The IUCN Wetlands Programme

Freshwater Wetlands in Bangladesh: Issues and Approaches for Management

Edited by

Ainun Nishat, Zakir Hussain, Monoj K. Roy and Ansarul Karim

Freshwater Wetlands in Bangladesh: Issues and Approaches for Management

IUCN - The World Conservation Union

Founded in 1948, IUCN - The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: some 650 members in all, spread across 120 countries.

As a union, IUCN exists to serve its members - to represent their views on the world stage and to provide them with the concepts, strategies and technical support they need to achieve their goals. Through its six Commissions, IUCN draws together over 5,000 expert volunteers in project teams and action groups. A central secretariat coordinates the IUCN Programme and leads initiatives on the conservation and sustainable use of the world's biological diversity and the management of habitats and natural resources, as well as providing a range of services. The Union has helped many countries to prepare National Conservation Strategies, and demonstrates the application of its knowledge through the field projects it supervises. Operations are increasingly decentralized and are carried forward by an expanding network of regional and country offices, located principally in developing countries.

IUCN - The World Conservation Union - seeks to work with its members to achieve development that is sustainable and that provides a lasting improvement in the quality of life for people all over the world.

IUCN Wetlands Programme

The IUCN Wetlands Programme coordinates and reinforces activities of the Union concerned with the management of wetland ecosystems. The Programme focuses upon the conservation of ecological and hydrological processes, in particular by developing, testing and promoting means of sustainable utilisation of wetlands. It does so in collaboration with IUCN members and partners, in particular those other international institutions with a specific wetland mandate, especially the Ramsar Convention Bureau, and the International Waterfowl and Wetlands Research Bureau (IWRB).

The core of the programme is a series of field projects which develop the methodologies for wetland management, in particular in the countries of the developing world where wetlands are used intensively by local communities which depend upon these for their well-being. Related strategic and policy initiatives draw upon the results of these projects and present their conclusions in a form useful for government decision makers and planners.

The activities of the Programme are designed on the basis of the concerns and information provided by IUCN members. To facilitate this, the Programme works through IUCN's regional offices. The Programme also works closely with the major development assistance agencies to ensure that conservation considerations are adequately addressed in their projects. It is coordinated from the IUCN Headquarters in Switzerland, with regional coordinators in Asia, Central America, South America, Brazil, West Africa and Southern Africa.

IUCN Country Programme in Bangladesh

In Bangladesh IUCN has been cooperating with the Government in developing the National Conservation Strategy (NCS). Through the development of NCS IUCN has become an active working partner with the Government of Bangladesh in the field of natural resource management. IUCN is supporting non-government research organisations to undertake pilot studies and to develop materials for environmental education and public awareness. With generous help of CIDA, IUCN assisted the Ministry of Environment and Forests in organizing a National Workshop on "Conservation and Sustainable Management of Freshwater Wetlands in Bangladesh". IUCN has also assisted Bangladesh Rural Development Board (BRDB) to organize a national symposium on "People, Environment and Development".

IUCN plans to support projects to implement NCS recommendations in the fields of biodiversity, wetland conservation and people's participation in environment protection. IUCN Country Office in Bangladesh maintains close cooperation with the government, donor agencies and the NGOs and joins hands in sustainable development in Bangladesh for the welfare of the people.

Freshwater Wetlands in Bangladesh: Issues and Approaches for Management

Editors
Ainun Nishat, Zakir Hussain, Monoj K. Roy, Ansarul Karim

IUCN-The World Conservation Union
1993

Published by : IUCN
The World Conservation Union

Citation : A. Nishat, Z. Hussain, M.K. Roy, and A. Karim (Eds.), 1993. Freshwater Wetlands in Bangladesh: Issues and Approaches for Management. IUCN, Gland, Switzerland. xii + 283 pp.

ISBN : 2-8317-0167-8

Layout : Arif Rana

Printed by : Momin Offset Press, 9 Nilkhet, Dhaka-1205, Bangladesh

Cover Design : Sarah Skinner

Cover Photograph Zakir Hussain

Available from : IUCN Wetlands Programme,
Rue Mauverney 28, 1196 Gland, Switzerland

IUCN South-East Asia
GPO Box 2754, Bangkok 10501, Thailand

IUCN Bangladesh Country Office,
76, Satmasjid Road, Dhaka-1209, Bangladesh

CONTENTS

FOREWORD

Bangladesh possesses enormous areas of wetland, and during the rainy season about half of the country turns into wetland. The principal wetlands are rivers and streams, shallow freshwater lakes and marshes, water storage reservoirs, fish ponds, seasonally flooded cultivated plains, and estuarine systems including mangrove swamps.

Till recently, concern for wetlands centered round their role in supporting large populations of waterbirds and other wildlife. However, over the course of the past decade, many nations including Bangladesh has begun to recognize that wetlands not only support wildlife but also play an important role in flood control and storm surge protection. They also support fisheries, wildlife and forest resources. Wetlands are unique for their rich biological diversity and cultural heritage. It is the combination of all these functions, yields and values that makes wetlands so important to the society.

Today these benefits are threatened as wetlands are drained, dredged and filled, embankments are built, water supplies diverted, and coastal wetlands are converted to aquaculture. This happens because some people have viewed eliminating wetlands as a small price to pay for the benefits expected from wetlands conversion. In most cases, the benefits derived are far short of the predicted ones bringing hardship to those communities dependent upon the wetlands. To restore and conserve degraded wetlands for their beneficial functions people associated with wetland management should have access to information and data on resources, functions and values of wetlands. These are scanty in a developing country like Bangladesh.

There are different types of wetlands in Bangladesh and wetland issues vary from type to type. Freshwater wetlands commonly known as *haors*, *baors*, *beels* and *jheels* which possess enormous resources are affected most as a result of development activities. To bring into focus issues pertinent and relevant to conservation of freshwater wetlands in Bangladesh a workshop was held in Dhaka in December 1992. It was organized by the Ministry of Environment and Forests in collaboration with the Canadian International Development Agency (CIDA) and the IUCN - the World Conservation Union.

The objective of the workshop was to improve information and database and create awareness among concerned professionals and to identify interventions required for conservation and sustainable management of freshwater wetlands.

More specifically, the objectives were:

a) to know the present status of freshwater wetlands in Bangladesh;
b) to identify functions and values of freshwater wetlands of the country;
c) to highlight environmental impacts of various development projects on wetlands;

d) to identify and recommend approaches and strategies for wetland conservation and management including policy and institutional issues and involvement of local people;
e) to create awareness among policy makers, administrators and public in general on concerns related to wetland degradation and pertinent management approaches; and
f) to prepare and recommend necessary interventions and future action programmes.

This book is primarily based on papers presented at the workshop. Several contributions have been added to cover some other relevant issues. Consensus and recommendations of the workshop have also been included in this book. The papers have been edited to a common format and abridged for reasons of space without in any way affecting the views of the authors.

This book has brought under one cover an overview of concerns, issues, extent of data availability and possible freshwater wetland management approaches perceived by professionals, academics and researchers who come from divergent backgrounds. It is hoped that this book will provide a guideline for future wetland management in Bangladesh.

Ainun Nishat
Zakir Hussain
Monoj K. Roy
Ansarul Karim

ACKNOWLEDGEMENTS

The workshop on Conservation and Sustainable Management of Freshwater Wetlands in Bangladesh provided the first draft of the papers contained in this book. The cooperation of Mr Md. Fazlul Haq, Joint Secretary of the Ministry of Environment and Forest, in successfully holding the workshop deserves special mention. Thanks are also due to Mr Sultan Mahmud Khan and Mr Saifuddin Ahmed of the Ministry of Environment and Forest, Mr Someswar Das, Mr A.K.M. Fazlul Huq and Mr A.W. Akonda of the Department of Forest, Mr Nazrul Islam of the Department of Fisheries, Mr Mohiuddin Ahmed of the Department of Environment and Mr Fariduddin Ahmed of Bangladesh Agricultural Research Council for their valuable support in organizing the workshop.

Participation of Dr Kamal Uddin Siddiqui, Secretary, Prime Minister's Office, Mr M. Asafuddowlah, Secretary, Ministry of Irrigation, Water Development and Flood Control, Dr M.S.U. Chowdhury, Executive Vice Chairman, Bangladesh Agricultural Research Council, Mr M.N.A. Katebi, Chief Conservator of Forests, Mr A.K.M. Kamaluddin Choudhury, Member, Planning Commission, and Mr M. Mokammel Haque, Member, Planning Commission as Chairmen of different sessions enriched the workshop deliberations and their contributions are gratefully acknowledged.

The editors gratefully acknowledge the cooperation extended by the authors in editing their papers. Mr M. Sultan Mahmud Khan of the Ministry of Environment and Forests, Dr Z. Karim and Dr A.K.M. Nuruzzaman of Bangladesh Agricultural Research Council, Mr Shahidul Islam of Bangladesh Agricultural Development Corporation, Mr Someswar Das of the Forest Department, Professor Mahmud-ul-Ameen of Dhaka University, Mr Gias Kamal Chowdhury of Bangladesh Sangbad Sangstha, Dr A. Moyeen Khan, Member of Parliament, and Mr Haroun-Er-Rashid of POUSH (a local NGO) had commented on the first draft of various papers and in some cases the papers were revised on the basis of these comments. Their contributions in improving the quality of the papers are appreciated.

The editors would also like to put on record their deep appreciation for the valuable support provided by Mr Enamul Haq, Senior Fellow of Bangladesh Centre for Advanced Studies, in the final editing of the book.

Thanks are specially due to Mr A.M. Choudhury, Country Representative, IUCN Bangladesh, for his support and guidance in compilation of the book.

The editors acknowledge with thanks the services rendered by Mr Md. Razzakul Haider in supervising the publication of the book and by Mr Md. Golam Kibria and Ms Dominica Rozario in providing secretarial support. Service rendered by Mr Abul Kalam Azad in drawing the figures and maps is appreciated.

GLOSSARY OF LOCAL TERMS

Aman	Rice planted before or during the monsoon beginning in June and harvested in November-December
Aus	Rice planted during March-April and harvested during July and August
Baor	An oxbow lake or wetland formed in an abandoned arm of a river
Barman	A sub-caste of Hindus who are traditionally fishermen
Barsha	Normal flood which is not considered disastrous or damaging
Batak	A local variety of boro rice
Beel	A saucer-like depression which generally retains water throughout the year
Begunbichi	A local variety of boro rice
Bichar	To mediate a social dispute
Bonna	Flood which is perceived as disastrous or damaging
Boro	Winter rice planted in November and December and harvested before the onset of monsoon
Chai	Bamboo trap used for fishing
Chailya/ Dud-Chailla	*Hemarthria protensa*, a long grass
Chana/Chola	Gram, seeds of *Cicer arietinum*
Chapati	Pancake
Char	A newly formed island or a point-bar formed in a river
Chukti	A lease stipulating an agreed quantity of crop payable after harvest
Demi dhan	Ratoon crop
Deta	Rice straw
Dighee	A big pond
Foni-boro	A local variety of boro rice
Gach-Alu	*Dioscorea* spp., a popular vegetable in Bangladesh before the advent of potatoes
Gangajoli	A local variety of wheat
Ganja	Marijuana
Ghechu	Rhizome of *Aponogeton natans* and *A. echinatus*
Gopalbhog	A local variety of mango
Guin	Same as Chai
Haor	A backswamp or bowlshaped depression between the natural levees of a river
Hati	A cluster of homesteads
Hijal	*Barringtonia acutangula*, a wetland tree
Hogla	*Typha* spp., a perennial herb of marshes
Ikor	*Sclerostachya fusca*, a grass
Jagli	A local variety of boro rice
Jalmahals	Waterbodies leased for fishing
Jamali	A local variety of wheat
Jheel	A freshwater marsh
Joalbhanga	A local variety of boro rice
Kachu	Rhizome of *Colocasia esculenta*
Kalai	*Vigna mungo*, a pulse
Kali-boro	A local variety of boro rice
Kamranga	An edible sour fruit of *Averrhoa carambola*
Kanda	High and terrace land which remains above the water level during the dry season in haor areas
Kharif	Wet season (Mid-April to September)
Khas	Government-owned
Khas Mahal	Public land
Khesari	*Lathyrus sativus*, a pulse
Khirshapat	A local variety of mango

Koibarta	A sub-caste of the Hindus who are traditionally fishermen
Koroch	*Pongamia pinnata*, a wetland tree
Kusum	Safflower
Lakhaya	A local variety of boro rice
Lata Bombay	A variety of mango
Lengra	A local variety of mango
Majhi	Boatman
Makna/Makhna	*Euryale ferox*, an aquatic plant
Mahal	Estate
Maimol	Traditional fishermen among the Muslims
Mexi-Pak	A modern variety of wheat
Mohanbhog	A local variety of mango
Motor	Pea/field pea
Mung	*Vigna radiata*, a pulse
Musur	Lentil, seeds of *Lens culinaris*
Namasudra	A sub-caste of the Hindus who have low position in social structure
Para	Synonymous with *hati*
Parials	Hired musclemen of lease-holders of *jalmahals*
Patni	A sub-caste of the Hindus who were traditionally boatmen.
Pawra	Monsoon fodder
Penjamo	A modern variety of wheat
Pusa	Varieties of wheat named after a city in Bihar where these were developed
Rabi	Dry season (October to March)
Rai Sarisha	A variety of mustard
Rata	A local variety of boro rice
Rayada	An old local variety of deepwater of rice
Salish	Synonymous with *bichar*
Sheetal Pati	A type of mat made from *Clinogyne dichotom*
Sholar Tupi	A special type of hat used earlier by government officials and made from the pith of Bhatsola (*Aeschynomene aspera*)
Rangjama	A lease on payment of cash in advance
Singra	*Trapa maximowiczii*, a perennial aquatic herb
Sonalika	A modern variety of wheat
Sonora	A modern variety of wheat
Tilapia	*Tilapia mossambica*, an exotic fish introduced in Bangladesh during the fifties.
Toria-maghi Sarisha	A variety of mustard
Thana	Police station, the lowest administrative unit in Bangladesh
Ujaiya	Movement against water flow
Zamindar	Feudal landlord
Zamindari	Feudal system

ABBREVIATIONS

AER	- Agro-Ecological Region
BCAS	- Bangladesh Centre for Advanced Studies
BWDB	- Bangladesh Water Development Board
CS	- Cadastral Survey
DC	- Deputy Commissioner
DOE	- Department of Environment
DOF	- Department of Fisheries
DTW	- Deep Tube Well
FAP	- Flood Action Plan
FCD	- Flood Control and Drainage
FCDI	- Flood Control, Drainage and Irrigation
FD	- Forest Department
FMP	- Forestry Master Plan
FPCO	- Flood Plan Coordination Organization
HYV	- High Yielding Variety
LLP	- Low Lift Pump
MOEF	- Ministry of Environment and Forest
MPO	- Master Plan Organization
MSL	- Mean Sea Level
MSY	- Maximum Sustainable Yield
NCA	- Net Cultivable Area
NCS	- National Conservation Strategy
NFMP	- New Fisheries Management Policy
NEMAP	- National Environment Management Action Plan
ROR	- Record of Rights
RRA	- Rapid Rural Appraisal
SAARC	- South Asian Association for Regional Cooperation
SAT	- State Acquisition Tenancy Act
SCONE	- Society for Conservation of Nature and Environment
SLW	- Standard Low Water
SPARRSO	- Space Research and Remote Sensing Organization
SRDI	- Soil Resource Development Institute
STW	- Shallow Tube Well
TNO	- Thana Nirbahi (Executive) Officer

Freshwater Wetlands in Bangladesh: Issues and Approaches for Management

FRESHWATER WETLANDS IN BANGLADESH: OPPORTUNITIES AND OPTIONS

Akbar Ali Khan

ABSTRACT: The paper gives a historical account of the state of wetlands in Bangladesh. While recent rapid expansion of physical infrastructure in the floodplains and wetlands yielded two beneficial effects - increased food production and improved road communication - their adverse effects on fisheries, wildlife, flora and fauna and the ecosystem have been of far-reaching consequences. The paper recommends urgent actions to arrest further degradation of wetlands due to human interference. For this, three distinct, though not mutually exclusive, strategies for preservation of wetlands in Bangladesh have been suggested. These are: moratorium on development in at least a few ecologically sensitive wetlands, inclusion of environmental mitigation components in all development projects in the wetlands and rehabilitation of critically essential degraded wetlands. Success of such an approach is contingent on continuous research and monitoring of wetlands.

INTRODUCTION

About a thousand years ago Tirumulai inscription of Rajendra Cola (1012-1044 AD) described "Vangaladesa" as a land "where the rainwater never stopped..... on the shore of the expansive ocean producing pearls and the Ganga whose water bearing flagrant flowers dashed against the bathing places" (Chowdhury, 1967 : 81-82). The abundance of water and wetlands has always been the geographical and historical destiny of Bangladesh. More than two thirds of Bangladesh may be classified as wetland according to the definition enunciated in the Ramsar Convention. About 6.7 percent of Bangladesh is always under water, 21 percent is deeply flooded (more than 90 cm) and around 35 percent 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 variety of dynamic ecosystems ranging from mangrove forests (about 577,100 ha), natural lakes (Rainkhyongkine and Bogakine lakes and Ashuhila Beel), man-made reservoir (Kaptai lake), freshwater marshes (about 400 *haors*), oxbow lakes (about 5,488 ha, locally known as *baors*), freshwater depressions (about 1,000 *beels*), fish ponds and tanks (about 115,000 ha), estuaries and seasonally inundated extensive floodplains (Akonda, 1989). The wetlands are the key to Bangladesh economy and environment. Nowhere in the world is the life of so many (about 110 million) inextricably linked to the productivity and sustainability of wetlands.

