It was found that variety did not influence, but the various methods of grafting showed significant differences on the percentage of grafting success as observed and measured 100 days after grafting operation. The highest success was recorded in contact grafting (93.33 %) followed by veneer grafting (68.89 %) and cleft grafting gave the lowest percentage of success (52.22 %) as shown in Figure 1. These results are partially supported by

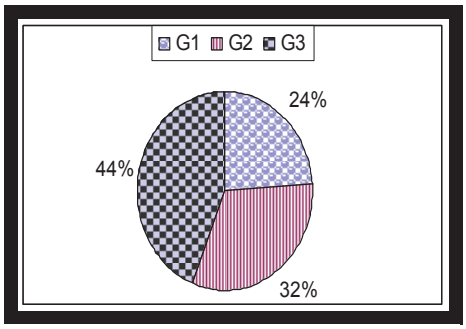

Figure 1 *Effect of methods of grafting on the success of grafts in guava (G1= Contact, G2=Veneer; G3= Cleft).*

that of Roy and Sinha (1994) who got 90 % and 80 % success in mango grafting done in approach and veneer method, respectively. Hartmann and Kester (1983) also found 93 % success in contact grafting in mango. Faruque and Fakir (1973), Mitra and Bose (1990), and Bhagat *et al*. (1999) also found maximum percentage of success in contact grafting method. Bhandary and Mukherjee (1970) got better success in veneer method of grafting in guava. The present result of cleft grafting was found to be similar to that of Farque and Fakir (1973) who got 48-52 % success in cleft grafting method in Mango. The highest percentage of success in contact grafting method might be due to allowing the scion shoot attached to the mother plant for a substantial period that prevented the scion shoot from drying. The scion tissue of guava is hard and dry but, a continuous sap flow is essential for successful graft union. As contact grafting and veneer grafting ensure (the sap flow) this might be the cause of greater grafting success in the methods. The top portion of the rootstock is cut off in the cleft method, which possibly hindered sap flow in the

dry tissue of guava and caused lower grafting success.

The effect of scion type on the success of grafting was found to be highly significant. The hard wood scion gave 80.7 % graft success whereas; the soft wood scion gave only 62.2 % graft success (Figure 2). This can be explained in the light of the work of Jagirder and Bhatti (1968) who stated that the percentage of success in grafting differed for scion type. They found 95 % success with mature wood scion while immature scion wood gave only 74.16 % grafting success. The higher grafting success in the hard wood scion might be due to the physiological maturity of the scion with enough stored material that caused rapid callus formation and so far wound healing whereas the soft wood scions are succulent pithy and low in stored carbohydrate, which might have played significant role in hindering the graft union with decreased callus formation, which ultimately resulted in low percentage of grafting success. Regarding best scion type for grafting HRDP (1995b) ventilated the same opinion.

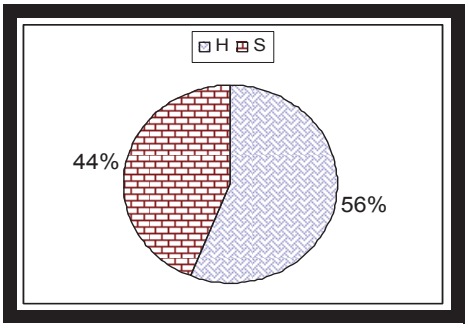

Figure 2 *Effect of scion type on the on the success of grafts in guava (H Hard wood; S=Soft wood).*

The interaction effect between variety and method of grafting was found insignificant but variety and scion interacted significantly. The variety Kazi gave the highest percentage of success (88.9 %) with hard scion type followed by L 49 (80 %) while Swarupkathi gave the lowest percentage of success (73.3 %) with hard wood scion as shown in Table 3.

Table 3 *Combined effect of variety and methods and variety and scion type on the success percentage in guava grafting.*

Treatment	Methods of grafting			Scion type	
	V_1	V_2	V_3	H	S
V_1	56.67	70.00	96.67	80.89	60.00
V_3	46.67	66.67	90.00	73.33	62.22
V_2	53.33	70.00	93.33	80.00	64.44
LSD (0.05)				7.89	
LSD (0.01)				10.23	

V_1: Kazipiara, V_2: Swarupkathi, V_3: L49, G_1: Cleft, G_2: Veneer, H: Hard, S: Soft

But in case of soft wood scion, the grafting success of all the three varieties were statistically similar (60 %, 62 %, 64 % for Kazi, Swarupkathi, and L 49, respectively). The results indicated that the varieties were more responsive to the hard scion type that leads to higher percentage of grafting success.

A highly significant interaction effect was also observed between method of grafting and scion type. Contact grafting with hard scion type gave the maximum percentage of grafting success (95.56 %) but it was statistically similar to that obtained from soft wood scion whereas in veneer and cleft grafting this varied greatly with scion type (Table 4). In veneer grafting hard wood scion gave only 55.6 % of grafting success and in case of cleft grafting, hard wood scion gave 64.4 % per cent graft success, which is only 40 % in case of soft wood scion. In contact grafting as the scion shoot remained attached with the mother plant and it availed all the favourable conditions causing higher grafting success. It was also apparent from the method of grafting that both the soft and hard wood scion showed similar degree of success because after some days the soft wood scion shoot got matured and played same role as that of hard one.

Table 4 *Combined effect of methods of grafting and scion type on the success percentage in guava grafting.*

Methods of grafting	Scion type	
	H	S
G_1	64.44	40.00
G_2	82.22	55.56
G_3	95.56	91.11
LSD (0.05)		8.461
LSD (0.01)		11.36

G_1: Cleft, G_2: Veneer, G_3: Contact, H: Hard, S: Soft

Both the three factors viz., variety, method of grafting, and scion type did not interact significantly. But the combined effect was significant (Table 5). In the combined effect it was found that the highest percentage of success (100 %) was obtained from the variety Kazi when grafted with hard scion through contact grafting whereas, it was the lowest (40 %) in Swarupkathi. But it was invariable low in case of soft wood scion in cleft grafting irrespective of the variety used (Table 5).

Scion height

Increase in the scion height is the indication of a successful graft and its subsequent growth and development (Table 6). Considering height of the scion, Kazipiara appeared to be the best. At every measuring date from 45 DAG (Days after grafting) to 150 DAG grafts of Kazipiara showed increased scion height (33.0 cm) followed by L49 (32.2 cm) whereas, Swarupkathi gave the lowest scion growth (31.70 cm). Plate 1 showing the relative growth in different grafting plants. Contact grafting produced highest scion height followed by veneer and then cleft.

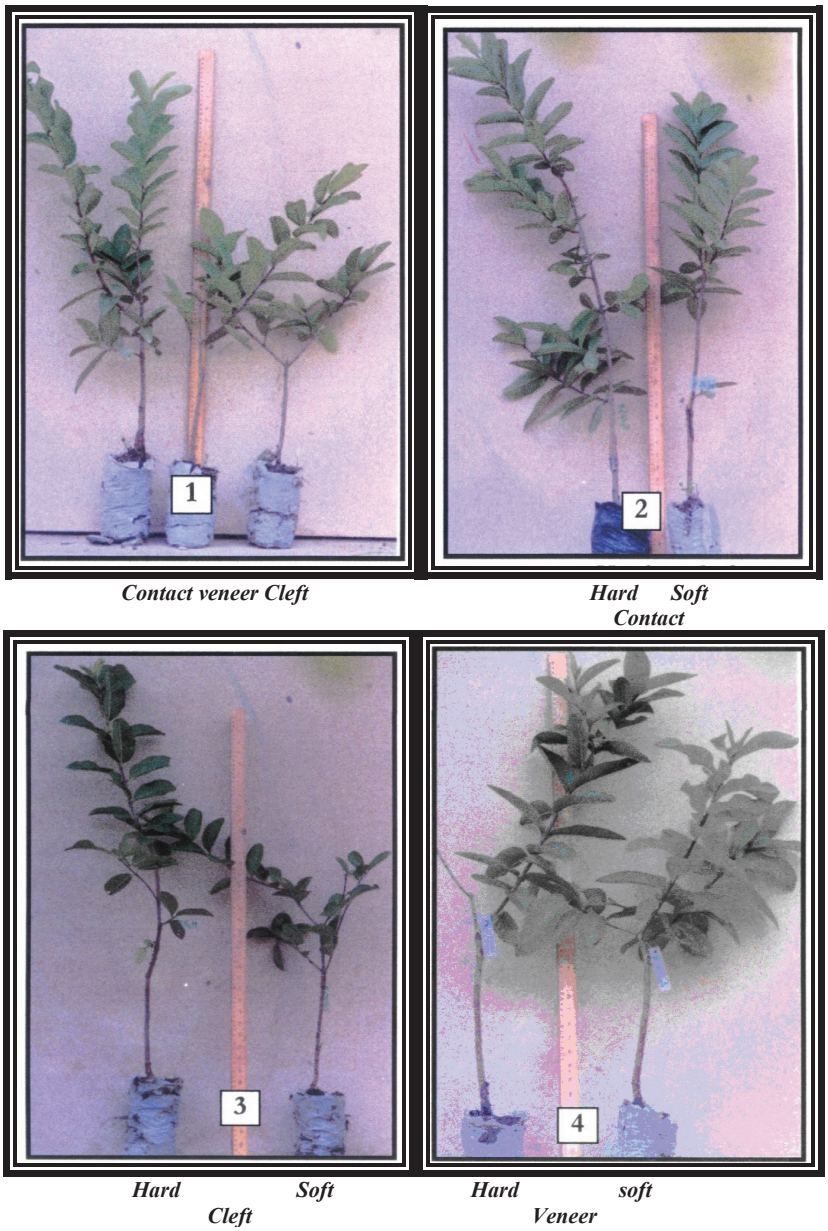

Plate 1 *Photograph showing the effects of methods of grafting and scion type on the growth and development of guava grafts (No. 1 showing the effects of method and No. 2, 3, and 4 showing the effects of scion type).*

Table 5 *Combined effect of variety, methods, and scion type on the success percentage in guava grafting.*

Treatment	Percentage of success					
	G_1		G_2		G_3	
	H	S	H	S	H	S
V_1	73.33	40.00	93.33	46.67	100.00	93.33
V_2	53.33	40.00	73.03	60.00	93.33	86.67
V_3	66.67	40.00	80.00	60.00	93.33	93.33
LSD (0.05)						14.65
LSD (0.01)						19.67

V_1: Kazipiara, V_2: Swarupkathi, V_3: L49, G_1: Cleft, G_2: Veneer, G_3: Contact, H: Hard, S: Soft

Table 6 *Combined effect of variety, methods, and scion type on the survival per cent in guava grafts.*

Treatment	Survival percentage in guava grafts					
	G_1		G_2		G_3	
	H	S	H	S	H	S
V_1	91.67	66.67	93.33	83.33	100.00	93.33
V_2	76.67	50.00	93.33	72.22	100.00	91.67
V_3	82.22	83.33	91.67	83.33	100.00	88.89
LSD (0.05)				28.70		
(0.01)				38.53		

V_1: Kazipiara, V_2: Swarupkathi, V_3: L49, G_1: Cleft, G_2: Veneer, G_3: Contact, H: hard, S: Soft

Survival rate in grafting

Success in grafting was evaluated 100 days after operation when the grafts were taken care specially by providing shade and other necessities. But under field condition some of the grafts died possibly due to improper graft union. The statistical analysis showed a significant variation in graft survival due to some of the factors employed in the experiment. Variety did not show any significant variation in graft survival. While methods of grafting showed highly significant variation in graft survival. The highest survival percentage was obtained from contact grafting method followed by veneer and cleft methods (Table 6), which were 95.6 %, 86.2 %, and 75.1 %, respectively.

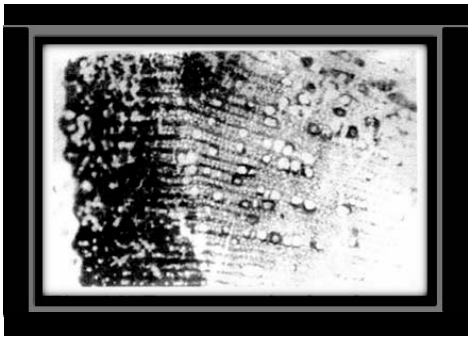

Plate 2 *Transverse section through a part of stem (cv. Kazipiara) showing the radial arrangement of vessels in the xylem and the presence of tannin cells in the cortex. (X 130).*

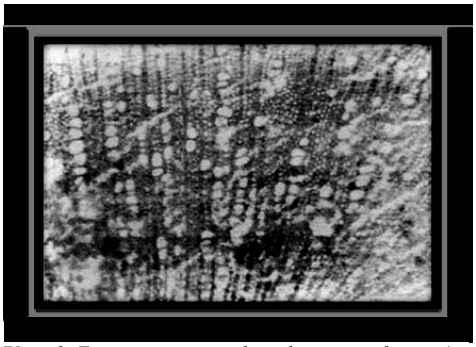

Plate 3 *Transverse section through a part of stem (cv. Kazipiara) showing the radial arrangement of vessels in the xylem (X 132).*

The present results differed to some extent from the findings of Majhail and Singh (1962) who obtained 100 % success, when the grafts were detached after 80 days in the spring in mango. They reported that mortality could be reduced in grafts when separated 60 or more days after marching. Per cent survival obtained in cleft graft in the present experiment was similar with the results obtained by Gunjate (1989) in mango who found 72-78 % survival rate in mango.

A highly significant variation was observed in graft survival percentage in guava for the factor of scion. The hardwood scion grafts gave 92.1 % success in graft survival while it was 79.2 % in case of soft wood scion type. The hard wood scions being physiologically mature ones gave better graft union through uniform and better callus formation which might have caused successful graft union and showed higher graft survival rate. The interaction effects between the variety and grafting, variety and scion type and methods of grafting and scion type did not show any significant variation in the survival of guava grafts.

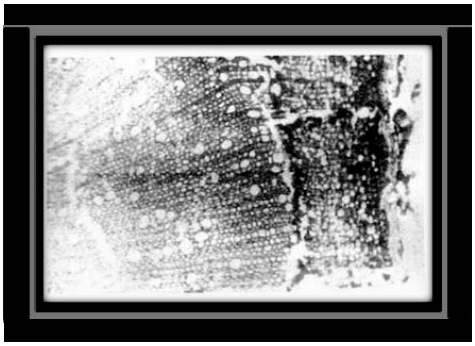

Plate 4 *Transverse section through a part of stem (cv. Polypiara) showing the scattered arrangement of vessels in the xylem and absence of tannin cells in the cortex. (X 130).*

Regarding survival percentage, all the three factors viz, variety, methods of grafting, and scion type did not show any significant variation. However, all the three varieties viz. Kazi, Swarupkathi and L49 gave highest survival rate (100 %) when contact grafting method was applied in combination with hard wood scion but Swarupkathi contributed the lowest graft survival percentage (50 %) when soft scions were grafted

though cleft method of grafting combindly. The results are presented in Table 6.

Experiment 2: Anatomical studies of the grafted plants.