Despite their uninviting appearance, the wetlands in Bangladesh had been the inexhaustible source of its wealth. The medieval travellers used to describe Bangladesh as a "hell full of bounties" (Ali, 1985). The inhospitable terrain and the humid climate of Bangladesh gave the impression of hell to the travellers. However, much of the bounties of nature originated in the wetlands. Its extensive wetlands may be compared to "legendary pitchers of wine that are never emptied" despite their continuous use (Niering, 1966). The biological productivity of wetlands as measured in terms of volume of biomass, intensity of their use and rate of their replacement is significantly higher than in other ecosystems. The wetlands are also ecological safety valves which

were designed by nature as reservoirs for mitigation of floods, as sinks for pollutants and toxicants and as regulators of recharge and discharge of groundwater. They are also the stabilizers of local climatic conditions particularly rainfall and temperatures through the overall hydrological, nutrient and material cycles (Dugan, 1990). The inaccessible wetlands are also the cornucopia of nutrients. They provide sanctuary to a wide variety of wildlife. They provide sheltered habitat for fish for spawning and nursery and as natural surrounding for growth. Globally two thirds of fish for human consumption depend upon wetlands at some stage in their life cycle. About 260 species of freshwater fish belonging to 55 families, 25 types of tortoises and turtles and 56 species of palacemonid and panaeid prawns live in the wetlands of Bangladesh (Ali, 1991). About 150 species of waterfowl and 50 species of reptiles including *gharial (Gavialis gangeticus)*, 42 species of mammals and 8 species of amphibians have been located in the wetlands of Bangladesh (World Bank, 1991a).

DEGRADATION OF WETLANDS

Apparently the wetlands are static, inert and unchanging. In reality, they are self-destructive ecosystems which are in a process of transition from permanently wet to generally dry environment. In the ultimate analysis, the wetlands are doomed to die. Usually the natural process of change takes place so slowly over so many years that it may seem that nothing at all is happening (Niering, 1966). Sometimes, however, the process of degeneration of wetlands is accelerated by sudden natural change or human intervention. The ecological dislocation in the moribund delta in South West Bengal in the late nineteenth and early twentieth century is a case in point (Ganguly, 1938). Rivers in the moribund delta died as the main channel of the Ganges shifted from the Bhagirathi to the Padma. The stagnation of rivers contributed to recurrence of malarial epidemics and shrinkage in cultivated area. Similarly, Chalan Beel, the largest waterbody in Bangladesh, experienced rapid siltation in the early twentieth century owing to natural causes. It was estimated in 1916 that about 169 million cubic feet of silt were being deposited in Chalan Beel every year. About a hundred years back, the area of the *beel* stood at 421 square miles. In 1909 it shrank to 33 square miles; in 1913 it was further reduced to 12 to 15 square miles (O'Malley, 1916). In June 1987, the *beel* was completely dry except for some small manmade ponds (Akonda, 1989).

In recent years, human intervention has speeded up the loss of wetlands in Bangladesh. The natural order was disturbed by the significant increase in population since the late nineteenth century. Bangladesh's population was virtually stationary for two thousand years preceding the establishment of the British rule (Davis, 1951). The upward trend in population in this region began in the early years of the nineteenth century and accelerated as 1870s approached. The increase in population was triggered by a fall in the death rate resulting from improvement in the supply system of foodgrains and improved health measures. In last one hundred years, population in Bangladesh quadrupled - increasing from 26.8 million in 1891 to 109.8 million in 1991. This has necessitated dramatic expansion of cultivated areas in the wetlands.

Similar population explosion also occurred in the neighbouring countries which share the watersheds with Bangladesh. During the eighties, Nepal lost forests at the alarming rate of 4 percent per year (World Resources Institute, 1988). The rate of deforestation in India as a whole was 0.3 percent per year. However, the rate of deforestation was much higher in Assam, Meghalaya and Tripura states which border on the wetlands of northern Bangladesh. The rate of forest loss in Bangladesh was 0.9 percent per year.

Of late there has been dramatic expansion of physical infrastructure in the floodplains of Bangladesh. The total length of road network has increased rapidly. The length of national and regional roads increased from 4,265 kms in 1973 to 12,321 kms in 1990. In addition, there are over 90,000 kms of feeder roads. The density of road network (in kms) per 100 square miles of land in Bangladesh is 7.6; in Burma 3.8; in China 2.7; in India 1.0; in Indonesia 2.4; and in Pakistan 4.8. Bangladesh thus has the highest road density in the region (World Bank, 1991b). As early as 1890s when the road network was very limited, railroads and highways which interfered with the natural drainage system were blamed for ecological dislocation in Bengal (O'Donnel, 1891). The problem has been compounded in last one hundred years. Poor planning of road alignments in utter disregard of natural hydrology and inadequate provision of drainage structures in extensive embankments for both rural road network as well as for the main roads had contributed to periodic drainage congestion.

For millennia the inhabitants of Bengal delta had lived with floods. Though embankment is the simplest and oldest technique for flood mitigation, largescale embankments were unknown to Bangladesh before the 1960s.The construction of massive flood embankments started with the establishment of East Pakistan Water and Power Development Authority in 1959. By 1969, flood control and drainage facilities were provided to 0.47 million hectares of cropland (IBRD, 1972:I-67). It increased to 2.74 million hectares in 1985 - an increase of about 580 percent in 16 years. Nearly 20 percent of the total area in the country is protected by 6,134 km embankments, 4,521 hydraulic structures and 958 river closures (MPO, 1986). About 31 percent of total protected area is contained in the Coastal Embankment Project located in the estuaries and coastal areas of southern Bangladesh. Most of the embankments are designed for protection against peak floods. Some of the embankments are constructed for limited protection in deeply flooded areas. These are known as submersible embankments. They protect crops against early floods and in some cases contribute to retention of water.

The rapid expansion of physical infrastructure in the floodplains and wetlands in Bangladesh yielded two beneficial effects. First, foodgrains production increased from 11.9 million tons in 1969-70 to 18.83 million tons in 1990-91. Much of the increased production came from the irrigated areas in wetlands. Secondly, rural roads contributed to alleviation of poverty through generation of employment, adoption of new agricultural technology and increasing income of the poor (Ahmed and Hossain, 1990).

Though the immediate benefits of physical infrastructure are well-known, the adverse effects of the tragedy of wetlands in Bangladesh have not, however, been catalogued

as yet. The most dramatic impact of increased withdrawal of water for irrigation, drainage and flood control measures and the submersible embankments is evident on the open water fisheries in the wetlands of Bangladesh. Various water control projects have reduced the size of fish habitats. Submersible embankments which are designed to prevent early floods impede the migration of river breeding fishes like major carps from the *beels* into the rivers in the spawning season leading to autolysis (reabsorption of the ripe eggs in the ovaries of the female fish). The flood control and drainage projects also prevent the movement of new-born hatchlings of major carps into the nursery and grazing grounds of floodplains (Ali, 1991). For example, an evaluation of Chandpur Irrigation Project indicates a 35 percent decrease in total fish catch in the first two years after the project became operational (MPO, 1987). However, the adverse effect of the degradation of wetland is not confined to the fall of fish productivity alone. The diversity of the fish species in the wetlands was also reduced. In Chandpur Irrigation Project, human interference resulted in the displacement of commercial prawn species by non-commercial small resident prawn. The carps, namely, *katla* (*Catla catla*), *mrigal* (*Cirrhinus mrigala*) and *nandail* (*Labeo nandina*) are fast disappearing from the *haor* areas of Sylhet. In Karchar Beel in Sunamganj, the harvest of *rohu* (*Labeo rohita*) fell by 85 percent, *kalibaus* (*Labeo calbasu*) by 98.75 percent and *ghonia* (*L. Gonius*) by 97.36 percent.

Similar adverse effects of recent development in the wetlands can be easily discerned on birds and reptiles. Of the recorded 150 species of waterfowl in the wetlands of Bangladesh, over 70 are now rare. The large species such as grey leg goose (*Anser anser*), Brahminy duck (*Tadorna ferruginea*) and Mukra or combduck (*Sarkidiornis melanotos*) have virtually disappeared (Akonda, 1989). The white winged wood duck is on the verge of extinction. A few species of reptiles are also fast disappearing. The marsh crocodile or mugger (*Crocodylus palustris*) is extinct. The total population of *gharial* (*Gavialis gangeticus*) may be as low as 8 to 10. The wetlands of Bangladesh were the natural habitats of wide varieties of wild rice and plants (330 species). With the propagation of high yielding varieties of rice, the traditional varieties were pushed out leading to irreparable loss of genetic resource pool. A variety of *shati* weed (*Mantisia spathulata*) and a ricefield weed (*Rotala simpliciuscula*) are now threatened.

It is not certain that the gains in agricultural productivity in the wetlands of Bangladesh would be sustainable. The following factors are likely to undermine crop production in the reclaimed and drained wetlands in the foreseeable future (FAO, 1988):

- reduction in the amount of nitrogen added to the soils by bluegreen algae which existed in deep flooded water;
- rapid decomposition of soil organic matters during the period when soils are not flooded;
- reduction in the addition of calcareous silt;
- nitrogen enrichment in depression soils resulting from heavy use of fertilizer uptake;
- ponding of water in depressions owing to construction of road and flood protection embankments and consequent damage to crops; and
- recurrence of flashfloods in eastern wetlands resulting from increasing degradation of hill areas upstream.

The ecological stress in the wetland areas is not confined to threatened flora and fauna only. It extends to human habitations also. Though there has been significant rise of population in the wetlands like the *haor* areas, the increase in population mostly came from immigration. A survey in the *haor* areas indicate that (i) life expectancy in these areas is significantly shorter than the national average and (ii) the child mortality exceeds the national average by more than 200 percent (Islam, 1985). Because of the acute shortage of high ground in the rainy season, the wetlands in Bangladesh today contain the worst rural slums in the world. Most of the new settlements are built on artificial mounds which have no vegetation at all because of space constraints. Such villages are appropriately described by Islam as "naked villages". Life in such an environment continues to be "nasty, brutish and short".

As the Karachi Declaration on the Conservation of Wetlands and Waterfowls in South West Asia rightly emphasized, "non-sustainable development leading to the destruction and degradation of wetland ecosystems threatens both the natural resources base used by local human populations as well as wildlife". Urgent action is needed before human interference in the wetlands results in irreversible damage.

STRATEGY FOR PRESERVATION OF WETLANDS IN BANGLADESH

There may be four distinct (though not mutually exclusive) strategies for preservation of wetlands in Bangladesh:

- moratorium on further development of wetlands;
- protection of ecologically sensitive wetlands;
- restoration of degraded wetlands; and
- inclusion of mitigation measures in wetland development projects.

The first strategy is officially practised in USA. President Carter established a national policy of no "net loss of wetland" (Finlayson and Moser, 1991). A similar provision was included in the Ramsar Convention which laid down that "when a contracting party in its urgent national interest deletes or restricts the boundaries of a wetland included in the list, it should as far as possible compensate for any loss of wetland resources". The Action Plan of National Environment Policy in Bangladesh also mandates preservation of all existing wetlands for pisciculture and prohibits any measure which would result in reduction of existing wetland. The objective of this directive is obviously laudable from the protection point of view. However, it will be difficult to implement this directive in Bangladesh for two reasons. First, as Dugan (1990) rightly points out, "wetlands are dynamic ecosystems which change over time. Merely protecting them from external threats may be insufficient to save them". The rivers in Bangladesh carry an annual silt load of 2.4 billion tons. This implies that about one fifth of total annual sediment load in the world is transported through Bangladesh which occupies only one thousandth of the land in the globe (Khan, 1987). Even without human interference, some of the wetlands in Bangladesh would be silted up. An enormous investment would be needed to protect many of these wetlands. Secondly, the

wetlands in Bangladesh are not empty lands. Because of the high density of population, wetlands cannot be protected on government initiative alone. The total ban on development of the existing wetlands is not likely to be acceptable to local population.

Instead of protecting all wetlands it will be easier to protect ecologically sensitive wetlands. "Areas of outstanding natural value for hydrological, geological, scenic, wildlife or vegetation reasons should, therefore, be converted with great care and not at all be termed ecologically sensitive areas" (ADB, 1991). Such an approach would reduce the cost of conservation. The logical first step in this approach is to determine which wetlands have the highest value in their present form and the least value if transformed (i.e. the least opportunity cost for conservation). There are, however, two weaknesses of this strategy. First , while it reduces the direct cost of protection and investment it involves very high information cost. Adequate data for selecting ecologically sensitive areas are not always available. Secondly, it is difficult to segregate ecologically sensitive areas from adjoining areas. Wetlands are open systems influenced by activities well beyond their boundaries. Because of externalities, the protection of ecologically sensitive wetlands will have to be undertaken within a framework for national planning.

In some countries, efforts have been made to restore degraded wetlands. Most of the wetland restoration initiatives had little success. The reasons for limited success of restoration efforts may be attributed to the following factors (Dugan, 1990).

a) The complex ecosystem of wetland is the product of evolution over a long time and it cannot be replicated quickly.
b) Information about the processes which created wetlands are extremely limited and there is no blueprint for restoration.
c) The interrelationship between the species and substrate types is not properly understood and is not possible to recreate biodiversity artificially.
d) Wetlands are always in a process of change. There is, therefore, no ideal state which may be replicated.

Furthermore, most of the degraded wetlands in Bangladesh are densely populated. It will not, therefore, be possible to uproot the existing population in order to restore the wetlands. Though rehabilitation of all degraded wetlands is not a feasible option, restoration of a few strategic wetlands may be necessary. The wanton destruction of Chokoria Sundarban for shrimp pond and other aquaculture projects is a case in point. Apart from the loss of biodiversity it has undermined the very basis of shrimp cultivation by destroying natural nutrient cycle and exposing the area to cyclone storms and tidal surges. Despite implementation difficulties and lack of resources, rehabilitation of a few wetlands may turn out to be unavoidable.

The wetlands are the last frontiers of Bangladesh. Because of the urgency to raise more food for ever growing population, there will be persistent demand for the development of wetlands. There are two arguments in favour of this strategy. First, the development of wetlands contributes to human welfare in the short run by increasing production and promoting a more healthy environment. Secondly, some of the projects would mitigate

the adverse effects of natural changes which are continuously taking place in the wetlands. In the long run, however, many of these projects may prove to be counterproductive unless mitigation measures are taken to protect the environment.

The mitigation measures include regulation structures for fish movement and fishery replacement measures such as fish hatcheries, rearing of hatchlings, stocking of the fingerlings and management of standing waterbodies for fish production and sanctuaries and other measures for protection of reptiles and animals. There are, however, two main problems of this strategy. First, the mitigation measures are very often excluded or kept at minimum to reduce project cost. Half-hearted mitigation measures do not serve any useful propose. Secondly, mitigation measures, however effective, cannot be a substitute for the natural process. The loss of biodiversity is inevitable despite the mitigation measures.

CONCLUDING REMARKS

An analysis of the conventional strategies indicates the complexities of conservation of wetlands in Bangladesh. No single strategy is likely to be successful. There should be at least three elements in the environmental management of the wetlands:

- moratorium on development in at least a few ecologically sensitive wetlands;
- inclusion of environmental mitigation components in all development projects in the wetlands; and
- rehabilitation of critically essential degraded wetlands.

The success of such an approach is contingent on continuous research on and monitoring of the wetlands. Obviously, there will be resource constraints. However, we should not be deluded by short-term economic gains to ignore environmental costs. As World Commission on Environment and Development(WCED) rightly pointed out, "Environment and development are not separate challenges, they are inexorably linked. Development cannot subsist upon a deteriorating environmental resource base; the environment cannot be protected where growth leaves out of account the costs of environmental protection. These problems cannot be treated separately by fragmented institutions and policies. They are linked in a complex system of cause and effect" (WCED, 1987).

REFERENCES

Ahmed, Raisuddin and Mahbub Hossain. 1990. *Development Impact on Rural Infrastructure in Bangladesh*. International Food Policy Research Institute, Washington.

Akonda, A.W. 1989. Bangladesh. pp541-581. D.A. Scott. (ed.) *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge.

Ali, Mohammad Mohar. 1985. *History of the Muslims of Bengal*. Imam Muhammad Ibn Saud Islamic University, Riyadh.

Ali, M. Youssouf. 1991. *Towards Sustainable Development : Fisheries Resources of Bangladesh* Ministry of Environment and Forest, Government of Bangladesh, Dhaka.

Asian Development Bank. 1991. *Minimum Quality Criteria for Ecologically Sensitive Areas*. Asian Development Bank, Manila.

Chowdhury, Abdul Momen. 1967. *Dynastic History of Bengal*. Asiatic Society of Pakistan, Dhaka.

Davis, Kingsley. 1951. *The Population of India and Pakistan*. Princeton University Press, Princeton.

Dugan, P.J.(ed.). 1990. *Wetland Conservation: A Review of Current Issues and Required Action*. IUCN, Gland, Switzerland.

Finalayson Max and Michael Moser (ed.). 1991. *Wetlands*. Facts on File, Oxford.

FAO. 1988. *Agroecological Regions of Bangladesh*. FAO, Rome.

Ganguly, B.N. 1938. *Trends of Agriculture and Population in the Ganges Valley*. Methewn and Company, London.

IBRD. 1972. *Land and Water Resoruces Sector Study, Bangladesh, 9 Vols*. World Bank, Washington D.C.

Islam, Serajul. 1985. *Studies in Socio Cultural Change in Rural Villages in Bangladesh*. University of Foreign Studies, Tokyo.

Khan, A.A. 1987. Economic considerations and alternatives in water policy formulation for Bengal. In: Mohammad Ali (ed.). *Water Resources Policy for Asia*. A.A. Bulkana, Rotterdam.

M.P.O , 1986. *National Water Plan* (mimeo). Ministry of Irrigation, Water Development and Flood Control, Government of Bangladesh, Dhaka.

M.P.O. 1987. *Fisheries and Flood Control, Drainage and Irrigation Development*. Ministry of Irrigation, Water Development and Flood Control, Dhaka.

Niering, William A. 1966. *The Life of the Marsh*. McGraw Hill, New York.

O'Donnel, C.J. 1893. *The Census of India*, 1991. Bengal Secretariat Press, Calcutta.

O'Malley, L.S.S. 1916. *Bengal District Gazetteers: Rajshahi*. Bengal Secretariat Press, Calcutta.

WCED. 1987. *Report of the World Commission on Environment and Development*. United Nations, New York.

World Bank. 1991a. *Bangladesh Environment Strategy Review*. World Bank, Washington D.C.

World Bank. 1991b. *Bangladesh Transport Sector Review*. World Bank, Washington D.C.

World Resource Institute. 1988. *World Resource 1988-89*. New York Basic Books.

FRESHWATER WETLANDS IN BANGLADESH: STATUS AND ISSUES

Ainun Nishat

ABSTRACT: The paper examines the definition of wetlands as adopted at RAMSAR convention and the classification of wetlands as developed by IUCN. The paper then argues that the study of *haor* areas, which offer a complex ecological, hydrological and geo-morphological landscape system, comprises all the elements of freshwater marshes, floodplains, swamp forests and lakes and covers all issues related to conservation and sustainable management of freshwater wetlands. The paper describes the characteristics of wetland in Bangladesh and identifies various causes of their degradation. Present-day approaches of development activities in *haors* are directly linked with the agricultural practices and cropping seasons. There are two distinct approaches: one that provides protection against early monsoon flood with the help of submersible dykes to save *boro* crop and the other for protection against the main monsoon flood that requires high embankments. The paper then evaluates adverse as well as positive impacts of these activities and finds that submersible dykes are more acceptable to local people.

INTRODUCTION

The RAMSAR Convention has defined wetlands as "*areas of marsh, fen, peatland 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*". Thus the term *wetlands* groups together a wide range of inland, coastal and marine habitats which share a number of common features (Dugan 1990).

The range of wetland habitats which come under the mandate of the RAMSAR Convention is enormous. According to their basic biological and physical characteristics IUCN has identified a total of 39 categories of wetlands of which 30 are natural wetlands and nine man-made (Dugan 1990). This categorisation given in Table 1 has been further simplified into seven landscape units which are wetlands or where wetlands form an important component in the planning framework. These are: estuaries, open coasts, floodplains, freshwater marshes, lakes, peatlands and swamp forests.

Haors, baors, beels and *jheels* are commonly identified as freshwater wetlands in Bangladesh and they have the characteristics of four landscape units - floodplains, freshwater marshes, lakes and swamp forests. Floodplains are the areas that undergo periodic flooding as a river channel overflows with flood water. Freshwater marshes are more or less permanent shallow water dominated by reeds etc. Lakes, natural or man-made, are deeper waterbodies. Swamp forests develop in still water areas around lake margins. These landscapes do not necessarily occur in individual pattern; rather, often a wetland may contain a combination of several such units (Dugan, 1990).

Beels may be taken to be a combination of freshwater marshes, lakes and swamp forests. *Baors* are *beels* which are actually oxbow lakes and *jheels* are freshwater marshes. *Haors* are combination of floodplains and *beels* which in monsoon go under water and in dry months the *beels* are isolated as the floodplains dry up. It may therefore be said that *haors* cover all the features and characteristics of freshwater wetlands.

This paper concentrates on issues related to *haors* and impact of development activities in these areas because they represent all issues related to conservation and sustainable management of freshwater wetlands in Bangladesh.

CHARACTERISTICS OF THE FRESHWATER WETLANDS

A *haor* is a backswamp or bowlshaped depression, between the natural levees of a river. These *haors* are flooded every year by monsoon floods. They remain under water for several months of the year and when drain out during the post-monsoon, some permanent waterbodies, or *beels*, remain in the deepest parts of the *haors*.

A *haor* in general may be subdivided into three major areas which have similar characteristics in terms of morphology and hydrology : the piedmont area (area around the hill foot), the floodplain and the deeply flooded area (Hossain and Nishat 1989). In each of these areas, the actual conditions of hydrology, morphology, fishery, agronomy, socio-economy and water resources are different.

The piedmont or foothill areas are the high grounds. In Sylhet they lie at the foot of the Meghalaya mountains in the north and at the foot of the Tripura hills in the east. These are areas of highly active rivers prone to flashfloods and carry considerable sediment loads. In the geomorphological process, piedmont areas are areas of accretion where the deposition of eroded material from the hills occur. Backswamps receive smaller portion of sediment load and the ground level rises slowly. This natural process of self deposition and changes in geomorphology is relatively fast on morphological time scale (BWDB, 1986).

The backswamps have very important function in storing water and sediment. In the piedmont and floodplain areas the river banks are the most elevated soils in the cross-section and the river bed lies more deeply than the backswamp. When a flood wave moves through the river, the flood waters overtop the banks into the backswamp and thus the floodpeak downstream is lowered. After the flood has receded the backswamp drains into the river, augmenting the flow downstream.

There are higher isolated grounds within the floodplains which are part of the piedmont areas, but these clearly do not have the same hydrological and morphological characteristics. They are just isolated areas which never, or rarely ever, suffer from flooding.

Table 1: Classification of Wetlands [Source: Dugan 1990]

1. Salt Water		
1.1. Marine	*1. Subtidal*	i) permanent unvegetated shallow waters less than 6m depth at low tide, including sea bays, straits. ii) subtidal aquatic vegetation, including kelp beds, sea grasses, tropical marine meadows. iii) coral reefs
	2. Intertidal	i) Rocky marine shores, including cliffs and rocky shores. ii) Shores of mobile stones and shingle. iii) Intertidal mobile unvegetated mud, sand or salt flats. iv) Intertidal vegetated sediments, including salt marshes and mangroves, on sheltered coasts.
1.2. Estuarine	*1. Subtidal*	i) Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.
	2. Intertidal	i) Intertidal mud, sand or salt flats, with limited vegetation. ii) Intertidal marshes, including salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes. iii) Intertidal forested wetlands, including mangrove swamp, nipa swamp, tidal freshwater swamp forest.
1.3. Lagoonar		i) Brackish to saline lagoons with one or more relatively narrow connections with the sea.
1.4. Salt lake		i) Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.
2. Freshwater		
2.1. Riverine	*Perennial*	i) Permanent rivers and streams, including waterfalls. ii) Inland deltas.
	Temporary	i) Seasonal and irregular rivers and streams. ii) Riverine floodplains, including river flats, flooded river basins, seasonally flooded grassland.
2.2. Lacustrine	*Permanent*	i) Permanent freshwater lakes (>8 ha), including shores subject to seasonal or irregular inundation. ii) Permanent freshwater ponds (<8 ha).
	Seasonal	i) Seasonal freshwater lakes (>8 ha), including floodplain lakes.
2.3. Palustrine	*Emergent*	i) Permanent freshwater marshes and swamps on inorganic soils, with emergent vegetation whose bases lie below the water table for at least most of the growing season. ii) Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by *Papyrus* or *Typha*. iii) Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes, and dambos. iv) Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, and fens of all types. v) Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt. vi) Freshwater springs and oases with surrounding vegetation. vii) Volcanic fumaroles continually moistened by emerging and condensing water vapour.
	Forested	i) Shrub swamps, including shrub-dominated freshwater marsh, shrub carr and thickets, on inorganic soils. ii) Freshwater swamp forest, including seasonally flooded forest, wooded swamps on inorganic soils. iii) Forested peatlands, including peat swamp forest.
3. Man-Made Wetlands		
3.1. Aquaculture/Mariculture		i) Aquaculture ponds, including fish ponds and shrimp ponds.
3.2. Agriculture		i) Ponds, including farm ponds, stock ponds, small tanks. ii) Irrigated land and irrigation channels, including rice fields, canals and ditches. iii) Seasonally flooded arable land.
3.3. Salt Exploitation		i) Salt pans and salines.
3.4. Urban/Industrial		i) Excavations, including gravel pits, borrow pits and mining pools. ii) Wastewater treatment areas, including sewage farms, settling ponds and oxidation basins.
3.5. Water-storage areas		i) Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, draw down of water level. ii) Hydro-dams with regular fluctuations in water level on a weekly or monthly basis

The second area is the floodplain. The morphological process in this area is similar to that in the piedmont area but with a milder slope. The average slope of the Manu River in the piedmont area is 0.0002 but the average slope of the Surma River in the floodplain is 0.0003. Levees form much more slowly and sediment loads are considerably less. Although susceptible to severe floods, the rivers in the area have the characteristics of lowland rivers. Embanking the backswamps here does not have the same morphological impact as in the piedmont areas, but it has a serious impact on the water levels. The backswamps fill and drain several times during each monsoon, each time reducing the floodpeaks downstream. Although the first flood is more reduced than the following floods, (because the first flood also fills the dead storage in permanent waterbodies or *beels*), the backswamps in the floodplains alternatively offer storage for each floodpeak.

The third area is no longer a floodplain. It no longer serves as a storage medium which is filled and emptied several times in each monsoon. Instead, it serves as a single reservoir which reaches its highest waterlevel at the middle of the monsoon and then gradually drains out. It is the deeply flooded area of the Surma-Meghna basin.

Hydrology of the Wetland Areas

The hydrographs of the rivers in the *haor* areas show that two floods, the early monsoon flood and the monsoon flood, occur almost every year. Fig. 1 shows a typical hydrograph of a river in the area. The early monsoon flood which has the characteristics of flashflood mostly occurs between the period of late April to middle of May. The gradual monsoon floods occur later on in July-August. In fact, in a typical year the entire *haor* area would go under water which is considered to be normal.

Agriculture in the Wetlands

Figure 2 shows a typical cropping pattern along with the time and duration of occurence of floods and need for irrigation water. Fig. 3 shows the agro-ecological divisions of a typical *haor* area. The pre-monsoon floods frequently damage the *boro* crop and the monsoon floods damage transplanted *aman*. Details of relationship between hydrological and topographical characteristics and agricultural parctices are discussed in another paper in this book.

STATUS OF WETLANDS IN BANGLADESH

Wetland Coverage

The total area of wetlands in Bangladesh has been variously estimated at seven to eight million hectares, i.e. about 50% of the total land surface. Table 2 gives the breakup.

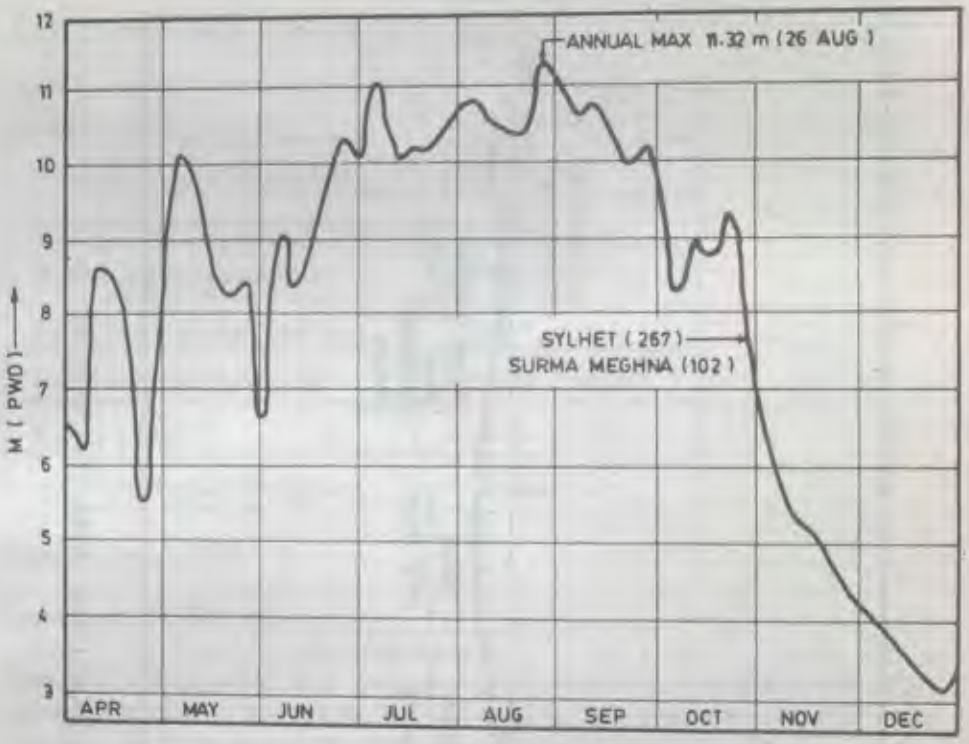


Figure 1: Typical Hydrograph of a River in Haor Area

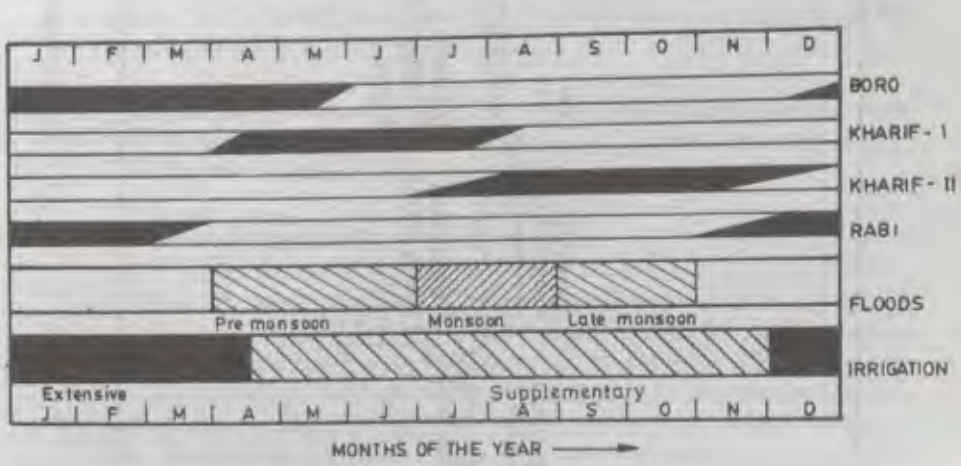


Figure 2: Relation of Crops with Flood and Irrigation

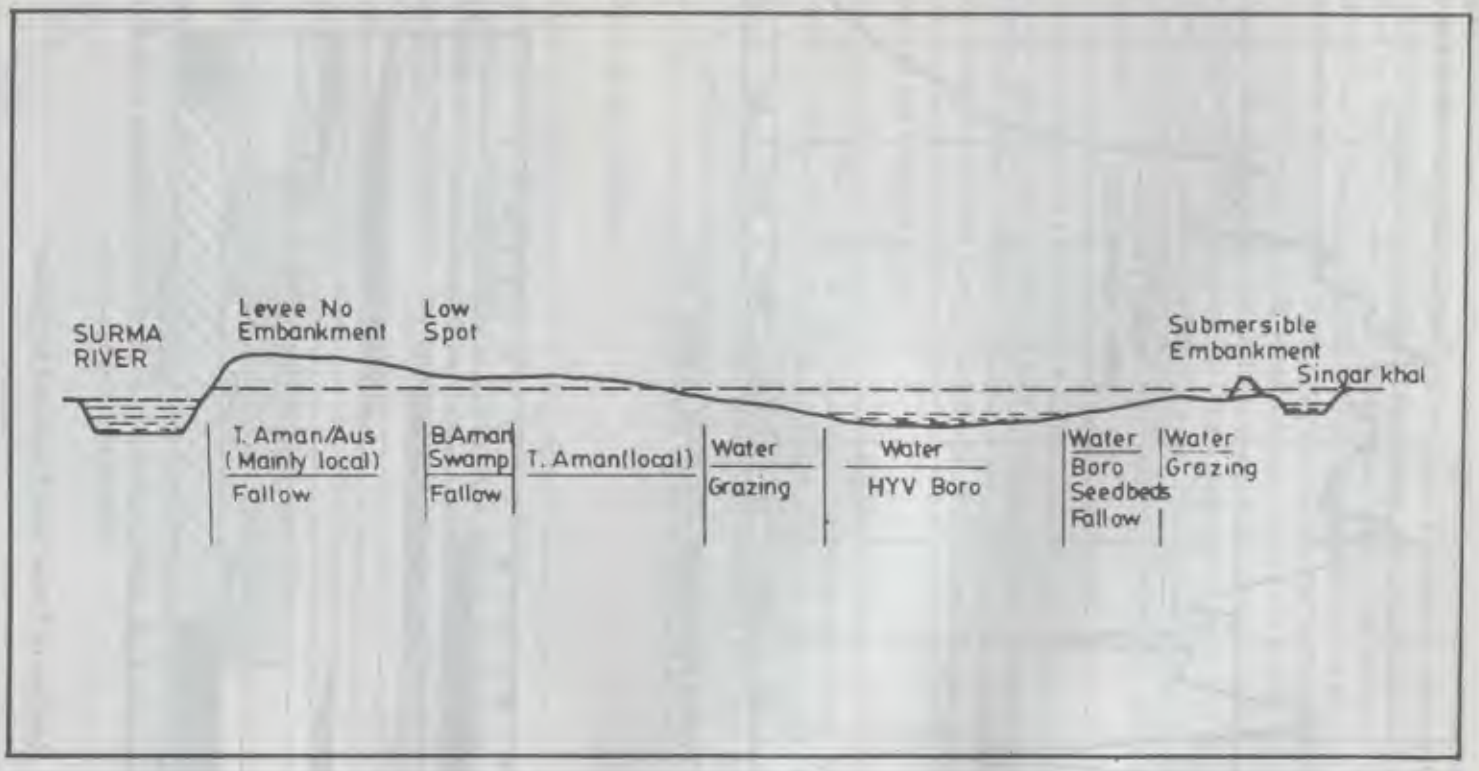


Figure 3: Agroecological Division of a Typical Haor (Zilkar Haor in Sylhet)