Anatomical studies of the graft union gave the opportunity to find out the anatomical differences between the Polypiara (used as root stock) and the other guava varieties (used as scion) (Plates 2, 3, 4, and 5). During this observation it was found that Polypiara possessed tannin cells only in the pith, had sclereids in the cortex and the most important characters of having scattered vessels. But in the other varieties there were much tannin cells both in the cortex and in pith, absence of sclereids in the cortex and the radial arrangement of vessels.

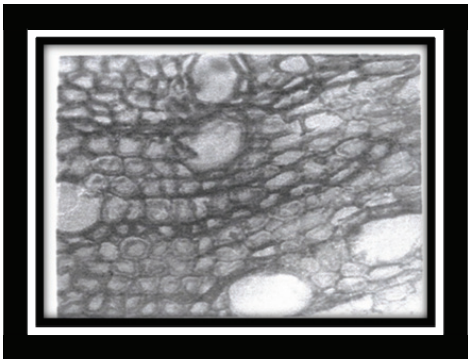

Plate 5 *Transverse section through a part of stem (cv. Polypiara) showing the scattered arrangement of vessels in the xylem. (X 130).*

Being a systemic pathogen *fusarium oxysporum* f. sp. *psidii* might have found unfavourable condition for invasion as the cortex having sclereid and scattered vessels in Polypiara. As in Kazipiara and other guava varieties used, the vessels were in radial rows, which might have formed situation favourable for *Fusarium* invasion, multiplication arid infection. The tannin cells present in the cortex of Kazipiara, Swarupkathi etc. possibly had favoured fungal growth and multiplication, which was absent in the Polypiara. Thus, the peculiar anatomical features possibly provided convincible resistance to *Fusarium* wilt in polypiara.

Experiment 3: Study of tolerance of the resultant graft to *Fusarium* wilt.

Development of wilt symptoms

External features

The disease was first recognized by pale-green colour of the foliage with slight curling of the leaves (Plate 6). Yellowing of the leaves of either the affected branch or the entire plant was followed by withering of leaves and thereafter leaf drop. With progress of the disease, some of the twigs and sometime the whole treated plant became bate and fail to bring forth new leaves and eventually dries up. Later on, the entire plant became defoliated and dead afterwards. Symptoms of guava wilt as observed in the present study have conformity with those previously reported (Dwivedi 1996; Meah & Mamun 1991; Pathak 1980; Singh & Chakraborti 1989).

Plate 6 *Photograph showing initial stages of wilting symptoms developed in the inoculated seedlings of Kazi and Swarupkathi.*

Plate 7 *Photograph showing wilts infected root system of guava plant.*

Table 7 *Effects of variety on the proportion of increase in shoot height, leaf number, new shoot developed and leaf infection, leaf drop, and mortality of the guava seedlings.*

Treatment	% Shoot height increase	% increase in new leaf formation	% increase in new shoot developed	% leaf infection	% leaf drop	% mortality
Factor A (Variety)						
V_1 (Kazi piara)	23.25	65.65	70.04	12.58	11.97	66.67
V_2 (Swarupkathi)	16.35	55.69	59.84	9.25	10.03	38.89
V_3 (Grafted plants)	20.13	56.29	73.29	1.46	3.84	0.00
V_4 (Polly piara)	24.61	53.30	50.50	1.61	3.05	0.00
LSD (0.05)	2.45	3.68	17.34	1.39	1.38	8.18
(0.01)	3.33	4.99	NS	1.88	1.88	11.07

Underground symptoms

The roots showed rotting at the basal region. Almost all feeder roots were rotten. The secondary and primary roots were found partially rotten (Plate 7). The rotten roots were discoloured. The bark was easily detachable from the centre. Upon longitudinal splitting, light brown to black discolouration was noticed in vascular tissues. These observations arc in accordance with those reported by Edward (1960), Meah *et al.* (1995), and Hamiduzzaman (1995).

Effects of inoculation of wilt-pathogen in the increase in height, leaf number, and shoot number of 3 guava varieties along with the grafted plants.

Effects on % shoot height of seedling: The increase in plant height varied significantly due to the effects of variety. The plant height increased after 80 days of inoculation of the guava varieties have been presented in Table 7. The highest shoot length increase (24.6 %) was noticed in Polypiara, which was statistically similar to Kazipiara (23.3 %) whereas, Swarupkathi gave the lowest shoot height increase (16.4 %). Actually Kazi and Swarupkathi seedlings were badly affected by the inoculated pathogen, which ultimately caused lower shoot increase (comparatively). The grafted plants and Polypiara seedlings were not affected by the pathogen, which caused higher percentage of shoot increase.

The effects of inoculation on the percentage of height increase were found highly significant. The non-inoculated plants showed the highest percentage of shoot increase (25.8 %) whereas, the treated plants showed least increase in shoot height. The root inoculation and soil inoculation did not show significant variation (18.6 % and 18.9 %, respectively, Table 8) in the increase of shoot height. The reduction in the percentage of shoot height was due to the infection of the seedlings by the inoculated, pathogen.

The interaction effect of variety avid inoculation on shoot height increase was also found significant. Maximum shoot height increase (35.3 %) was found in the combined effects of non-inoculated and Kazipiara seedlings but it reduced drastically with the inoculation of the pathogens in both root and soil inoculation (only 16.9 % and 17.6 % for root and soil inoculation, respectively). Plant height reduced significantly in Swarupkathi also due to inoculation (22.9 % in non-inoculated seedling and 13.3 % and 12.86 % in root and soil inoculated seedlings, respectively. But combindly in the grafted plants and in Polypiara seedlings the shoot height increase was statistically identical for both the non-inoculated and the inoculated seedlings. In the grafted plants shoot height increase were 20.1 %, 19.5 %, and 21.1 % for non-inoculated, root inoculated and soil inoculated respectively. In Polypiara there were 24.2 %, 24.5 %, and 25.1 % shoot increase for the same treatments respectively, indicating that inoculation did not affect the grafted plants to cause wilting.

Effects on new leaf formation: Varietal effects on new leaf formation were found to be highly significant. Maximum leaf formation (65.7 %) was found in the Kazipiara and the lowest (53.3 %) in Polypiara, which was statistically similar to that of grafted plants (56.3 %) and in Swarupkathi (55.7 %).

Inoculation caused significant variation in the formation of new leaves. The highest percentage of leaf formation was observed in the non-inoculated seedlings whereas, both the root and soil inoculation caused reduction in percent new leaf formation. However, the effects of root inoculation and shoot inoculation were statistically similar (Table 8).

The inoculation and variety interacted significantly on the percentage of new leaf formation. The combined effect of inoculation and variety gave clear idea about the varietal response to *Fusarim oxysporum* (Table 9). The highest percentage of new leaf formation was found in non-inoculated seedlings of Kazipiara (72.6 %), which was significantly higher than that of root inoculated (61.4 %) and soil inoculated (62.9 %) seedlings. In Swarupkathi the variation was again significant when compared with inoculated and non-inoculated one. The variations observed in the grafted plants and in Polypiara were statistically similar for the inoculated plants and the non-inoculated plants combindly. The effect of root inoculation and soil

Table 8 *Effects of methods of inoculation on the proportion of increase in shoot height, leaf number, new shoot developed and leaf infection, leaf drop, and mortality of the guava seedlings.*

Treatment	% Shoot height increase	% increase in new leaf formation	% increase in new shoot developed	% leaf infection	% leaf drop	% mortality
Factor B (Methods of inoculation)						
T_0 (Non-inoculated)	25.78	61.27	77.54	1.99	3.39	0.00
T_1 (Root inoculation)	25.78	55.75	58.04	8.31	9.01	41.67
T_2 (Soil inoculation)	25.78	56.18	58.43	8.38	9.28	37.50
LSD (0.05)	25.78	3.18	15.02	1.20	1.19	7.06
(0.01)	25.78	4.33	NS	1.63	1.63	9.59

inoculation was statistically similar. The non-significant variation in percentage of leaf formation in the grafted plants and in Polypiara revealed that the pathogen inoculated to the seedlings of Polypiara and grafted plants did not cause infection i.e., they were (grafted plants and polypiara) resistant to this pathogen.