Table 2: **Distribution of Wetlands in Bangladesh**

Type	Area in hectare
Permanent rivers and streams	480,000
Estuaries and mangrove swamps	610,000
Shallow lakes and marshes	120,000 - 290,000
Large water storage reservoirs	90,000
Small tanks and fish ponds	150,000 - 180,000
Shrimp ponds	90,000 - 115,000
Seasonally-flooded floodplains	5,770,000

Source: Akonda 1989

Importance of Wetlands

Wetlands in Bangladesh have great ecological, economic, commercial and socio-economic importance and values. They contain very rich components of bio-diversity like flora and fauna of important local, national and regional significance.
The principal functions of wetlands are:

> ground water recharge, ground water discharge, storage of flood water, shoreline stabilization and reduction of erosion, sediment trapping, nutrient retention/removal, support for food chains, fisheries production, habitat for wildlife, recreation, natural heritage values, biomass production, water transport, bio-diversity preservation and micro-climate stabilization (IWRB 1992, Dugan 1990).

Wetlands in Bangladesh are a very rich depository of vegetations, aquatic plants, reeds and algae. The floral composition is relatively uniform throughout the *haors*, *jheels*, *beels* and *baors* but the dominance varies seasonally.

Wetlands are nationally important for a variety of reasons:

> **Biodiversity**: The large and varied wetland environment is rich in species diversity. Of more than 5,000 species of flowering plants and 1,500 species of vertebrates, of which approximately 750 are birds and over 500 are coastal, estuarine and freshwater fish, some 400 vertebrate species and between 200 and 300 plant species are judged to be dependent on wetlands for all or part of their life spans. Wetlands provide habitat for a rich variety of resident and migratory waterfowls, a number of endangered species of international interest, and a large number of species of commercial importance.

Fisheries: The inland capture fishery is the most important subsector in terms of total catch, source of employment and supply of animal protein. It is based on the country's vast freshwater resources and some 270 species of fin and shellfish which inhabit them. Essential habitats for the inland fisheries comprise open and closed water habitats, including rivers, canals, floodplains, *haors, beels, baors* and small roadside depressions. Although discrete in the dry season, these waterbodies become interconnected during the monsoon and provide critical habitats for completion of the life cycles of a large number of fish species.

Agricultural diversity: There are many local varieties of rice, conservatively estimated to number in the thousands, as well as other existing or potential commercially-important plants, which provide a valuable gene pool to ensure continued development of improved varieties for the future.

Tourism: It remains an infant if not non-existent economic activity, but there is substantial foundation for the view that the country's natural resources, especially the Sundarbans, could support the development of this sector.

Other economic activities: The country's wetland resources support a significant range of economic activities other than fishing, such as extraction of reed and other plant products, harvesting of aquatic vegetation, herbs, etc.

Degradation of Wetlands

Since independence in December 1971 there has been an accelerated expansion of physical infrastructure in the floodplains and *haor* areas. In recent years, decentralisation of administration at the *thana* level also led to a rapid expansion of roads and feeder roads even in the rural areas of the *haor* basins. These infrastructures were often done without proper planning or due regard to natural waterflows. These poorly planned roads and drainage structures created waterlogging and also had serious impact on the water regimes in the flood plains.

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 ricefields; flood control and irrigation projects for enhancement of agricultural productivity; national, local and rural infrastructures like ill-planned roads, narrow culverts etc.; over-felling of wetland trees; over-grazing by livestock; over-fishing and associated disturbances; siltation due to degradation of the watershed areas which are often transboundary in nature; indiscriminate control/ regulation/use of waterflows of main river systems in the upper riparian; and pollution of water due to industrial, urban, agrochemical and other types of pollutants including pollution from transboundary sources.

Degradation of the wetlands in Bangladesh have created the following impacts:

a) serious reduction in fish habitat, fish population and diversity;
b) extinction and reduction of wildlife including birds and reptiles;
c) extinction of many indigenous varieties of rice with the propagation of high-yielding varieties;
d) loss of many indigenous aquatic plants, weeds and shrubs;
e) loss of natural soil nutrients;
f) increase in the recurrence of flashfloods;
g) deterioration of living conditions;
h) loss of natural water reservoirs and of their resultant benefits; and
i) degeneration of wetland-based ecosystems, occupations, socio-economic institutions and cultures.

DEVELOPMENT ACTIVITIES AND THEIR IMPACT

Bangladesh's wetland resources have suffered considerably from the impacts of a burgeoning human population, including direct extraction and habitat loss. In the Ganges-Brahmaputra floodplain alone, an estimated 2.1 million ha of wetland have been lost to flood control, drainage and irrigation development (Akonda, 1989). Amongst these are nationally important wetland areas such as Arial Beel and Chalan Beel.

The impact of human interference has been particularly damaging to the fragile ecosystem and sustainability of the *haor* basins. The exploitation of the *haor* basin ecosystem by man began with the agrarian settlement of the *haor* basins. In the beginning its productivity and favourable tenurial terms attracted people for settling in the *haor* region from the surrounding districts. They founded villages in the region and organised production systems in the framework of subsistence economy to exploit the resources of the *haor* region. By 1770s almost the whole of the cultivable area of the *haor* basins came under the plough. During the period 1780-1900, under a stressed environmental condition migration to the *haor* basins declined and there was considerable outward migration. As a result, the basins so populous and prosperous were nearly depopulated by the 1860s (Islam, 1985). The cause of this decline has been attributed to the successive natural calamities and consequent environmental changes which produced a situation unfavourable to husbandry and population growth. However, the *haor* basin ecosystem sustained this environmental stress and regained its productivity. From the first quarter of the 20th century the *haor* basins began to attract settlers again from surrounding densely populated regions. Since then the *haor* basins are experiencing exploitation of ecosystems with increasing intensity by man causing adverse effects.

Apart from changes in the landuse pattern, increased human activities in the *haor* areas, have put pressure on their ecosystem. Exploitation of aquatic vegetation and fruits like *makna, singra*, lotus, lily, *hogla* on a large scale has caused increase in the area under thin aquatic vegetation. This has also contributed to the decline of fish and migratory

birds. The noise produced by power pumps along the *boro* fields has scared away birds to a calmer environment.

Many partial flood control projects with the help of submersible dykes have been taken up to protect the *boro* from pre-monsoon flooding. Full flood control projects have also been implemented for providing a controlled water regime for agriculture. Projects for drainage improvement have also been undertaken.

Embankment for flood control, drainage and irrigation reduce floodplains and obstruct fish movement and migration from rivers as well as *beels* to the remaining floodplains, for breeding and feeding. These also alter growth pattern, species composition etc.

River closures and barrages - both major and minor - obstruct upstream and downstream migrations of fish and prawn populations and thereby inhibit or disrupt their reproduction and sustenance. The barrages and closures also change the flow pattern and the characteristics of the river water turn lentic or stagnant from lotic or flowing waterbodies. As a result, species composition and species diversity in the modified hydrological regimes are altered drastically. Fish and prawn conditioned to live and grow in flowing waters are replaced by species which prefer stagnant water above the barrages and closures.

During January-April period, when both surface area and volume of standing waters are low, the standing crops of fish, prawn and other aquatic animals are most vulnerable to fishing and alternations in habitat conditions. This is the period when demand for abstraction of surface water for crop irrigation is also at its maximum and water is abstracted indiscriminately without any consideration for the water needs for fish, prawn and other aquatic animals. Reduction of surface area and volume of standing water through abstraction for irrigation reduces dry season fish habitat further. It promotes overfishing.

Impact of these development activities have been studied in depth recently under the Flood Action Plan (Northeast Regional Water Management Project/FAP6, 1992 and FCDI/Agricultural Study/FAP12, 1992).

It has been identified that some of the impacts have been positive; however there are some adverse impacts of major concern from environmental consideration. In the following paragraphs these impacts are summarised.

Impact on Agriculture

In general, changes in cropping patterns made possible by these interventions tend to increase the preponderance of paddy, as this is the main monsoon crop and it generally gives the highest financial returns.

The major impact has been on cropping patterns in the *kharif* season. Reduced flood depths and durations have led to a move from *B aman* or *aus/aman* to *TL aman* and *T aman* HYV, and sometimes from *B aman* to *aus* followed by *T aman*. Where land has

been brought under early monsoon flood protection it has promoted expansion of *L boro* and adoption of HYV *boro*.

FCD/I projects have rarely resulted in increase in cropping intensities. In many successful projects the cropping intensity has actually fallen when a *rabi/aus* cropping pattern is replaced by a single *boro* crops. This is, however, often an effect of the irrigation component of such projects.

Where flood protection is effective there is evidence that increased levels of inputs are applied, both to paddy HYVs and to other crops.

Impact on Fisheries

The development activities have a major negative impact on capture fisheries from substantial reductions in the areas of regularly inundated floodplains, in the areas of permanent *beels* the blockages to fish migration routes. Many fishermen have lost their livelihoods, or been diverted to river fisheries, leading to overfishing in these areas which are also adversely affected by the changes in fish migration potential. The magnitude of these losses in most cases appears to be substantially greater than has been previously estimated.

The absence of integrated flood control and fisheries planning has led in some cases to acute social conflicts between fishermen and farmers. Flood control has provided opportunities for development of culture fisheries in some areas.

Impact on Livestock

Project impacts on bovine populations are complex. Bulk fodder availability tends to be adversely affected by development projects as a side-effect of their impact on crop production. Grazing opportunities are reduced where there are fewer crop losses and more switch over to HYV paddy varieties.

Non-Farm Economic Impact

Infrastructure development have both a direct and an indirect impact on non-farm economic activities. The direct impacts relate to communications and to employment in construction. In many projects the embankments provide an important communication network, and have stimulated the development of road transport, and subsequently improved the marketing infrastructure and access to social and other services. On the other hand there has been a negative impact on navigation, as previous waterways have been closed. In some cases this has seriously impeded freight transport within the project area. In general, road transport benefits outweigh water transport shrinkage, but the benefits and adverse effects do not accrue to the same groups.

Environmental Impact

The environmental impacts of the projects have been assessed in terms of three categories of issues: physical, biological and human. These have been evaluated in both the project areas and in external impact areas affected by the projects. In some cases external (off-site) impacts comprised the incremental effects of a project, taking into account the combined contributions from other geographically related FCD projects.

The most common positive direct environmental impacts were:

> reduced flooding, in terms of level, timing, rate of rise, duration and extent of floods; increased land availability due to the reduced extent of wetlands ; improved soil moisture status at critical periods, due to reduced wetness in the monsoon and, in some cases, to irrigation or water for post-monsoon and dry season use; improved land capability through the reduction of flood hazard and increased cropping severity and flexibility; improved opportunities for culture fisheries; and greater opportunities for afforestation and other tree-planting.

These in turn have provided significant benefits to the human populations, including:

> substantial rises in human carrying capacity; some improvement in human health and nutritution; greater protection for infrastructure with increased human safety and diminished disruption; improved access and communications, if only via the embankments themselves; substantial, if somewhat inequitable, economic benefits to the people in terms of income, employment, land values and credit-worthiness; generally favorable social attitudes to the projects, despite many complaints; and overall improvement in the quality of life due to these positive physical and socio-economic impacts.

The most common negative environmental impacts are:

> cummulative influences in the external areas in increasing riverflows, bank erosion and bed scouring, siltation, and flooding levels; drainage congestion due to inadequate design, operation and maintenance of drainage structures and channels; high risk in specific areas of certain projects of future catastrophic flooding, with associated hazards to infrastructure, life and property; decline in the quality of subsurface, river and wetlands waters, and thereby domestic water supplies (although data to quantify this impact are generally lacking); reduced extent of wetlands, which is ecologically negative; decline in soil fertility due to diminished aquatic vegetation and micro-biota; contribution to the general decline in fish ecology and capture fisheries; in one or two study areas, contribution to a continuing decline in bird communities and habitats; some decrease and deterioration in the livestock sector; loss of land to the embankments and other projects works, often with inadequate compensation; disproportionate distribution of project benefits causing some strains on social cohesion.

CONCLUDING REMARKS

Wetlands of Bangladesh are shrinking fast and at the same time the remaining areas are being degraded to an unsustainable level. Pressure from increasing population and demand to bring more land under paddy cultivation might aggravate the situation unless steps to reverse the trend is taken.

Development activities in the *haor* areas were principally aimed at reduction of flood level and reduction in the size of the wetlands to facilitate agriculture. Construction of flood protection embankments have altered the hydraulic regime which is much detrimental to the concept of sustainable management of wetlands. Present-day planning approach needs total recasting.

Development strategy for *haor* areas need special considerations due to a different type of water regime and landuse pattern prevailing there. Efforts were made by the local people to construct low embankments around the *haors* and to close drainage channels during the dry season to prevent pre-monsoon floods from entering the *haor* areas and destroying the standing *boro* crops. This appears to be in agreement with the concept of protection against early flashfloods just before the harvest which is a common feature in the *haor* areas. The need to preserve and protect silted *haors* for conservation of bio-diversity is well recognised.

REFERENCES

Akonda, A.W. 1989. Bangladesh. In: D.A. Scott (ed.). *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge. pp.541-581.

BWDB. 1986. *Haor Development Reconnaissance Study*. Prepared by the Early Implementation Cell and DPS-IV, Bangladesh Water Development Board, Dhaka.

Dugan, P.J. (ed.). 1990. *Wetland Conservation: a Review of Current Issues and Required Action*. IUCN, Gland, Switzerland. 96 pp.

FCD/I Agricultural Study (FAP 12). 1992. *Final Report Volume-1 Main Report*. Flood Plan Coordination Organisation, Government of Bangladesh, Dhaka.

Hossain, G.M. Akram and A. Nishat. 1989. Planning Considerations for Water Resources Development in the Haor Areas. AIT-BUET Workshops on Development and Technology, Bangladesh University of Engineering and Technology, Dhaka.

Islam, Serajul. 1985. *Studies in Socio Cultural Change in Rural Villages in Bangladesh*. University of Foreign Studies, Tokyo.

IWRB. 1992. Action Programme for the Conservation of Wetlands in South and West Asia.

Northeast Regional Water Management Project (FAP 6). 1992. *Draft Thematic Study*. Regional Water Resources Development Status, Flood Plan Coordination Organisation, Government of Bangladesh, Dhaka.

WATER DEVELOPMENT ACTIVITIES AND THEIR IMPACTS ON WETLANDS

Hamidur Rahman Khan

ABSTRACT: The paper presents an overview of water development activities in Bangladesh and their impact on wetlands. The development imperatives of the recent past have guided the activities and investments in the water sector to the objective of increased foodgrain production. Consequently, improvements in water resources management have taken place in water level control in the monsoon season and in expanding water supply for irrigation in the dry season. Flood control and drainage projects consist of embankments, river closures, excavation of drainage channels and drainage control structures. The embankments stop the overbank flooding from rivers and the control structures prevent backflow from high river levels into low-lying areas. This results in reduction of wetland areas. Such lowering of flood water levels is intended to increase the intensity of agricultural activities in lands which used to be subjected to medium and deep flooding. The irrigation consists mainly of small manual and power pumps to lift surface or groundwater with earthen distribution systems constructed by the farmers. The exploitation of surface water by low-lift pumps during dry season dried up small rivers and natural waterbodies (*beels*, *haors* and *baors*). Large groundwater withdrawals also caused major lowering of groundwater in the dry season which reduced the availability of dry-season surface water in wetlands. In other words, largescale utilization of surface and groundwater has greatly reduced the wetland areas.

INTRODUCTION

The annual cycle of water from overabundance to scarcity is a dominant factor of life in Bangladesh. Patterns of activity in crop production, fisheries and transportation follow this annual cycle. Public health problems intensify or diminish with the cycle. About 85 percent of the 110 million people of Bangladesh live in rural areas. Their main occupation is agriculture supplemented by subsistence fishing. The dominant characteristics of the traditional agricultural practices of Bangladesh are its adaptation to climatic and environmental hazards and minimization of risk. The dominant environmental feature of agriculture is water. Eighty percent of rainfall is concentrated in four monsoon months during which about two-thirds of the country becomes flood vulnerable. During the remainder period agriculture is limited to areas with high soil moisture or to areas that are near an adequate source of irrigation water. The development imperatives of the recent past have guided the activities and investments in the water sector to the objective of increased foodgrain production. Consequently, improvements in water resources management have taken place in water level control in the monsoon season and in expanding water supply for irrigation in the dry season. The main factors determining cropping patterns and crop yields in the floodplains of Bangladesh are the monsoon climate, soil properties, the depth, timing and duration of floods, salinity (in coastal areas), the presence or absence of irrigation, access to markets and farm management levels. Local variations in soils, the timing and duration of seasonal flooding and the provision of irrigation often lead to complex cropping patterns. Crop yields and production vary from year to year depending on the sufficiency of pre-monsoon and post-monsoon rainfall for non-irrigated crops, the

incidence of untimely or high floods for dryland *rabi* crops, the speed of recession of floodwater from the land and rainfall during the dry season. Six million ha of land is subject to annual inundation ranging from 30 cm to 2m and above. The land resources of Bangladesh have been classified into five types on the basis of flood depth (Table 1). According to this classification F2, F3, F4 lands may be considered as wetlands.

Table 1: **Land Types by Flood Depth**

Land Type	Description	Flood Depth	Nature of Flooding
F0	Highland	Not flooded	Intermittent or flooded up to 30cm
F1	Medium highland	30 to 90 cm	Seasonal
F2	Medium lowland	90 to 180 cm	Seasonal
F3	Lowland	Over 180 cm	Seasonal (<9 months)
F4	Low/very lowland	Over 180 cm	Seasonal (>9 months) or perennial

Source: MPO, 1986

Table 2 shows the main cereal cropping patterns by depth of flooding and land types (under normal flooding) and the changes that can occur with irrigation. The impact of flood control and drainage is to reduce the flooding depth and to make it possible to grow higher yielding crops.

On non-irrigated land, paddy yield and overall output generally decline with increasing depth of flooding. Yields of transplanted rice normally exceed those of broadcast varieties. Farmers on F0 and F1 land with permeable soils generally grow broadcast *aus* or jute followed by *rabi* crops; on impermeable soils, they grow local or HYV transplanted *aman*, preceded in wetter parts of the country by broadcast or transplanted *aus*. On F2 land, mixed *aus* and *aman* or jute are grown followed by *rabi* crops (wheat, oilseeds, pulses). On F3 land, farmers grow deepwater broadcast *aman* which may be followed by *rabi* crops on the higher parts. Local *boro* is the only crop grown on F4 land. Two or three crops a year are grown on F0 and F1 land in the wetter eastern and central districts and on F2 land and on the higher parts of F3 land.

On irrigated land, *boro* paddy is the principal crop on impermeable soils on all land types (F0 to F4). High yielding varieties of rice (HYVs) are grown, except in some depressions subject to early flooding, where traditional *boro* varieties continue to be grown. On impermeable FO and F1 soils, HYV *boro* is generally followed by transplanted *aman* (HYV or local, rainfed or irrigated). Elsewhere, irrigated *boro* has displaced some rainfed *aus* and jute on F1 and F2 land and deepwater *aman* on F2 and

F3 land. On permeable F0 to F2 soils, wheat, potato, vegetables and salads are the principal crops grown with irrigation.

Table 2: **Main Cereal Cropping Patterns**

Land type	Early kharif	Late kharif	Rabi
Non-irrigated			
F0	B Aus	Fallow	Wheat
		LVT Aman	Fallow
F1	B Aus	LVT Aman	Fallow
	HYV T Aus	LVT Aman	Fallow
F2	B Aus	mixed with B Aman	Wheat
	B Aus	mixed with B Aman	Fallow
F3	Fallow	B Aman	Fallow
Irrigated			
F0	Fallow	HYV T Aman	Wheat
	Fallow	HYV T Aman	HYV Boro
F1	Fallow	LVT Aman	Wheat
	Fallow	LVT Aman	HYV Boro
F2	Fallow	T Aman	HYV Boro
	Fallow	Fallow	HYV Boro
F3	Fallow	Fallow	HYV Boro
F4	Fallow	Fallow	

B = Broadcast; T = Transplanted; LV = Local Variety; HYV = High Yielding Variety

Flood control and drainage are provided for two purposes. Where pump or tidal drainage can be provided, the objective is to reduce the depth of flooding so as to convert the greater part of the protected area to FO and F1 land and thereby enable intensive cropping practices in the rainy season and, with irrigation, in the dry season also. Elsewhere, the objective is to eliminate floods so as to provide greater security of crop production in the rainy season. Embankments (including submersible embankments) are needed in some areas to protect *boro* paddy from early floods.

FLOOD CONTROL AND DRAINAGE PROJECTS

Development of flood and drainage projects have consisted basically of embankments, river closures, excavation of drainage channels and drainage control structures. Drainage by centrally located large pumps were provided in selected large projects where high river level during monsoon prevents gravity drainage.

Inundation of the land by overbank flooding from rivers is prevented by the embankments and the control structures prevent backflow from high river levels into low-lying areas. However, concentration of runoff inside low-lying areas of the polders restricts the benefited area. Highland and medium highland areas that were formerly

flooded to shallow or moderate depths are generally benefited by the reduced water levels.

Gravity drainage controls are supposed to have significant impacts on the entire cropping calendar. Gated hydraulic structures are planned to be used effectively in Bangladesh to restrict pre-monsoon backflows into low-lying areas preventing damage to the harvest of irrigated winter rice. These are planned to lower maximum flood levels in the polder by preventing inundation from high river levels and to control outflow when river levels are low thereby conserving water for supplemental irrigation of late monsoon crops and early winter upland crops.

IRRIGATION

Non-traditional mechanized irrigation is relatively recent in the farming system of Bangladesh, generally becoming significant only in the last 25 years. For historical and institutional reasons non-traditional irrigation is classified into major and minor irrigation. The major irrigation consists of primary pumping plants and gravity diversion schemes often with canal distribution systems but also including a second lift by low-lift pumps. The minor irrigation consists mainly of small and powered pumps to lift surface or groundwater with earthen distribution systems constructed by the farmers. The major components of minor irrigation are low-lift pumps (LLPs), deep tubewells (DTWs), shallow tubewells (STWs), manually operated shallow tubewells for irrigation (MOSTI) and traditional manual waterlifting devices constructed by the farmers.

GROWTH OF FLOOD CONTROL, DRAINAGE AND IRRIGATION FACILITIES

The area provided with flood control and drainage facilities has grown steadily since mid 1960s to about 3.37 million ha through the construction of 7,555 km of embankment (coastal embankment 3,674 km and embankment in upland areas 3,881 kms), 7,907 hydraulic structures which include sluices and regulators and 1,082 river closures by Bangladesh Water Development Board. In addition BWDB has constructed 3,204 km of drainage channels, 4,620 km of irrigation canals and 4,095 bridges and culverts. BWDB has developed irrigation facilities for 0.44 m ha and has reclaimed 0.1 m ha of land. Figure 1 gives a graphical representation of development of FCD and irrigated areas in Bangladesh.

Development of FCD facilities by BWDB for 3.37 m ha is equivalent to 24 percent of total area and 39 percent of net cultivable area. The FCD facilities have been developed steadily from mid-sixties to present time. Irrigation facilities exist for 3.10 m ha or 32 percent of Net Cultivable Area (NCA) of which Bangladesh Water Development Board(BWDB) developed 0.44 m ha (14 percent of irrigated area or 4.5 percent of NCA).

IMPACT OF FCD PROJECTS

Flood control and drainage projects are designed "to establish conditions for adoption of HYV-fertilizer technology" (MPO, 1986). FCD projects, in other words, are to be designed to establish conditions in which the annual depth, timing and duration of flooding are reduced and maintained within a definite range with a high degree of probability. This will enable the farmer to shift to local improved and high yielding varieties of transplanted *aman* in these areas. In other words, the FCD projects will increase the cropping intensity and production of *aman* and *aus* rice.

To understand the impact of FCD projects on wetlands let us refer to the feasibility study of a smallscale project, Char Faradhee-Jangalia project, which is located in Kishoreganj (NHC, 1988). As shown in Figure 2, the development activities will reduce the maximum flood depth by more than 2m, which will increase the flood-free cultivated area from 14% to 45% with a corresponding decrease in wetland area (Table 3). Improved drainage systems will drain the basin faster in post-monsoon.

Table 3: Changes in Flood Depths Due to Project (during monsoon)

Flood Depth	Pre-Project Condition				Post-Project Condition			
	Gross Area (ha)	(%)	Cultivated Area (ha)	(%)	Gross Area (ha)	(%)	Cultivated area (ha)	(%)
Up to 0.3m	577	17	427	14	1482	42	1332	45
0.3 to 0.9m	606	17	606	20	583	17	583	19
0.9 to 1.8m	882	25	882	29	731	21	731	24
More than 1.8 m	1420	41	1100	37	689	20	369	12
Total Area	3485	100	3015	100	3485	100	3015	100

The above reduction of flood depth will intensify agricultural activities in the area and will greatly increase the use of chemical fertilizers, pesticides etc. Flooding conditions during the monsoon and pre-monsoon seasons dictate cropping patterns in the project area. Dominance of moderately to deeply flooded area, coupled with the possibility of early floods during the pre-monsoon season required farmers to grow mixed *aus-aman*, B. *aman*, and L. *boro*, mostly as single crops. Pulses follow B. *aman* on a minor part of this land type. HYV *boro* is also grown as a single crop on this land type in areas where pre-monsoon season depths of inundation remains within the tolerance limit of the crop. B. *aus* followed by L.T. *aman* is practised on shallowly flooded land, on part of which HYV wheat follows jute. HYV *aus* and HYV *aman* are grown on areas flooded upto 0.3 m. On part of this land type oilseeds are grown in the winter season.

With project implementation, substantial increases are expected in area under L.T. *aman* and HYV *aman*, associated with a resultant reduction in area under B. *aman* and mixed *aus-aman*. This is expected to take place as a result of conversion of the

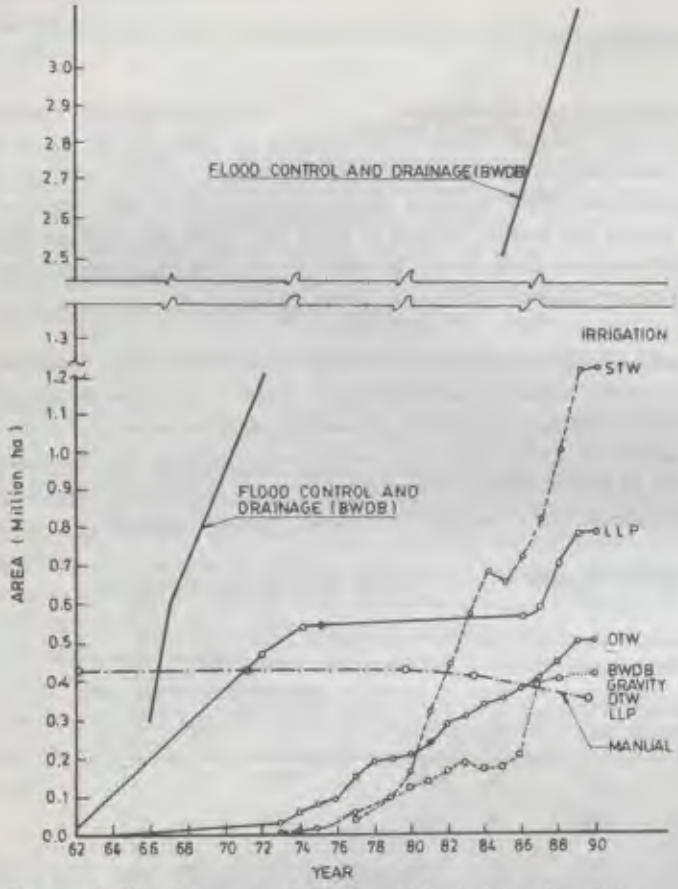


Figure 1: **Development of FCD and Irrigation Facilities**

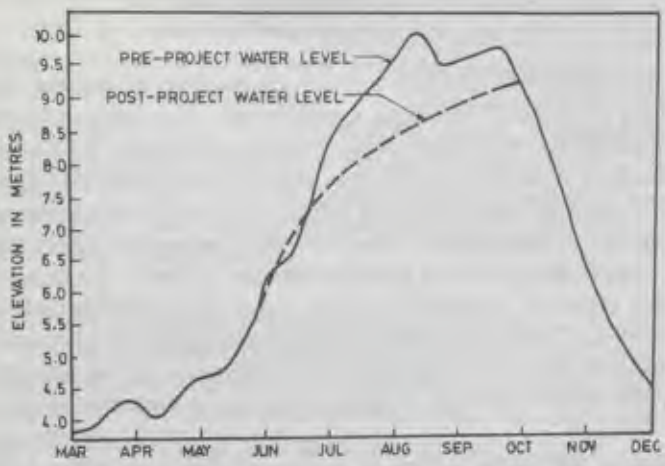


Figure 2: **Lowering of Flood Water Level by FCD Project**

moderately to deeply flooded area into shallowly flooded to flood free area due to implementation of the sub-project. B. *aus* area is also expected to increase slightly through adoption of double cropping on the increased shallowly flooded area.

Post-monsoon flood control measures would enable farmers to replace some of the L. *boro* by the high-return HYV *boro*. Post-monsoon drainage improvements would make the land available early in the *rabi* season, so that an increase in area under HYV wheat is expected (Table 4). Figure 3 shows similar lowering of surface water level by a smallscale drainage project.

Table 4: **Changes in Cropping Area due to Project (during monsoon)**

Crop	Pre-project (Area in ha)	Post-project (Area in ha)
B. Aus	420	600
HYV Aus	100	100
B. Aman	650	270
Mixed Aus-Aman	370	280
LT Aman	540	850
HYV Aman	420	650
L. Boro	600	520
HYV Boro	520	600
HYV Wheat	300	350
Pulses	100	100
Oil Seeds	150	150
Jute	360	360

Source: NHC, 1988

GROUNDWATER IRRIGATION

The groundwater aquifers have been divided into upper and lower aquifer sequences on the basis of differing hydrogeological characteristics. The upper aquifer sequence is a heterogeneous assemblage of sands, silts and clays essentially in hydraulic continuity. This upper aquifer has three subdivisions. The lower aquifer sequence has been provisionally subdivided into five aquifers separated by impervious clay layers.

Empirical data shows that the water resource of the upper aquifer sequence is annually refilled by recharge from rainfall, floods and rivers and that the horizontal component of recharge is only about 0.04 percent of the vertical potential recharge. Thus the behaviour of the upper aquifer is similar to a surface water reservoir where water level elevation and storage volume are functions of inflow and withdrawal. The upper aquifer is frequently described as the groundwater reservoir. The upper aquifer is hydraulically connected with the streams, rivers and other waterbodies.