Effects of inoculation on leaf infection, leaf drop, and mortality of the guava varieties: Inoculation of the *fusarium oxysporum* f. sp. *psidii* caused infection of some of the seedlings and was identified through the observation of infected leaves, dropping of leaves, and mortality of the seedlings. But the rate of above variables was different in different varieties and in different treatments, which are described below –

Effects on the percentage of leaf infection

A significant variation was observed in the percentage of leaf infection in different guava varieties. Higher leaf infection (12.6 %) was observed in Kazipiara followed by Swarupkathi (9.3 %) whereas, in the grafted plants the percentage of leaf infection was very low (only 1.5 %). The highest leaf infection in Kazipiara revealed that the Kazipiara was very much susceptible to wilt pathogen.

Effects of inoculation were found highly significant with respect to leaf infection. Percentage leaf infection after 90 days of inoculation is presented in Table 8. The lowest leaf infection was recorded in the non-inoculated seedlings whereas, inoculation caused higher leaf infection but the effect was statistically similar for both the root and soil inoculation methods, having 8.3 % and 8.4 %, respectively. A significant interaction was observed between the varieties and inoculation regarding leaf infection. Significant difference was observed in leaf infection when seedlings of Kazipiara were inoculated than that in the non-inoculated seedlings (l8.07-2.6 %) in the inoculated and non-inoculated seedlings, respectively. The variation was also high in Swarupkathi. Percentage of leaf infection was statistically similar in the grafted plants and in the Polypiara. In all cases (for grafted plants and Polypiara), the percentage of infection was less than 2, which clearly indicates that the grafted plants and the seedlings of Polypiara were wilt resistant and Kazipiara was highly susceptible.

Effects on the percentage of leaf drop

After successful infection of the pathogen, the leaves were infected and dropped gradually. The percentage of leaf drop was measured after 90 days of inoculation and there were variations among guava varieties.

Variety showed significant variation in percentage of leaf drop. Higher percentage of leaf drop was observed in Kazi (12 %) and Swarupkathi (10 %) which was statistically significant, but the leaf dropping occurred in grafted plants and in the Polypiara seedlings was significantly lower than the other two varieties i.e., only 3.8 % and 3.1 % for grafted and Polypiara, respectively (Table 9).

Methods of inoculation i.e., inoculation caused significant variation in the percentage of leaf drop in guava varieties. Non-inoculated seedlings showed lower leaf drop (3.4 % only). But inoculation affected some of the plants badly causing higher significant leaf drop (9-9.3 %). The percent leaf drop occurred in both the root inoculation and soil inoculation was statistically identical (Table 9).

The interaction effects on intensity of leaf drop due to the variety and inoculation method were found significant. Combindly the highest leaf drop (16.8 %) occurred in soil inoculated seedlings of Kazipiara, which was statistically similar to the root inoculated., seedlings of the same variety (Plate 8), but the non-inoculated seedlings of Kazipiara caused only 3.4 % leaf drop. The variation in the percentage of the leaf drop was also significant in the seedlings of Swarupkathi. Leaf drop was the lowest and statistically identical in grafted plants and also in Polypiara seedlings. This again proved that inoculation had no significant effect on Polypiara.

Effects on mortality

Wilting stopped the growth of seedlings of guava, killed plant parts and caused death of entire plants. The mortality rate was observed after 100 days of inoculation and the results are presented (Table 9).

A highly significant variation was observed in the percentage of mortality among the varieties due

Plate 8 *Photograph showing the effects of root inoculation of F. oxysporum f. sp. psidii on three guava varieties and grafted plants. a. Kazipiara (V_1) b. Swarupkathi (V_2), c. Grafted plants (V_3), d. Polypiara (V_4). In all cases (a, b, c, and d plant at the right is control one).*

Table 9 *Combined effects of variety and methods of inoculation on the % increase in leaf number, new shoot developed, and mortality of the guava seedlings.*

Treatment	% increase in new leaf formation	% increase in new shoot developed	% mortality
	Factor A × Factor B		
V_1T_0	72.62	108.75	0.00
V_1T_1	61.44	59.33	100.00
V_1T_2	62.88	57.05	100.00
V_2T_0	62.77	77.11	0.00
V_2T_1	51.57	48.55	66.67
V_2T_2	52.72	53.86	50.00
V_3T_0	56.25	71.33	0.00
V_3T_1	57.10	74.28	0.00
V_3T_2	55.52	74.26	0.00
V_4T_0	53.45	52.96	0.00
V_4T_1	52.87	49.99	0.00
V_4T_2	53.58	48.55	0.00
LSD (0.05)	6.37	30.03	14.11
(0.01)	8.65	40.82	19.18
CV	6.51	27.42	31.58

V_1 = Kazipiara, V_2 = Swarupkathi, V_3 =Grafted plants, V_4 = Pollypiar, T_0 = Non inoculated, T_1 = Root inoculation, T_2 = Shoot inoculation

to inoculation (Table 9). Kazi variety showed the highest percentage of mortality (66.7 %) followed by Swarupkathi (38.9 %). But none of the inoculated grafts and Polypiara seedlings died due to inoculation, indicating that the Polypiara variety of guava was wilt resistant, which ensured the resultant grafts to wilt resistant (Plate 8). Similar views have been reported by Bose *et al.* (1986) and Pathak (1980).

The percentage of mortality caused by the inoculation with the pathogen was significant. There was no mortality in the non-inoculated seedlings. There are reports about the association of *F. oxysporum* f. sp. *psidii* with guava wilt complex (Meah 1992; Pandey & Dwivedi 1985). Root inoculation caused highest mortality (41.670 o) in the guava plants than the soil inoculation (37.5 %), but it was statistically similar by the inoculation. Mechanical injury during root inoculation might cause the plants more prone to wilting by the inoculation. These results are in accordance with that of Hwang (1980), who reported that mechanical wounding of root increased the wilt incidence.

The interaction effects of variety and inoculation methods were also found highly significant. Seedlings of Kazipiara showed 100 % mortality for both the soil inoculation and root inoculation methods combined whereas, it was only 50 % and 66.7 % in Swarurkathi with the same treatments. This indicates that Kazipiara was more susceptible than Swarupkathi. But in case of the grafts and Polypiara seedlings, inoculation did not interact positively to cause death either of these plants (Table 9). This proves that Polypiara is wilt resistant.

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Chapter 13: A Critique on Sustainable Natural Resources of Bangladesh and Their Management: The Role of the Media

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Abstract

Humankind now experiences the both benefits and problems of rapid development throughout the world and Bangladesh is no different, but with limited natural resources and environment, facing a stiff challenge from continuous degradation and eradication of resources due to unplanned, uncaring, and unsustainable management. The media in this case should have an appropriate role of development agent, to focus the issue with an aim to reach it the people and policy makers. The media should also make people aware and motivate them to create that environment, which would help the policy makers, mainly the government and NGOs, to take appropriate policies and formulate rules and regulations. Despite some rules and regulations and some political pledge/rhetoric from the governments, however, it is apparent that the natural resources of the country are not being consumed in a very sustainable manner. Moreover the increased population is also responsible for excessive consumption of resources. On the other hand, a few journalists in Bangladesh are involved in writing and presenting news/findings regarding natural resources. Apart from focusing the issue to a significant extent, however the media is apparently not successful to educate and motivate the people to that level would enable them to perceive realistically the issue of sustainability of the resources and to use it in a very philosophical and patriotic manner. Thus, in this paper the nature, volume, and sustainability of the major natural resources of the country in one end are explored to understand how well we are managing our natural resources, and how appropriately the media is playing their role on the other.