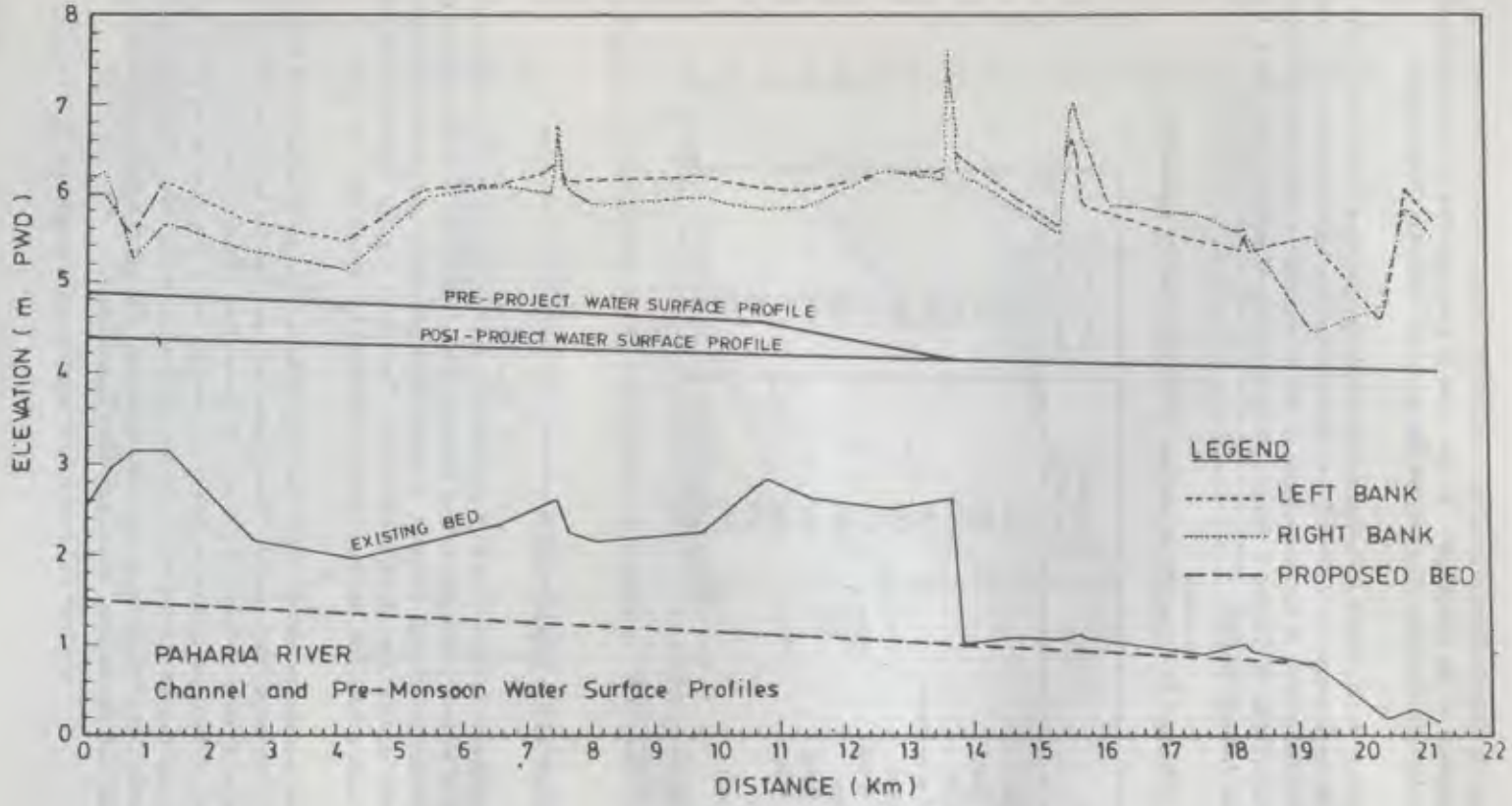


Figure 3: Lowering of Floodwater Level by Drainage Project

Groundwater levels fall after mid-October in response to evapotranspiration and rapid drainage of surface water. The natural rate of fall is the highest in October-November. During the dry season nearly all minor rivers are sustained by groundwater outflows, and there is significant loss of bank storage adjacent to the major rivers because of their large change in water level. In several areas, groundwater withdrawals are causing a large decline in groundwater levels during the dry season.

One of the major findings on the variability of potential recharge is that flood control and drainage (FCD) development will reduce potential recharge estimates because it reduces depth of flooding. Baseflow reduction caused by increased withdrawal of groundwater affects LLP potential and FCDI schemes. Benefits of additional groundwater development must be traded off against lost surface water development. Nationally the volume of dry season surface water that may be lost at full groundwater development is 2,305 Mm^3, equivalent to approximately 370,000 ha of irrigation. Table 5 summarizes the calculated regional baseflow reduction for January-April (*rabi* season). It should be noted that additional field data are required to improve the estimate. Additional interactive surfacewater-groundwater models are essential for realistic trade-off analyses.

Table 5: **Baseflow Reduction Caused by Groundwater Development January-April (Mm^3)**

	NW	NE	SE[a]	SC[b]	SW[c]	AFP	Bangladesh
STW	710	150	45	100	80	105	1,190
DSSTW	1,050	410	65	120	125	140	1,910
DTW	1,200	570	85	140	140	170	2,305

a/ Excludes PAs 35, 36,37,38,39,40,41 and 60
b/ Excludes PAs 54 and 55
c/ Excludes PAs 49, 53 and 59

Source: MPO, 1986.

CONCLUDING REMARKS

The present trend of water development activities brings changes in agricultural practices in the wetland areas. FCD projects are reducing inundated area and preventing free flow of water to and from rivers to wetlands. Largescale utilisation of surface and ground water for irrigation has greatly reduced the wetland areas.

REFERENCES

Master Plan Organization (MPO). 1986. *National Water Plan*, Summary Report. Dhaka.
Northwest Hydraulic Consultants (NHC). 1988. *Feasibility Study of Char Faradhee Jangalia Project*.

CHARACTERISTICS AND DYNAMICS OF WETLAND SOILS

S.M. Imamul Huq and Golam Monowar Kamal

ABSTRACT: Both mineral and organic soils occur in Bangladesh. Out of a total of 483 soil series, around 416 have developed under aquic moisture regime. Most of Bangladesh's mineral soils contain less than 3% organic matter which is the standard for wetland soils of tropical Asia. The pH of mineral wetland soils is around 7.0 becoming acidic or alkaline on drying depending upon parent material while the organic wetland soils are acidic. The CEC of mineral wetland soils range between 10 and 20 meq%, while that of organic wetland soils, because of the presence of high clay content, is relatively higher. The organic wetland soils are deficient in some micronutrients. A substantial change occurs in the influx and efflux of various nutrients including the organic matter turnover in the wetland soils which is mostly controlled by the source of water, the positional situation of the wetlands and the parent materials. The nutrient dynamics of a few wetland soils and water of Bangladesh are also discussed.

INTRODUCTION

Wetland soils can be defined as soils whose development and properties are strongly influenced by topography or permanent saturation in the upper part of the land (Moormann and Watering, 1985). In fact, wetland soils or wet soils are known under different names: hydric soils, hydromorphic soils, waterlogged soils, gley soils, pseudogley soils, stagnosols, meadow soils, aquic soils etc. (Dudal, 1992). The classification of wet soils depends on how farmers, soil scientists, agronomists, engineers or ecologists perceive the concept of wetness.

Wet soils are acquiring increasing importance in land development and environmental protection. Knowledge of the duration and periodicity of wetness is important in evaluating possible use of soils and formulating remedial measures for temporary chemical and physical changes caused by the surfacial horizons for long periods. In most cases, such temporary changes are apt to impose permanent characteristics during a year or between years. Variations in the rainfall regime and seasonal fluctuations strongly influence perched water tables. The impact of wetness also depends on the period of the year during which it occurs, either during the growing period or in the "dead season". About 10% of the non-ice covered landmass of the world is occupied by "wet soils". Of this, 80% is influenced by ground water and 20% by surface water stagnation (FAO, 1979 - 1981). Wetlands constitute about 70% of the territory of Bangladesh (Saheed, 1984). It is thus obvious that study of wetland soil in Bangladesh occupies an important position so far as their characteristics and management are concerned because 95% of the total rice area of Bangladesh is on wetland soils.

GEOMORPHOLOGY, GEOLOGY AND PHYSIOGRAPHY

Depending on the land levels in relation to seasonal flooding (depth of flooding and duration of flooding) six broad land types (Table 1) are recognized in Bangladesh (FAO, 1988).

Table 1: **Land Types by Inundation Depth**

Land Level	Type	Scale and duration of inundation
Highland (H)	F0	Land which is above normal flood level
Medium Highland (MH)	F1	Land which normally is flooded upto 90 cm deep during flood season
Medium Lowland (ML)	F2	Land which normally is flooded upto 180 cm deep during flood season
Lowland (L)	F3	Land which normally is flooded upto 300 cm deep during flood season. Duration of flooding is <9 months.
Very Lowland (VL)	F4	Land which normally is flooded deeper than 300 cm during flood season. Duration of flooding >9 months
Bottomland (B)	F4	Depression sites in any land level class that remains wet throughout the year. These constitute the perennial wetlands.

Of these land classes ML through B are to be considered "wetlands" and "wetland soils". These lands have constraints of various degrees so far as their uses are concerned. A generalized map of the inaundation land types is shown in figure 1. The area distribution of various land classes are shown in Table 2.

Table 2: **Area Distribution of Various Land Classes**

Land Classes	Area (Km^2)	% of total area
Highland	41,757	29
Medium highland	50,106	35
Medium lowland	17,609	12
Lowland	10,952	8
Very lowland and bottomland	1,921	1
Settlements and water bodies	21,655	15
Total	144,000	100

Source : SRDI Staff (1965-86)

Agro-Ecological Regions (AER)

The Land Resources Appraisal of Bangladesh (FAO 1988) has classified the whole of the country into 30 different agro-ecological regions in which depth and duration of seasonal flooding has been one of the component information layers (Figure 2). Distribution of various land types in different agro-ecological regions has been incorporated as an Annexure. It may be seen that the 'wetlands' are mostly

concentrated in the agro-ecological regions 4,5,6,7,8,9,12,14,15,16,19,20,21 and 30. They occupy about 50% of the areas of these agro-ecological regions and about 17% of the total areas of Bangladesh. However, these estimates exclude the waterbodies like rivers. Figure 2 indicates the various agro-ecological regions where 'wetlands' and 'wetland soils' are present. The regions 3, 10, 11, 17, 22 and 28 also contain some medium to lowlands which at times of the year become wetlands. It is interesting to note that wetlands occur at contour lines as high as 15 meters. This phenomenon is principally due to local hydrology and geomorphologic formations.

Geology

There are three major geological formations in Bangladesh which are important to the context of soils in general and 'wetlands' and 'wetland soils' in particular. These are: Tertiary hill sediments in the northern and eastern hills, the Modhupur clay of the Modhupur and Barind tract in the center and west and recent alluvium in the floodplains and estuarine areas. Geologically, the Bengal basin is an active tectonic region where some areas are believed to be undergoing subsistence, thus causing the formation of a few synclines (Morgan and McIntire, 1959). Flood water stands in synclines have given rise to many 'wetlands' in areas which are topographically at higher elevations. Thus, one can see the occurrence of wetlands in the inland valleys inside older land formations of terraces and hills (Saheed and Hussain, 1992).

The tertiary hill sediments comprise mainly unconsolidated and little consolidated beds of sandstones, siltstone, shales and some conglomerates. They have been folded into a succession of pitching anticlines and synclines. These are aligned approximately north-northwest to south-southwest in Chittagong and to south of Sylhet, swinging round to almost east-west in the north of Sylhet and Mymensingh. These folds are interrupted by major linear and transverse faults in places. The frequent changes in lithology from sandstone to shale, and the close dissection of the hill ranges provide complex soil patterns in many areas (FAO, 1971).

The Madhupur clay underlies the Madhupur and Barind tracts and possibly on the Akhaura Terrace area or the summit of Lalmai hills in the east of Comilla. The formation is remarkably homogenous in appearance, both vertically and laterally. Extensive areas of the Barind tract and parts of the Madhupur tract have almost level, terrace-like topography. The homogenous nature of the Madhupur clay, both vertically and horizontally over great distances, suggest that it is a marine deposit (FAO, 1971). Unconsolidated floodplain sediments occupy the greater part of the country. The floodplains of the Ganges, the Brahmaputra and the Meghna cover approximately 40% of Bangladesh (Khan, 1991). The floodplain sediments are far from homogenous in age, texture and mineralogy. They have been deposited under piedmont, meander floodplain, estuaries and tidal conditions in different areas. New alluvium is still being deposited near active river channels, but most floodplain land has apparently received little new alluvium for hundreds years or more. Rivers have changed their courses from time to time in the past, abandoning and re-occupying various parts of their floodplains and

thus providing sediments of different ages in different areas. Some floodplains areas have also been uplifted in Sylhet and Mymensingh areas, and there are numerous sand-filled earthquake fissures in part of these areas.

Most floodplain sediments have a high silt content. This is particularly so in the case of Brahmaphutra/Jamuna and Meghna sediments. Tista floodplains and west of Ganges floodplains have sandy sediments in the sub-surface horizons while most of the Ganges floodplains have clay deposits on the surface. Peat has accumulated in some permanent wet basins throughout the country. In most areas they are at shallow depth; it can be up to 5m thick as in the Gopalganj- Khulna peat basins.

Geomorphology

An understanding of geomorphology is especially important in Bangladesh where differences between soils are particularly related to their positions in the landscape. The country comprises hill, terrace and floodplain areas. It may be classified into four distinct regions as shown in Figure 3:

1. The eastern and northern frontier hilly regions comprising of the eastern hilly regions, hills of Lalmai and northeastern Sylhet district and a narrow strip of a series of low hill ranges and isolated circular and elongated hillocks represented by recent alluvium along the northern frontiers of the districts of Sylhet and Mymensingh. (Hills)
2. The Great Table Land (Terraces)
3. Floodplains of the Ganges, the Brahmaputra and the Meghna river systems (Floodplains)
4. The Delta (Reef Floodplains)

The hilly regions occupy whole of the districts of Chittagong Hill Tract. The anticlines form the hills and the synclines the valley. These valleys are seasonally flooded. A narrow stretch of coastal plain, averaging 10 km in width, has developed due to a thrust fault along the western flank of the Sitakunda anticline.

The Great Table land extends from the Lalmai hills of Comilla district and the marginal low hills of Chittagong and Sylhet regions in the east through Dhaka and Rajshahi districts to India. The Table land has been trisected by the Meghna and the Jamuna river systems. This has given rise to three large blocks of high lands: the Barind tract, the Modhupur tract and Lalmai and the marginal hills of Chittagong and Sylhet districts.

The floodplains of the Ganges, the Brahmaputra and the Meghna cover approximately 40% of Bangladesh. Numerous swamps have developed in the floodplains of the Brahmaputra and the Meghna. The Chalan Beel is the largest wetland of the area.

The floodplains and the delta are studded all over with clusters of wetlands or swamps, both big and small, commonly called *haors* or *beels*. The floodplains contain two large clusters: one close to the northern formation of Sylhet and Mymensingh districts and the other in the districts of Rajshahi and Pabna.

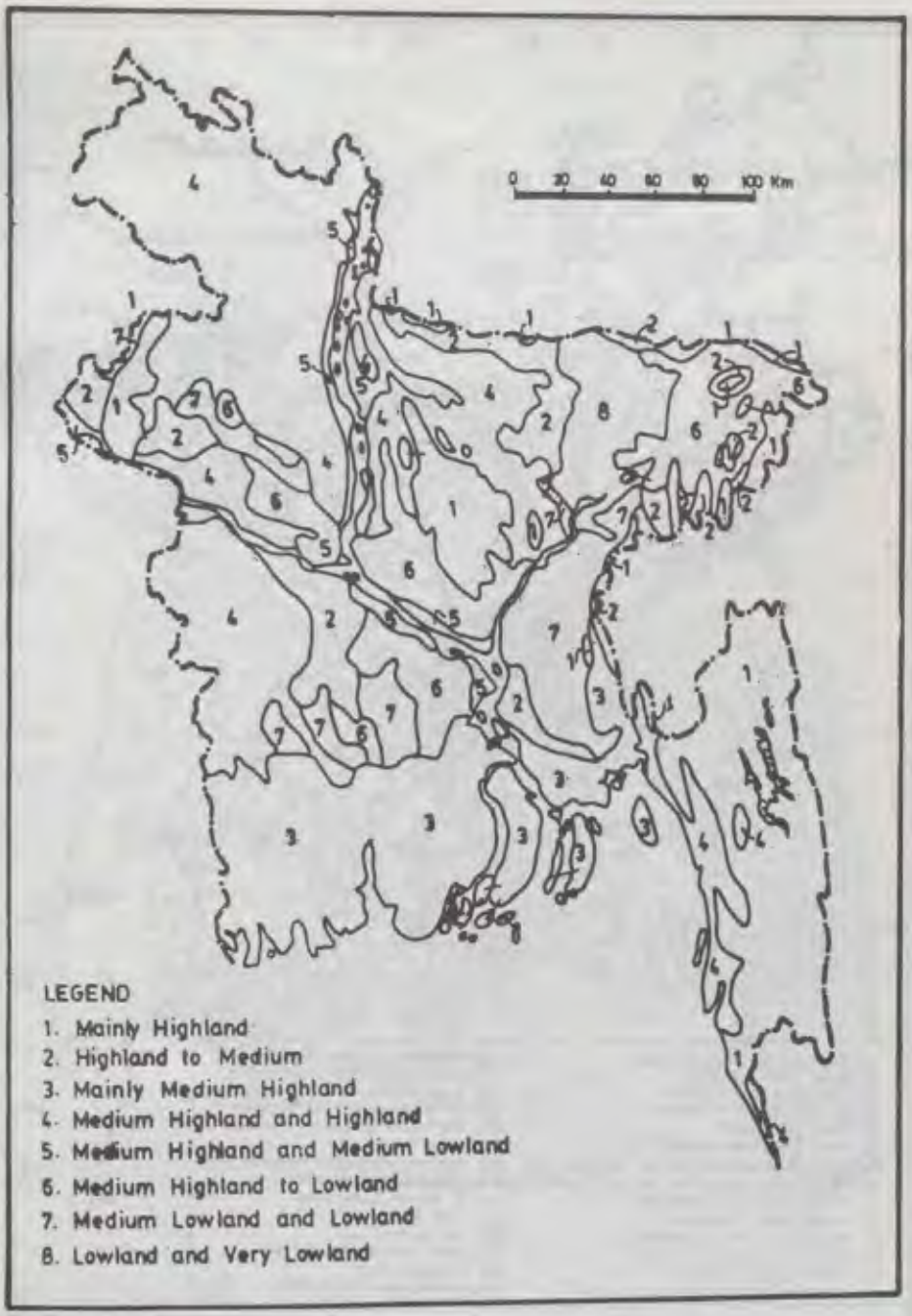


Figure 1: Inundation Land Types (Generalized)

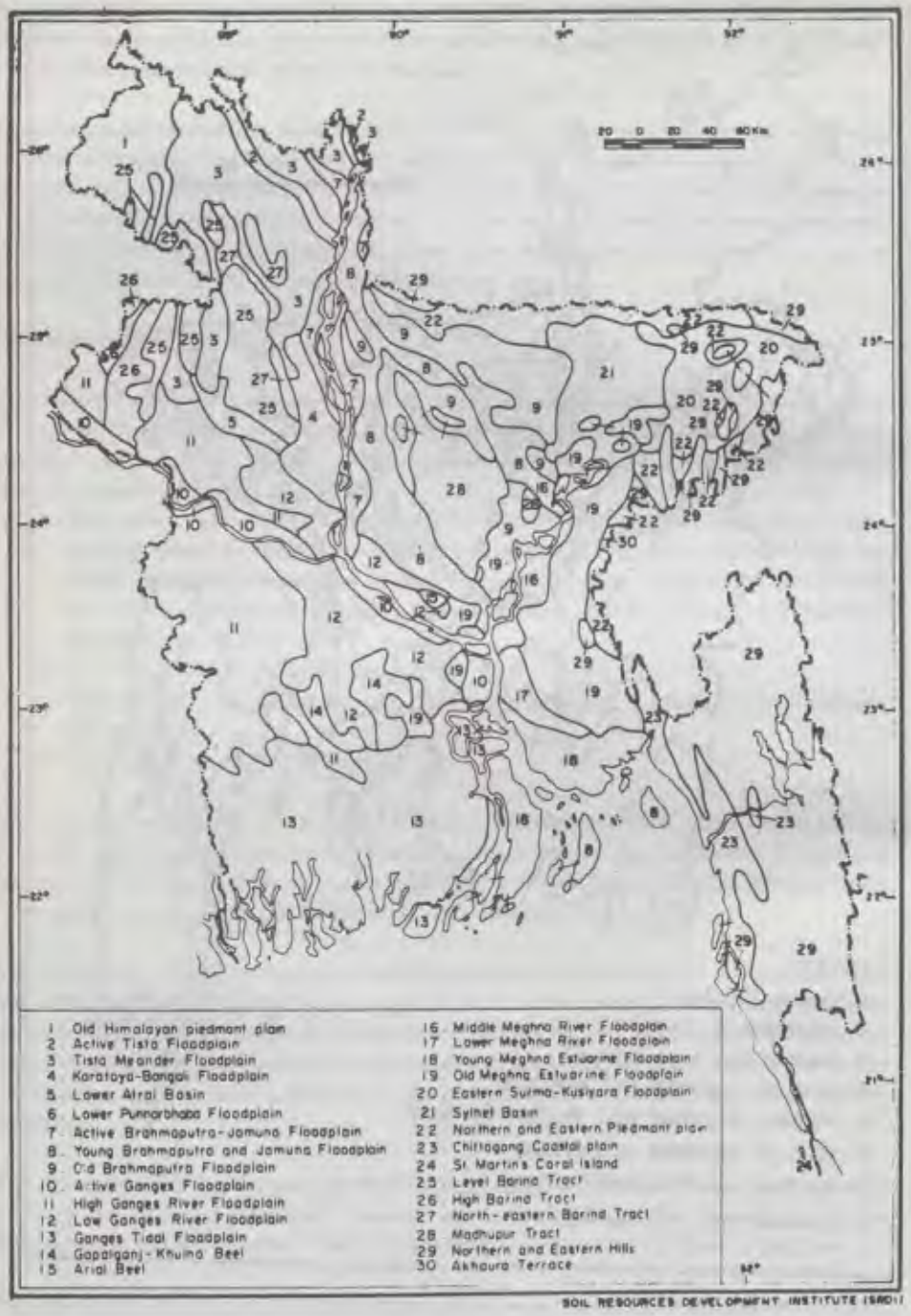


Figure 2: Agroecological Regions of Bangladesh (Generalized)

Figure 3: **Physiographic Divisions of Bangladesh**

The freshwater swamps appear to be tectonic in origin. Those of the districts of Rajshahi and Pabna and the Delta seem to have formed due to changing stream courses at short intervals and rapid building up of high levees by the streams. The swamps have also developed in many of the valleys of the hilly regions due mainly to poor drainage.

Physiography and Sedimentation

The term physiography includes combination of the geological material in which particular kinds of soil have formed and the landscape on which they occur. Thirtyfour physiographic units and subunits are recognized in Bangladesh (FAO, 1988). These are shown in Figure 4.

The wetlands (*haors*, *baors*, *beels* etc.) are mainly concentrated in the physiographic units 3,4,5,6,7c,9,10,11a,12c,13 and 20. Of these, the principal wetlands are on units 4,5,9,10,13 and 20. The rest of the wetlands and wetland soils are scattered all over the floodplains. The main wetlands and their physiographic units are as follows:

A. **Lower Atrai Basin (Physiographic unit 4):** This unit coincides with the agro-ecological region (AER) 5. It occupies a low-lying area between the Barind tract and the Ganges river floodplain. On the northern side of the Atrai river, Atrai sediments have buried the southern edge of the level Barind tract and the relief is smooth. Elsewhere, where Atrai alluvium has buried older sediments of the Atrai, Little Jamuna or the Ganges floodplains, there are broad low ridges and basins. Heavy clays occupy most of the land, but more silty and calcareous soils occupy some ridges adjoining the Ganges river floodplains. This basin area receives floodwater from the Atrai and the Jamuna rivers and from the Ganges distributaries as well as run-off from the Barind tract. Flooding formerly was very deep and large areas (in Chalan Beel) remained wet through the dry season. Heavy rainfall combined with flashfloods coming down the Atrai river or run-off from the Barind tract can cause temporary flooding.

B. **Lower Punarbhaba Floodplain (Physiographic unit 5):** This unit occupies a narrow strip of floodplain land along the lower course of the Punarbhaba river in the west of Naogaon and the north of Chapai Nawabganj districts. It coincides with the AER 6. The relief comprises broad ridges and basins, with *beels* occupying the basin centres. Most of the area is deeply flooded in the rainy season, and is subject to flashfloods descending the Punarbhaba river and running off the adjoining high Barind tract during periods of heavy rainfall. Heavy clays occupy almost the whole landscape including the basins.

C. **Gopalganj-Khulna Beels (Physiographic unit 9):** This unit underlies AER 14. It occupies a low-lying area between the Ganges river floodplain and the Ganges tidal floodplain. It is divided by a number of separate basins by ridges of Ganges alluvium adjoining the rivers which pass through this area.

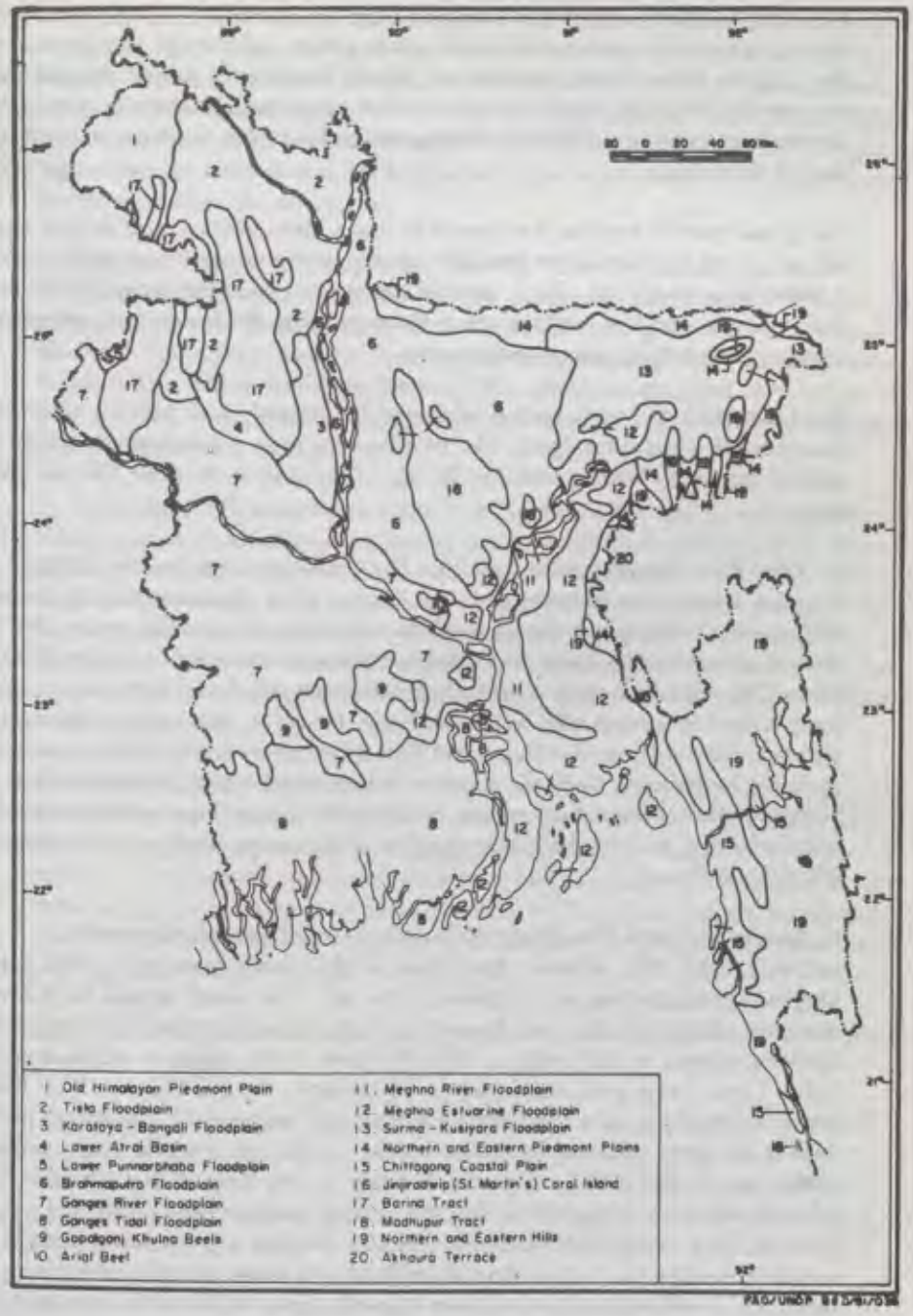


Figure 4: **Physiographic Units of Bangladesh (Generalized)**

The basin centres lie almost at sea-level. They are moderately deeply or deeply flooded in the rainy season and remain wet or submerged through the dry season. The slightly higher basin margins are mainly moderately deeply flooded and become dry for a time in the dry season. Seasonal flooding, which is entirely by accumulated rainwater or due to raised groundwater tables, is deeper in the north than in the south.

The greater part of the area is occupied by heavy clays which appear to have been laid on an old tidal landscape generally overlying one or more peat layers within a meter from the surface. Peaty material lies at or close to the surface of the wet basin centres. The low banks of small rivers crossing the basins have calcareous loamy soils overlying non-calcareous clay.

The basin clays and peats have a moderately to strongly acid reaction when dry (near-neutral when submerged). The peat deposits have a maximum thickness of about 5 meters. C^{14} dating indicates the age of the peats as between 200 and 3000 years.

D. **Arial Beel (Physiographic unit 10):** The Arial Beel comprises the AER 15. It occupies a low-lying basin between the Ganges river floodplain and the young Brahmaputra floodplain in the south of the old Dhaka district. The greater part of the unit is occupied by heavy acid clays resembling those in the Gopalganj-Khulna *beels*. The Arial Beel clays often include buried organic layers and have a rather peaty topsoil in permanently wet depressions. However, peat soils do not occur. Younger alluvium from the Ganges and Dhaleswari rivers is gradually encroaching upon the boundaries. Gangetic alluvium is calcareous while Dhaleswari type is neutral to alkaline but not calcareous. Seasonal flooding is deep in the basin centre and moderately deep on the higher margins. Basin centres remain wet for most or all of the dry season.

E. **Surma-Kusyiara Floodplain (Sub-unit: Sylhet Basin-physiographic sub-unit 13b):** The meander floodplains of the rivers flowing into the upper Meghna catchment area are included in this unit. The rivers include the Surma, Kusyiara, Manu, Dhalat and Khowai as well as smaller rivers flowing from Shillong plateau on the northern side. All these rivers originate in hill areas in India. These rivers pour into a vast low-lying area, the Sylhet basin. This basin seems constantly to have been sinking due to earth movements. The lowest parts, even in the north adjoining the Indian border and 300 km from the coast, are less than 5 meters above MSL. Seasonal flooding is very deep in this sub-unit. The alluvial sediments deposited in this sub-unit are predominantly silts and clays. Derived from tertiary hill sediments, the alluvium has a much lower content of weatherable minerals. Despite the sudden floods that occur, bringing with them vast quantities of sediments, the main river channels appear to be much more stable in their courses than Brahmaputra and Ganges channels probably because the eastern rivers carry little sand by the time they reach this area and because silt and clay floodplain sediments are themselves denser than the less consolidated, mixed-textured sediments of the Ganges and Brahmaputra floodplains.

The sub-unit Sylhet Basin corresponds to the AER 21. It mainly comprises extensive, low-lying basins (the *haors*) bordered by relatively narrow, high ridges. The relief is locally irregular due to erratic deposition of new sediments. Clay soils predominate, and peat occurs locally. Seasonal flooding is mainly deep, more than 5 meters in the basin centres. Water quickly drains from the floodplain ridges after the rainy season, but large areas in the basins remain wet or submerged for most or all of the dry season.

F. **Akhaura Terrace (Physiographic unit 20)**: This unit underlies the AER 30. It occupies small patches along the eastern border of Brahmanbaria district. It resembles parts of the Madhupur tract, the relief varying from level to strongly dissected. The greater part has level upland areas standing about 6 meters above broad valleys which dissect the terrace. The valleys are occupied by a variety of grey to black soils, some of them peaty, and ranging from shallowly to deeply-flooded in the rainy season.

G. **Floodplains (Physiographic units 3, 6, 7c, 11a, 12c)**: The floodplains contain noncalcareous recent alluvial sediments rich in weatherable minerals with illite as the dominant clay mineral. The exception is the Ganges alluvium which is calcareous at younger stage and montmorillonite forms an important part of its clay fraction. On lower sites, most of the soils are seasonally flooded, poorly to imperfectly drained with loams and clays as sediments. Flooded topsoils are near-neutral upon drying. They become acidic in non-calcareous soils and alkaline in calcareous soils.

The floodplain soils have formed in river and piedmont alluvium ranging from very recent to several thousand years old. Textually, these soils are silt loams or sandy loams on the highest points of floodplain ridges grading through silty or sandy clay loams on intermediate sites to silty clays or clays in basins. Flooding with silty water occurs in lands close to river channels, hillfoot areas and on unembanked parts of tidal and young estuarine floodplains. Flooding depth varies with physiography, being deepest in basins.

Table 3 summarizes the distribution of wetlands and wetland soils in various physiographic locations.

Table 3: **Physiography, Drainage and Hydrology of Bangladesh**

Physiography/Land form	% of total land area	Drainage	Hydrology
Hilly areas	12		
Hills	11	Well to excessive	Non-flooded
Valleys	1	Poor to imperfect	Intermittent Seasonal shallow
Terrace areas	8		
Dissected Terraces	3		
Terraces	2	Imperfect to well	Mainly nonflooded
Valleys	1	Poor	Seasonal shallow to deep
Level terrace areas	5		
Terraces	4.5	Poor to imperfect	Intermittent to seasonal shallow
Valleys	0.5	Poor	Seasonal shallow
Floodplain areas	80		
Piedmont alluvial plains and/or meander river floodplain	28	Poor to imperfect,	Intermittent to
levees	13	locally moderately well	seasonal shallow
Basins/Depressions	15	Mainly poor,locally very poor	Seasonal shallow to moderately deep
Meander rivers/ floodplains	26		
levees	9	Mainly poor	Seasonal shallow to moderately deep
Basins/Depressions	17	Mainly poor, locally very poor	Seasonal moderately deep to deep
Tidal/estuarine floodplains	20		
Low levees	6	Poor	Seasonal shallow(tidal)
Shallow basins	14	Mainly poor locally very poor	Seasonal shallow to to moderately deep(tidal)
Deep basins	6	Poor to very poor	Seasonal deep to very deep

Source: Saheed and Hussain 1992

NUTRIENT DYNAMICS IN WETLAND SOILS AND WETLANDS

Classes of Wetland Soils

The wetland soils in Bangladesh can be grouped into two broad classes: organic and mineral. The organic group (peats) consists of around 74,000 ha. These peats (histosols) are distributed over Bangladesh in around 12 depressions, of which the Gopalganj-Khulna basin areas have the largest areal extent. Hemists, Saprists, and Fibrists occur in Bangladesh. Seven soil series have been established for histosols (SRDI Staff, 1965-86). Mineral soils forming under the wetland conditions are the most extensive in Bangladesh (SRDI Staff, 1965-86). Out of a total of 483 soil series, around 416 have developed under aquic moisture regime (Table 4).