Keywords; *natural resources, sustainability, management, media, Bangladesh.*

Introduction

Bangladesh is a small country of only 147,570 km^2 located at the tip of Bay of Bengal, the northern extended arm of Indian Ocean. Bangladesh is deltaic by shape, created through continuous deposits of alluvial soil coming down with the onrushing waters of hundreds of rivers from the upper riparian Himalayan countries like India, China, Nepal, and Myanmar. Bangladesh has three distinctive landscapes; 80 % are flood plains created through the deposits of alluvial soil due to monsoon and flash flooding 8 % are terraces. *Madhupur tracts* are in a few central and northern districts of Tangail, Mymensing, Gazipur, and in the greater Rajshahi region, which is popularly known as *Barind Tracts* in the west. The remaining 12 % are hilly areas in the south-eastern regions of greater Chittagong, including the extensive *Chittagong Hill Tracts (CHTs)*.

The principal resources of Bangladesh are, no doubt, its fertile soils, water resources, the long growing season, and year-round heavy rainfall, being suitably distributed for growing rice, jute, tea, plenty of vegetables, and fruits. The nation's abundant water supplies are being used to produce hydro-electric power, such as Kaptai dam in the Chittagong Hill district of Rangamati and for irrigating farmlands during the dry season. Although minerals have traditionally been economically important, the country has large reserves of natural gas and some petroleum deposits. We also have deposits of coal and limestone and some other minerals, but most important resources are huge arable lands as 75 % of the population is directly or indirectly dependent on agriculture (Rasheed & Sajjadur 2002). One of the great assets of the country, however, are the most beautiful mangrove forests of *Sundarban*, a UNESCO heritage, which was listed as top contender for one of the seven modern wonders, in the southern region covering districts such as Khulna, Satkhira, Bagerhat, Patuakhali, and a few parts of the Indian State of West Bengal. There are also the huge, sprawling rain-forests of the CHTs bordering Myanmar and few regions of India and remnants of Sal forests of the Madhupur and Barind Tracts.

Natural resources – main values

First, we need to understand the meaning of natural resources. One definition says,

Natural resources include the renewable elements of the ecospheres such as water and the terrestrial and aquatic biomass, the non-renewable elements, such as land in general, minerals, metals and fossil fuels, and the semi-renewable elements such as the soil quality and the assimilative capacity of the environment (Hottler & Schakau 1996).

Bangladesh is a land of plenty of natural resources; a land is so fertile that sometimes you do not need to sow any seeds for germination. The natural forests, Sundarban with typical natural beauty is full of thousands of species of flora and fauna. The area renowned for the Royal Bengal Tiger and spotted deer are good examples of animals, while s*undari, bain, poshur, gewa, and keora* are typical plants. The Sundarban, surrounded by many meandering rivers, is the hub of different species of fresh-water fish and sea fish in nearby bays. Sundarban is prominent for its timbers and the *golpata* (virtually, long leaves) plant, which is hugely used for the thatched rural housing. The rural people throughout adjacent areas always harness honey, *golpata*, and twigs. Very many people of the vast areas surrounding Sundarban are dependent on them. Sundarban has deposits of 56 million tons of carbon in trees, different plants and bio-ingredients. An assessment entitled *Sundarban Forest Carbon Inventory 2009*, carried out by the Forest Department of Bangladesh Government in collaboration with different agencies/organizations of US government, showed that huge carbons are accumulated in different species of trees like *bain, poshur, and kankra*. The *Sundari*, the most popular and important tree from which the name of *Sundarban* (world largest mangrove forest) has evolved, has comparatively less carbon-accumulating capacity, while two other species, *gewa* and *keora,* have very little carbon (Mahmud 2010c).The overall scenario, however, is not very impressive in terms of the volume of forests in Bangladesh.

In 1947, 24 percent of Bangladesh was covered in forests, but this declined to only 8 percent in 1988. The Forest Department believes that systematic deforestation has now reduced the forest area to less than six percent. ...massive deforestation for timber and fuel has become a major environmental issue in the country. Conversion of forest land for infrastructure development and agricultural expansion has also contributed to shrinking of the forest area (Rasheed & Sajjadur 2002).

A few years back the American Centre (formerly United States Information Service) at Dhaka quoting a research report prepared by World Resources Institute, and sending a press statement to the media, said Bangladesh and other ten countries were on the verge of losing the remaining 5 % of their original (natural) forests. Given that logging and agricultural settlement, especially for meeting the demands of the escalating growth of population, are the main reasons for deforestation, the research institute warned the concerned countries to take immediate action. Of the total forest area of Bangladesh (about 2.44 million ha), 0.3 million ha are homestead groves and 1.46 million ha are state-owned reserved and protected forest (Akhter & Sarker 1998; cited in Barua & Wilson 2005). The average annual destruction of the forest in Bangladesh was 800 ha in 1980. This rate subsequently increased to 38,000 ha/year between 1981 and 1990 (Haque 2000; cited in Barua & Wilson 2005). Today, deforestation affects approximately one-eighth of the country (Barua & Wilson 2005).

During *Sidr*, the cyclone that swept over the shore areas of south-western regions in 2007, Sundarban experienced huge damages. Experts then forecasted that the forest needed ten years to recover, but, astonishingly the forest has been recovering fast, although it has been enduring the pain of destruction. The volume of destruction could have been less, if there had not been so much human intervention over last few decades. The Sundari trees in south-western Sundarban are suffering from *top-dying* affliction, which kills off the mangrove tree from the top down (Gain 1998). This disease was seen in other areas also, where industrial smoke from chimneys contaminates the vegetation. It is virtually the result of climate change. Global warming due to unchecked emission of carbons by the West has a huge impact on Sundarban and its surrounds. It is not only trees; sea fishes are also going far away from the reach of the fishermen due to considerable change of climate, which is reducing their jobs.

The World Bank in 2001 warned that sea level rise in the Bay of Bengal would produce changes in three areas of environment: (1) water level, submergence, and water logging; (2) soil, ground and surface water salinity; and (3) coastal morphology (Rasheed & Sajjadur 2008). The most serious consequence of climate change for Bangladesh would be a rise in the sea level of the Bay of Bengal coast. Even one-half metre of sea level rise along the coast of Bangladesh might submerge some 10 % of the land along the coastal zone including most of the Sundarban (Rasheed & Sajjadur 2008). The disappearance of the Sundarban, which is the only thing stopping Bangladesh from sliding into Bay of Bengal, would be an ecological catastrophe (Gain 1998). The 500 types of birds and 100 species of animal, including the globally-endangered salt-water crocodile, which lives in the Sundarban would be badly hit by further destruction of the Sundarban (Gain 1998). *Ila*, the cyclone in 2009, hit the south-western regions of Satkhira, with a huge tidal surge, turning the entire region saline, which made life miserable. We have no constitutional right, however, to protect against climate and no legal structure to fight against degraders, forcing them to pay compensation.

Sundarban – a great wetland

Despite continuous extinction, the wetlands eco-system in Bangladesh is extremely rich in species

diversity. Of more than 5000 species of flowering plants and 1500 vertebrate species, wetlands provide the habitat for about 300 plants and over 400 vertebrate species (Nishat *et al.* 1993; cited in Rasheed & Sajjadur 2002). The mangrove forest of the Sundarban in the southwest is the largest estuarine wetland in the world extending over 550,000 ha (Nishat *et al.* 1993; cited in Rasheed & Sajjadur 2002).

Tiger – the royal symbol of beauty of Sundarban

Bangladesh is one of the 13 countries where the tiger still survives. The world-renowned Royal Bengal Tiger is one of the five species of tigers still surviving, but three sub–species of Royal Bengal Tiger have already disappeared. The World Wildlife Fund says that, if the sea level of Bay of Bengal increases, then the Royal Bengal Tiger could disappear. In 2004, UNDP (United Nations Development Programme) and Forestry Department jointly carried out an assessment, which showed that there were only 440 Royal Bengal Tigers in the Bangladesh part of Sundarban, of which 121 were male, 298 female, and 21 cubs (Mahmud 2010b; Mahmud 2010c). Only the tigers of Sundarban are adapting to the saline environment of the area. There are no such numbers of tigers, which live in one single forest of the world, but, due to lack of awareness, around 25-40 people are being killed every year from the attack of tigers, while 2-3 tigers die at the hands of local people, having entered their lands (Mahmud 2010c). As in Sec. 2 (d) of Environment Conservation Act 1995, *environment* includes water, air, land, and physical properties and interrelationship, which exist among and between them and humans, other living creatures, plants, and micro-organisms. This very good symbiotic nature is still prevailing in the Sundarban, but this rhythm has time and again broken down, as the trees are being felled for household purposes due to increased population and agricultural settlements, causing reduction of plants. So, deer numbers have decreased due to shortage of plants or being killed; the tigers also to come out of their hub for their food and are killed, which breaks down the symbiotic nexus. Recently, regarding a report of 374 sea-living giant turtles caught for sale, the leading English daily of Bangladesh, *The Daily Star* in its editorial voiced:

Catching of these animals is a punishable offence under sections 5(1) and 15(1) of The Bangladesh Wildlife Preservation Act, 1974. …The government should take prompt action to apprehend those traders and bring them to justice.…the governments need to be more active in stopping the practice of catching, selling and smuggling of rare animals in the country. The way guest birds, which are also prohibited under law to be caught, sold or killed; one often comes across sale of these birds even within the city under the very nose of law enforcing agencies. So, it is again enforcement, rather than the mere existence of the laws that is the crucial part of the Wildlife Preservation Act. (p. 10).

Besides these problems, we have some glimpses of hope. Government recently approved a project involving about 250 thousand people of 76 villages around Sundarban, who would protect the forest with the forest people. These people would get 50 % of revenues they would earn from the resources of the forest (Mahmud 2010a).

Ailing Chittagong Hill and Madhupur and Barind Tracts

The hill forests in CHTs have been broadly classified as the tropical evergreen or semi-evergreen types which supply around 40 % of the commercial timber production (Gain 1998), but 'the remarkable loss of forest resources in the Chittagong Hill Tracts is attributed to commercial exploitation of immature trees for sale in the black markets with blessings of the Forest Department (Gain 1998). Deforestation is largely the result of poor management, illegal logging, and unplanned land clearing. In the past, the Forest Department not only remained aloof from the local population in its forest management affairs, but was also insensitive and often hostile to the indigenous and poor people living in and around the forest (Rasheed & Sajjadur 2008). In 1865, the British Indian Forest Act declared forests and wastelands as reserved forests. Enacted for *Scientific Management* of forests, the actual impact was deforestation, loss of local varieties of trees, enclosure of the forest, and restricted access of local people to the forests (Shiva 1999; cited in Barua & Wilson 2005). In the Chittagong and Chittagong Hill Tracts districts, forests policies had a direct and formidable impact on the destruction and mismanagement of the forests (Barua & Wilson 2005). The commercial use of forest land for monoculture of rubber and fuel wood also has negative impacts (Gain 1998). Different schemes for rubber production have flourished, which is economically not viable, but, eventually by 1980 rubber plantation had overtaken large portions of the arable land in the Chittagong Hill Tracts (Barua & Wilson 2005). By 1992, some 400 ha were given to rubber plantation (Mohsin 1997; cited in Barua & Wilson 2005). Commercial rubber and eucalyptus plantation impinge on community based gardening in the forest, resulting in loss of biodiversity, lack of interest and engagement by local populations and out-migration (Barua & Wilson 2005).

The process of modernization and industrialization led to intense deforestation in these (Chittagong)

regions through the building of dams and plantations of fast–growing eucalyptus trees, rubber plants, and timber or teak for markets and cash that effectively undermined natural forests. …Diverse varieties of trees have been replaced by mono-crop cultivation in the forests of…..south eastern Bangladesh (Barua 2010).

CHT still have some hopes, but Madhupur Tracts, the largest forest patch in the country, have almost lost their character, and Barind Tracts are virtually consigned to history. In the name of ADB or some other foreign-aided projects, mono-cropping, such as banana or pineapple have destroyed the natural *Sal* (a kind of heavy wood tree) forests at Tangail and its surrounding districts and, like CHT, the local indigenous people have had to be relocated to towns for newer different jobs. This is simply the practice of neo-colonialism. In the *Sal* forest, 70-75 % of the trees are *sal*, but today the forest has been exhausted to such an extent that it has lost the main features of the original *Sal* forest (Gain 1998). The process of modernization and scientific management of forest have forced us to forget that the forest is not a place for destruction but a place for animals, plants, and human beings to live in harmony (L. De–Silva, 1992; cited in Barua & Wilson 2005).

Natural gas – lifeblood of Bangladesh

About 90 % of the present power generation is based on natural gas (Matin 2010). A total of 22 natural gas fields had been discovered in Bangladesh by 2001. The total *gas initially in place* (GIIP) in these 22 fields is about 26 Tcf (Trillion cubic feet), of which about 16 Tcf is considered *recoverable*. By the end of 2000, a total of about 3.9 Tcf of gas has been produced leaving a reserve of about 12.1 Tcf, but we have different views also. Out of the 22 fields, two are offshore in the Bay of Bengal and the rest are located in the eastern onshore areas. Power generation and fertilizer production consumes about 80 % of the natural gas produced at present. The sector-wise use of gas as a percentage of total gas consumed stands as follows: power (45 %), fertilizer (35 %), industrial, commercial and domestic (20 %). The demand for natural gas in the country is increasing at a rate of 13.4 % annually.

The country is resourceful in natural gas, which is not infinite - rather it has rapidly dried up due to unplanned and reckless distribution and use. The term *sustainability* for natural gas is virtually absent. Gas is being consumed in every sphere of life, including pipe-connected household use, generation of power, industrial use, and fuel for almost all kinds of traffic. There is no strict rationing of gas use. The volume of use of natural gas is comparatively much greater than to-be harnessed gas, as these are drying out in proportion to exploration. Imam (2010a) mentioned that the everyday demand of gas in the country is 2,300 million cft, but production of gas against it is 2000 million cft. The deficit is 300 million cft, according to BAPEXC (Bangladesh Petroleum Exporting Corporation). The present demand has to rise up to 2,900 million cft by 2012-2013. This means, we have to increase our production of gas by another 900 million cft. Despite that, some people have been suggesting that Bangladesh should earn foreign exchange to boost its economy by exporting its natural gas to India. They also suggest that, in the near future, gas will become a backstage fuel and may not have its present value, due to the advent of alternative sources like solar energy (Imam 2010a). Imam (2010) raised the second view held by a large section of national experts and politicians, who tend to oppose strongly the option of pipeline export now. The opponents of pipeline-gas export pointed out that two factors should be considered seriously before exporting to a foreign country. These are (i) whether Bangladesh holds enough reserves to meet its future demand and (ii) the future of natural gas as a fuel.

According to the opponents of gas export, Imam (2010b) further said that the country's present gas reserve of 15 Tcf is modest and will perhaps be enough to meet the need of the immediate future, but not enough to meet the long-term future demand of the country. Bangladesh has been very much dependent on natural gas as its primary commercial fuel. It has no significant oil reserve, no prospect for further hydro-electric projects and the possibility of having nuclear power is as remote as ever. In the above context, natural gas will remain the sole source of commercial energy for a long time to come. If Bangladesh starts exporting natural gas now, the present reserve may well be exhausted before an alternative energy source is in sight. This will be catastrophic for the future energy scenario of the country.

Regarding the future of gas as a fuel, international energy experts say that oil and gas will remain the prime energy source till 2040, after which natural gas will be the near universal fuel. The use of natural gas will peak in 2050, following which its use will exceed that of oil and gas together. The take-off point of solar energy or other alternative energy will be delayed and will come before 2050. The opponents of gas export have suggested further that Bangladesh should wait for a substantially-large reserve to be discovered before considering gas export. Some of the objectives of the National Energy Policy 1996 (Rasheed & Sajjadur 2008) are: (1) to ensure sustainable operation of the energy utilities, (2) to ensure rational use of the total energy resources, (3) to ensure environmentally-sound sustainable energy development programmes causing minimum damage to the environment, and (4) to encourage

public and private sector participation in the development and management of the sector. Thus, energy policy must be concerned, not only with current supply, but also with the country's long-term needs. For example, in assessing any surplus of natural gas available for export, it is important to consider domestic energy needs long into the future, for a period of, say, 50 years.

Coal – the black gold or destroyers of environment!

Current interest in coal extraction in Bangladesh is focused on Barapukuria and Phulbari in the north-western district of Dinajpur, while the two other deposits (Khalashpir and Dighipara) - which lie at greater depth - are expected to be considered for exploration. It is claimed that the country has good deposits of coal, 2 GT (Gas Turbine) or more. Barapukuria coalmine is under production but its performance together with that of a pit-head coal fired power plant has been unsatisfactory due to poor planning and management (Matin 2010) Depending on what method of extraction is chosen, coal may sustain a total of 10,000 to 15,000 Megawatts (MW) of electric power when in full production. Further mining of coal is being delayed due to the absence of a national coal policy in the country (Matin 2010). Rasheed (2008) also identified the choice of mining method as a major problem for economic exploitation of coal. He elaborated further:

In Bangladesh, there is strong opposition to open pit mining of coal. Arguments against open pit mining includes loss of agricultural land and the need to relocate settlement-which is, however, not unique for Bangladesh. In open pit mining, nearly 90 percent of the coal deposits can be extracted, which is highly attractive scenario. On the other hand, only about 20-25 % of the deposits can be extracted by underground shaft mining. Underground shaft mining is also vulnerable to various types of hazards like land subsidence, gas explosion, flooding of shafts and emission/trapping of toxic gasses (146).

Asia Energy, a Bangladeshi subsidiary of a UK-based company, were almost ready to start open-pit mining at Phulbari coal mine and the company proposed a 500MW power plant at the mine site. On August 26, 2006, however, the local people staged a protest against the proposed open-pit mine, because of possible destruction of environment and forced relocation of people, and the law-enforcing agencies fired upon them, killing three and injuring several hundred, and that incident has led to the preparation of a Draft Coal Policy for Bangladesh. Prime Minister of Bangladesh, on October 13 2010, asked the authorities concerned to publish the National Coal Policy 2010 on the website, so that the people can get a clear picture of the policy and give their opinion before its final approval. From the country's electricity crisis aspect, Prime Minister said, coal extraction is a necessity, but, first, we have to ensure that people and environment do not suffer from any particular method of coal extraction (posted in *Banglapedia* on October 13, 2010).

Saikat (2010) reported that the coal-based power plant of Barapukuria, with the capacity of generating 250 MW power, has been so far produced 504,45,37,284 KW between June 2006 and May 2010; for that it burnt 2,084,905 tonnes of coal. In the process, the power plant produced 260,613 dry ashes, which were kept in a large pond nearby, but those ashes were not disposed in last four years due to governmental lethargic actions. So, the government is losing much money by not selling those ashes on the one hand, and the power plant is at risk of being shut down, as the water of the pond has almost dried out due to preservation of ash in that pond, on the other. The ash, a by-product of burning coal, has a high demand as raw material in cement factories. Quoting Biswanath Halder, the engineer of the power plant, Saikat (2010) further said, if the ash is not disposed of in the next six months the power plant could have been shut.

Legal/ instrumental protection

There was a growing awareness and understanding in the mid-1980s that the natural resources and the environment of the country were being degraded, which forced the government to recognize fully the importance of environmental sustainability as the basis for long-term development in the country. As a signatory to Agenda 21 of the Earth Summit of 1992 held in Rio, Bangladesh is committed to implement the international legal instrument, as national programme and policy. The National Environment Policy of 1992 was an important development in this regard.

Ministry of Environment and Forest (MOEF) was created in 1989 and within it a new department, Department of Environment (DOE) was formed as the technical arm of the ministry. The MOEF is a permanent member of the Executive Committee of the National Economic Council, which is the principal decision-making board for economic policy issues and public investment project. Despite the recognition of the importance of environmental management in policy decisions, the institutional capacity for implementing the planning, monitoring and enforcement mechanism are still very weak. Both MOEF and DOE are yet to develop the institutional strength required to adequately meet the challenges of environmental management and protection in Bangladesh (Rasheed & Sajjadur 2002).

Haque(1999) said that the 1992 Environment Policy by the Ministry of Environment was adopted with the objective of improving environment and ecology, controlling pollution, conserving and managing forest resources and maintaining natural resources and environmental stability. The specific objectives of the national policy were: (1) to maintain ecological balance and overall development through protection and improvement of the environment, (2) to protect the country against natural disasters, (3) to identify and regulate activities which pollute and degrade the environment, (4) to ensure sustainable, long term and environmentally sound use of all natural resources, and (5) to remain actively associated with all international environmental initiatives as much as possible. On the other hand, the objectives of National Forest Policy 1994 are, Haque (1999) pointed out: (1) to meet the basic needs of present and future generations and also ensure greater contribution of the forestry sector in economic development, (2) to create employment opportunities, strengthening the rural and national economy, (3) to enrich the biodiversity of existing degraded forests, (4) to strengthen the agriculture sector, (5) to implement government's various international commitments, and (6) to prevent illegal occupation of forest.

As in the National Environmental Management Action Plan (NEMAP) 1995, the environmental issues in Bangladesh are associated with forests, wildlife and biodiversity. They include: (1) encroachment of forest land for agricultural and human settlement, (2) uncontrolled depletion of forest resources and replacement by commercial forests, (3) management of wetlands within forests is still very poor and needs rehabilitation for keeping biodiversity intact, (4) destruction of mangrove forests, due to uncontrolled shrimp farming, and (5) prevention of hunting, trapping and disturbances of migratory and aquatic birds, which endanger these species and reduce their numbers (Gain 1998).

Violations still continue

Despite good intentions, violations of laws is frequent, not only from the general people but from the government itself. A very-recently-published news report said,

The government has permitted Chevron Bangladesh, a US-based energy corporation, to drill three wells and extract gas in block-14 within the periphery of Lawachhara (eastern Sylhet regions) reserve forest…..Article 23(3) of the Bangladesh Wildlife (Preservation) Order 1973 says, firing any gun or doing any other act which may disturb any wild animal or doing any act, which may interfere with the breeding places of any wild animal is prohibited (Roy 2010).

The Environment and Forest Ministry approved the Chevron project in August 2010. Nearly 460 species of flora and fauna thrive in merely 1,250 ha in the Lawachhara forest, one of the last patches of tropical forests.

Scope of renewable and non-renewable energy

As Rahman (2010) said conventional energy sources mean fossil fuels. Solid coals, liquid petroleum and natural gas are major fossil fuels. The qualities of these are good, because energy stored in these minerals is concentrated enough to run human civilization. Burning fossil fuels, however, is not a welcome activity, since its environmental cost is high and disruptive to the social nexus. Moreover, the reserves of fossil fuel are finite. On the other hand, Rahman (2010) further said,

Renewable energy sources get energy from the sun and are infinite in consideration of the geologic time span. Though renewable energy sources are more environment-friendly, yet it is a great question that is it possible to meet the growing need of energy for whole world from the renewable sources? …The best option among renewable energy sources perhaps is the solar energy, because it is the manmade imitation of natural process of photosynthesis. Biomass is produced by photosynthesis capturing the solar energy. If burnt, biomass is the completion of carbon cycle; it virtually does no harm to the environment. Hydropower harnessing sometimes harms aquatic life in the dam area or river. Wind energy harnessing can be a threat for birds but it is less harmful from environmental perspective. Capturing tidal power in the coastal region can harm the coastal ecosystems to a certain extent (p.13).

Solar energy is becoming popular among the people and private organizations in Bangladesh, who have been suffering from frequent load shedding of government-supplied energy. The office of the Vice Chancellor of the University of Dhaka, for instance, has installed a panel for generating solar energy. People of certain rural areas, who do not have any access to power supplied by the government or the private enterprises, have been installing solar energy systems in their premises. While solar energy, said to be one of the green energies, is becoming popular, the chance of installing and harnessing another type of energy i.e., windmill energy is not yet bright. The *white energy* – the wind energy, needs a continuous wind, but, Bangladesh, what we know is a deltaic by shape, located at the edge of Bay of Bengal, and not apparently suitable due to its large areas of plain land, which is only 10 m above sea level. A few hilly areas of the north-west

and south-east regions are potentially rich, having the right altitude for wind to generate energy.

What role do the media play?

It is apparent that we are not using our natural resources in a very systematic and sustainable manner. Besides traditionally huge consumptions of fuel wood, the use of natural gas for household and industrial purposes and for fertilizer production is reckless. The vehicles plying around the streets of the country mostly use natural gas due to unwise policy adopted and maintained by all succeeding governments. The government's claim to manage natural resources well, but, in reality, the management is not at a satisfactory level, but it is not the entire responsibility of the government, it is the duty of the people also. The duty of increasing the awareness level of people, however, is vested in the media by the side of the government, as in Third World countries, with the *development theory of press* by Wilbur Schramm, Theodore Peterson and Fred S. Siebert (Siebert *et al.* 1956), the media should work as the propaganda mechanism for developmental activities. In the news items on natural resources in Bangladesh, media coverage is not bad but motivational writing and presentation is comparatively weak, as well as the campaigns from governments or NGOs. Thus, the people sometimes use the resources without understanding their sustainability.

On the other hand, as far as the role of media is concerned, the issue of environment and natural resources has so far failed to emerge as the topic as do juicy items of politics, sports, crime and corruption, and some other sensational issues. Should media sell only, or aim to maintain social responsibility? The events that are most important to the lives of our readers are often very complicated and boring, and while a newspaper can easily go broke by reporting what's significant rather than what's personal or spicy, this is the primary responsibility of a serious newspaper (Ghosh 1996). Media is now successful to a large extent in dragging out important issues to make them gradually more popular for coverage in newspapers or on television channels. In terms of coverage, however, the degree of enlightenment of the readers/viewers, and through them to the general people is not yet significant. As in the agenda of setting the theory of mass communication, through which news influence on our pictures of the world (Black *et al.* 1998), the readers and viewers are much more oriented to sensational items. Any incident of killing tiger or human by the tiger or elephant, or selling migratory birds during winter or an explosion in a gas field, however, are treated by newspapers as a single event or incident, but those silent, but experiencing on-going events for a long time, are not being covered as news. When five people die of starvation in a certain village in an Asian country, newspapers report it as an event, but when tens of thousands of people go through slow starvation and widespread malnutrition for months or even years, it is a process that seldom gets covered (Sharma 2007). It is really a poor traditional journalistic instinct, which works in the minds of even some *environment beat* journalists, but, as in the theory of mass communication of Wilbur Schramm (1964), the media is to a large extent successful in terms of its watchman function, but they failed to educate properly or motivate the people as well as the policy makers, to go for positive action.

How much natural gas we are consuming (or misusing) we do not precisely know. The concerned authority from time to time has been asking people to be restrained, but the consumers are not apparently fully conscientious. Like this, we are destroying natural resources, such as wood resources at Sundarban, Madhupur, and CHTs. The monoculture plantation of trees at Madhupur and CHT has uprooted thousands of families, and forced them to migrate to the city areas to find newer and tougher jobs.

We are not clear whether we have huge deposit of gases, in spite of reckless consumption of gas for household purpose or for industrial usage, which has really created a big concern. The media quoting concerned officials has been writing that we are floating on gas; it will not be finished in next 50 years. At the same time there are arguments that it will be finished in the next few years. We do not know which one is true. The media just failed to come up with clear ideas to satisfy the policy makers, stakeholders or the consumers.

Extinction of natural resources is very rapid, but the media do not have much focus on population. Due to increasing population growth in Bangladesh, energy consumption is very high even for household use, apart from industrial purposes. Thus, felling the trees is one of the results of it, thereby creating agricultural fields for more production of food, and also for creating housing to accommodate the increased numbers of people. Consumption of natural resources and the environment is heavily related to the lives of people; it is not an isolated matter. Media's role here is to blend both and to highlight key issues for future action.

Conclusion

Our focus was to explore the nature and volume of major natural resources and to identify their sustainability and their management and, at the same time, how well our media are playing their role. From our discussion it is clear that we are not using our natural resources in a sustainable manner. The prevailing management process and the policy are not satisfactory, The most important thing is that the media must be successful in raising issues

but they are yet to reach the level from which they can make environmental issues core issues of journalism to be covered daily, as are political issues, and from which they can motivate the people and consumers to use resources in a restrained and patriotic manner. Hence, our suggestions are:

- We need effective environmental planning, which will direct and control the acquisition, distribution and disposal of resources in such manner as to sustain human activities, but these activities will be restricted so that there is a minimum of disruption of physical, ecological and social processes;
- We have to maintain monitoring of the environment and journalists group can play their role as development agent on environmental issues;
- We need to enforce more public-private partnership of creation and consumption of resources and to maintain a strong international network to get more legal and financial support;
- Enforcement, rather than mere existence of some laws and rule and regulations, should be made more effective, and in the process journalists should play their role as watchdog to monitor that enforcement;
- Environmental issues are very technical and complex, sometimes boring, so the media should cover it in much more familiar manner with high readability, so that the people understand it as well as they understand news of politics or sport;
- The media should shift their focus mainly from politics or crime/corruption issues to other areas such as the environment, shifting attention from the more sensational issues;
- Media should connect the issue of population with the environment, as the degradation of environment is hugely linked with ever-increasing population in Bangladesh, hitherto neglected; and
- Media's conventional tendency to cover environmental issues as isolated or single issues/events should be changed to more continuous progress reports.

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