Of the soils Inceptisols occupy more than 50% of the total area. Hydraquents are the deeply flooded soils. (Saheed and Hussain, 1992).

Around 381 soil series have developed under an aquic moisture regime where the whole profile remains saturated for certain periods (at least 15 days) of the year and therefore have been classified under the "aqu" suborder. Around 29 soil series have developed under an aquic moisture regime where only the lower part of the profiles remain saturated with water for a certain period every year. These soils have been classified in the aquic subgroup.

Aeric and Typic Haplaquepts are the most dominant wet subgroups of Bangladesh, followed by Typic and Aeric Fluvaquents. Around 17 soil series have been classified under the Aeric Albaquept subgroup where ferrolysis is the dominant pedogenic process. Aeric Haplaquents and Typic Psammaquents also occur in Bangladesh. Typic Sulfaquepts and Sulfic Haplaquepts occur along the sea coasts near Cox's Bazar and also in areas adjoining the mangrove forests of the Sundarbans in the southwest.

A correlation of the soils in Bangladesh forming under an aquic moisture regime (seasonally flooded conditions) is presented in Table 5. Gleysols, Fluvisols, Cambisols, Planosols and Histosols are the major soil groupings according to the FAO-UNESCO soil map of the world (FAO-UNESCO, 1988). Some Cambic Arenosols and Gleyic alisols in Bangladesh have also been found to occur under aquic moisture regime.

Characteristics of Wetland Soils

In wetland soils organic matter is the substrate for anaerobic microbial activity that results in 0_2 depletion and characteristic changes in redox potential, pH, and nutrient availability. Soil organic C accounts for 0.1-40% of wetland soils. Most mineral wetland soils of tropical Asia have only up to 3% organic matter content. In most of Bangladesh's mineral wetland soils, organic matter content is very low. More than half of the soils have organic matter in the range of 1 to 2%. A list of some soil properties of a few representative mineral wetland soils are presented in Table 6.

Table 4: Characterization of the Wetland Soil Series of Bangladesh in the U.S. Soil Taxonomy

Order	Great group	Subgroup	No. of series
Entisols	Fluvaquents	Typic Fluvaquents	32
		Aeric Fluvaquents	25
		Mollic Fluvaquents	2
		Sulfic Fluvaquents	2
		Thapto-Histic Fluvaquents	6
	Haplaquents	Typic Haplaquents	5
		Aeric Haplaquents	8
	Hydraquents	Haplic Hydraquents	1
	Psammaquents	Typic Psammaquents	8
		Aeric Psammaquents	2
	Sulfaquents	Typic Sulfaquents	1
	Udifluvents	Aquic Udifluvents	2
	Ustipsamments	Aquic Ustipsamments	4
Inceptisols	Albaquepts	Typic Albaquepts	1
		Aeric Albaquepts	17
	Dystrochrepts	Aquic Dystrochrepts	3
		Fluvaquentic Dystrochrepts	2
	Eutrochrepts	Aquic Eutrochrepts	7
		Aquic Dystric Eutrochrepts	6
	Haplaquepts	Typic Haplaquepts	80
		Aeric Haplaquepts	166
		Aeric lithic Haplaquepts	1
		Humic Haplaquepts	2
		Sulfic Haplaquepts	6
		Thapto-Histic Haplaquepts	4
	Humaquepts	Cumulic Humaquepts	2
		Fluvaquentic Humaquepts	1
	Sulfaquepts	Typic Sulfaquepts	2
	Ustrochrepts	Aquic Ustrochrepts	2
Mollisols	Haplaquolls	Aeric Haplaquolls	1
Alfisols	Albaqualfs	Aeric Albaqulfs	1
Ultisols	Haplustults	Aquic Haplustults	4
	Paleaquults	Aeric Paleaquults	1
	Paleustults	Albic Paleustults	1
		Aquic Paleustults	1
Histosols	Undiffrentiated	Undiffrentiated	7
6	20	36	416

Source : FAO-UNESCO 1988

Table 5: **Wetland Soils of Bangladesh in Relation to their Classification in the USDA Soil Taxonomy and the FAO-UNESCO Legend**

USDA Soil Taxonomy		FAO-UNESCO Legend	General Soil Type
Great groups	Subgroups		
Fluvaquents	Typic, Aeric Sulfic, Mollic	Calcaric Fluvisols Eutric Fluvisols	Calcareous Alluvium Noncalcareous Alluvium
Haplaquents	Typic, Aeric	Dystric Fluvisols	Noncalcareous Alluvium
Hydraquents	Haplic	Eutric Fluvisols	Noncalcareous Alluvium
Psammaquents	Typic, Aeric	Calcaric Fluvisols	Calcareous Alluvium
Sulfaquents	Typic	Thionic Gleysols	Acid Sulphate Soils
Udufluvents	Aquic	Cambic Arenosols	Noncalcareous Alluvium
Ustipsamments	Aquic	Cambic Arenosols	Calcareous Alluvium
Albaquepts	Typic, Aeric	Eutric Planosols	Shallow Gray Terrace Soils
Dystrochrepts	Aquic, Fluvaqentic	Haplic Alisols	Noncalcareous Brown Floodplain soils
Eutrochrepts	Aquic, Aquic-Dystric	Gleyic Cambisols	Calcareous Brown Floodplain Soils
Haplaquepts	Typic, Aeric Humic, Sulfic	Eutric Gleysols	Noncalcareous Gray Floodplain Soils
Humaquepts	Cumulic	Mollic Gleysols	Acid Basin Clays
Sulfaquepts	Typic	Thionic Gleysols	Acid Sulphate Soils
Ustochrepts	Aquic	Calcaric Cambisols	Calcareous Brown Floodplain Soils
Haplaquolls	Aeric	Mollic Gleysols	Noncalcareous Dark Gray Floodplain Soils
Albaqualfs	Aeric	Albic Gleysols	Deep Gray Terrace Soils
Haplustults	Aquic	Gleyic Alisols	Gray Piedmont Soils
Paleaquults	Albic	Gleyic Alisols	Deep Gray Terrace Soils
Paleustults	Aquic	Gleyic Alisols	Shallow Red Brown Terrace Soils
Histosols		Histosols	Peat

Source: FAO-UNESCO 1988

Table 6: **A few Characters of some Mineral Wetland Soils of Bangladesh**

Soils	Sand %	Silt %	Clay %	Organic carbon %	Total N %	pH (H_2O)	CEC (me %)	Base saturation%
Chandra series : Aeric Albaqualf								
0-10	47	32	21	0.78	0.06	5.6	6.09	55
10-18	42	31	27	0.58	0.05	6.0	7.36	56
18-36	37	21	42	0.58	0.06	5.8	11.35	47
36-90	33	19	48	0.42	0.04	5.8	12.39	58
Gangachara series : Typic Haplaquept								
0-15	62	24	14	0.64	0.05	6.3	6.01	50
15-45	50	25	17	0.56	0.04	6.5	8.80	67
45-73	58	28	14	0.16	0.03	6.5	8.00	72
Ghior series : Aeric Haplaquept								
0-12	5	22	73	1.58	0.12	6.5	44.4	86
12-32	1	24	75	0.71	0.06	6.9	43.5	61
32-53	1	27	72	0.49	0.05	7.1	41.5	96
Badarkhali series : Typic Sulfaquept								
0-8	35	32	33	2.00	0.16	4.5	15.1	--
8-15	34	34	32	1.83	0.15	4.1	14.7	--
15-33	32	31	37	1.09	0.11	3.9	15.3	--
33-65	33	37	30	---	---	4.1	---	--

Source: SRDI Staff (1965-86)

The decomposition and mineralization of organic matter are interrelated with successive microbial changes and are accompanied by a stepwise bio-chemical and chemical reduction of the soil resulting in the lowering of redox potential and changing of pH to near neutrality. Both organic matter and pH/Eh control the availability of many nutrients negatively affecting Zn, Cu and S. Changes in various properties at different periods of submergence are shown in Table 7 for three soil series (mineral soils).

The series of chemical and electrochemical changes that are set into motion due to flooding of a soil influence the nutrient dynamics. The lowering of redox potential destroys NO_3^-, decreases the availability of S and Zn, increases the availability of Fe and P, and promotes N fixation (Ponnamperuma, 1985). The increase in pH of acid soils enhances the availability of P and Mo while depressing the toxicity of Mn, Al, Fe and organic acids. The decrease in pH of alkaline soils increases the availability of P, Fe, and Mn.

Table 7: **Chemical and Physio-chemical Changes in Soil Solution due to submergence**

PROPERTIES	SOILS	DAYS FROM START								
		0	1	2	4	7	14	30	45	60
Eh (mv)	KALMA	268	159	135	108	80	20	- 1	-10	-40
	CHIATA	232	128	120	60	25	8	- 2	-30	-70
	BHARELLA	287	136	110	55	20	5	-12	-45	-80
pH	KALMA	5.1	5.2	5.4	5.8	5.9	6.9	6.9	7.0	7.1
	CHIATA	5.3	5.0	5.5	5.8	6.0	7.0	7.0	7.0	7.1
	BHARELLA	5.3	5.0	5.4	5.8	6.5	7.2	7.2	7.1	7.2
NH_4-N (ppm)	KALMA	0	1.6	1.84	2.05	2.85	3.06	3.68	3.60	350
	CHIATA	0	2.45	2.90	3.06	3.80	4.20	6.15	5.80	580
	BHARELLA	0	5.00	5.46	5.83	6.13	6.68	8.18	8.28	810
P (ppm)	KALMA	0.60	0.70	1.10	1.35	1.83	2.45	3.20	2.63	25
	CHIATA	0.14	0.32	0.40	0.65	1.00	2.05	2.65	3.01	26
	BHARELLA	0.70	0.85	0.95	1.20	1.83	3.24	4.67	5.84	44
K (ppm)	KALMA	8.0	10.5	12.0	14.0	16.0	25.0	37.0	44.0	50
	CHIATA	10.0	12.0	13.5	15.0	17.5	36.0	45.0	68.0	80
	BHARELLA	13.0	17.0	21.0	28.0	35.0	44.0	58.0	74.0	80
Ca (ppm)	KALMA	1.0	1.3	1.8	1.8	2.2	3.1	4.6	5.0	68
	CHIATA	2.0	2.2	2.6	3.1	4.0	6.0	7.8	9.0	88
	BHARELLA	2.8	3.3	3.2	4.2	6.1	8.2	10.0	11.6	120
Mg (ppm)	KALMA	1.1	1.0	1.8	2.2	2.8	4.1	5.6	7.5	89
	CHIATA	1.6	1.8	2.3	2.9	3.4	3.8	4.5	6.2	63
	BHARELLA	2.0	2.3	2.8	3.4	3.4	5.1	5.2	6.3	64
S (ppm)	KALMA	10.0	9.6	9.1	8.3	8.0	6.2	4.8	3.0	10
	CHIATA	3.0	3.0	2.6	2.4	2.1	1.0	0.5	0.0	0
	BHARELLA	8.0	6.0	7.6	7.2	7.2	6.0	5.1	4.0	38

Source: Hassan, 1992

The fact that most wetland soils occur in the most recent geological sediments and have very immature profile morphology implies that the soil characteristics are determined directly by the nature of the parent materials/sediments. It follows further that the variability of wetland soils is quite wide because the nature of the parent materials is determined by the degree of weathering in the catchment area or the milieu of sedimentation, or both (Kyuma, 1985).

In most Bangladesh wetland soils the pH value, in general, is around 7.0 which become alkaline on drying when the soils are calcareous and the noncalcareous soils become acidic. Gangetic alluvium, being calcareous, has higher pH when dry than other river alluvia. With depth, in almost all soils, there is an increase in pH (Saheed

and Hussain, 1992). Like organic matter, the total nitrogen contents in the mineral wetland soils range from 0.05 to 0.1 percent. The cation exchange capacity (CEC) of the soils range from as low as 6 meq% to as high as 45 meq% (Table 8). The CEC of soils that depends on its organic matter contents and the amount and nature of clay minerals rarely exceeds the value 45 meq% in the mineral soils of Bangladesh. More than 60% of the soils have CEC values ranging from 10 to 20 meq% (Saheed and Hussain, 1992). Exchangeable K is high in the Gangetic alluvium (Ghior series) and low in Pleistocene terrace soils (Chandra series).

Table 8: **A few Characters of some Organic Wet Soils of Bangladesh**

Depth cm	Clay %	CEC me/100g	Base Sat. %	pH (H_2O)	% Organic carbon	Total N (%)	C/N ratio
Harta series : Thapto-Histic Fluvaquent							
0-10	64	54.7	88	5.8	12.97	0.79	16
10-22	62	51.9	82	5.3	9.67	0.61	16
22-42	56	50.2	82	5.3	8.53	0.58	15
42-68	--	48.7	81	5.3	29.37	2.58	11
Satla series: Fibric Medihemist							
0-20	--	--	--	5.3	20.40	1.21	17
20-75	--	--	--	5.5	35.90	2.34	16
75-87	--	--	--	5.7	50.40	2.51	20
87-120	--	--	--	5.4	48.80	2.38	20

Source: SRDI Staff (1965-86)

Organic wetland soils in Bangladesh are acidic (Table 8). The organic matter contents range from 15 to about 87 percent. The peaty layer occurs at different depths in various soils. For example, in the Satla series, the peaty layer occurs at the surface while in the Harta the layer is at a depth between 25 and 50 cm (Saheed and Hussain, 1992). The nitrogen content is also high in these soils. As a result, the C:N ratios of these soils are not too wide. The CEC is relatively higher than in mineral wetland soils. This is because of substantial presence of clay (around 60 percent) in addition to the organic matter. Organic soils are deficient in some micronutrients like Cu and Zn.

A humid climate, particularly with a concentration of rainfall during the rainy season, favours seasonal saturation of soil with water and seasonal flooding of low-lying lands. An abundance of low-lying lands therefore contributes to the existence of wetland areas. Many of the wetlands in tropical Asia are the result of a combination of humid climate with a heavy concentration of rainfall and an abundance of low-lying land like

floodplains, deltas and wide coastal lowlands (Kyuma, 1985). Wetlands are not, however, confined to low-lying lands. Under heavy concentration of rainfall, even terraces and fans are flooded or saturated with water, as long as the land surface is level or depressional and soils are heavy textured and impervious. Both the situations occur in Bangladesh. In fact, the *haors*, *baors*, *beels* occupy a major part of level lands at higher elevations where rainwater accumulates and makes temporary or perennial freshwater wetlands.

Nutrient Dynamics

Very little data are available on the nutrient dynamics or the influx and efflux of various nutrients including the organic matter turnover in the wetlands (the perennial waterbodies including the *haors*, *baors* and *beels/jheels*). It is supposed to be governed by the source of water and the parent materials/ sediments. The depressions receiving the overflowing waters from the various rivers and their tributaries accumulate the silts and the nutrients which settle there. This again is determined by the quanta of discharges they receive as well as the nature of the incoming water. In most cases, the water leaving the depressions are relatively clear. This is mainly the case of Meghna and its tributaries. In a preliminary analysis of the water samples collected from Hail Haor, Kawadighi Haor, Kusyiara river and Monu river (Fig. 5), it was observed that the nutrient contents as well as the suspended solid contents vary in the same water depending on positional situation (Table 9). It appears that the waters are rather rich in Na,Fe and nitrogen. For a comparison, analyses of a few other water samples from different waterbodies/wetlands are presented in Table 10.

Table 9: **A few Properties of Water Collected from Various Sources**

Water	S S mg/L	N_T mg/L	O.M. mg/L	P_T mg/L	K mg/L	Na mg/L	Fe mg/L
Hail Haor(1)	120	20.21	Tr	1.25	5.0	15.5	2.5
Hail Haor(2)	80	16.03	33.04	1.25	6.0	15.0	2.5
Hail Haor	400	13.74	33.04	0.85	3.0	13.0	1.4
Kawadighi (Rokta channel)	94	10.51	Tr	1.10	2.0	12.0	1.9
Kawadighi (Khyiluia beel)	86	8.62	Tr	1.25	12.0	38.5	2.3
Kawadighi(Fish)	126	10.78	Tr	0.85	2.5	12.5	1.8
Monu(Kajar Bajar)	240	13.07	33.04	0.85	5.0	17.5	3.6
Kusyiara	214	9.43	33.04	0.80	3.5	14.0	4.1

Tr=Trace, SS=Suspended Solid

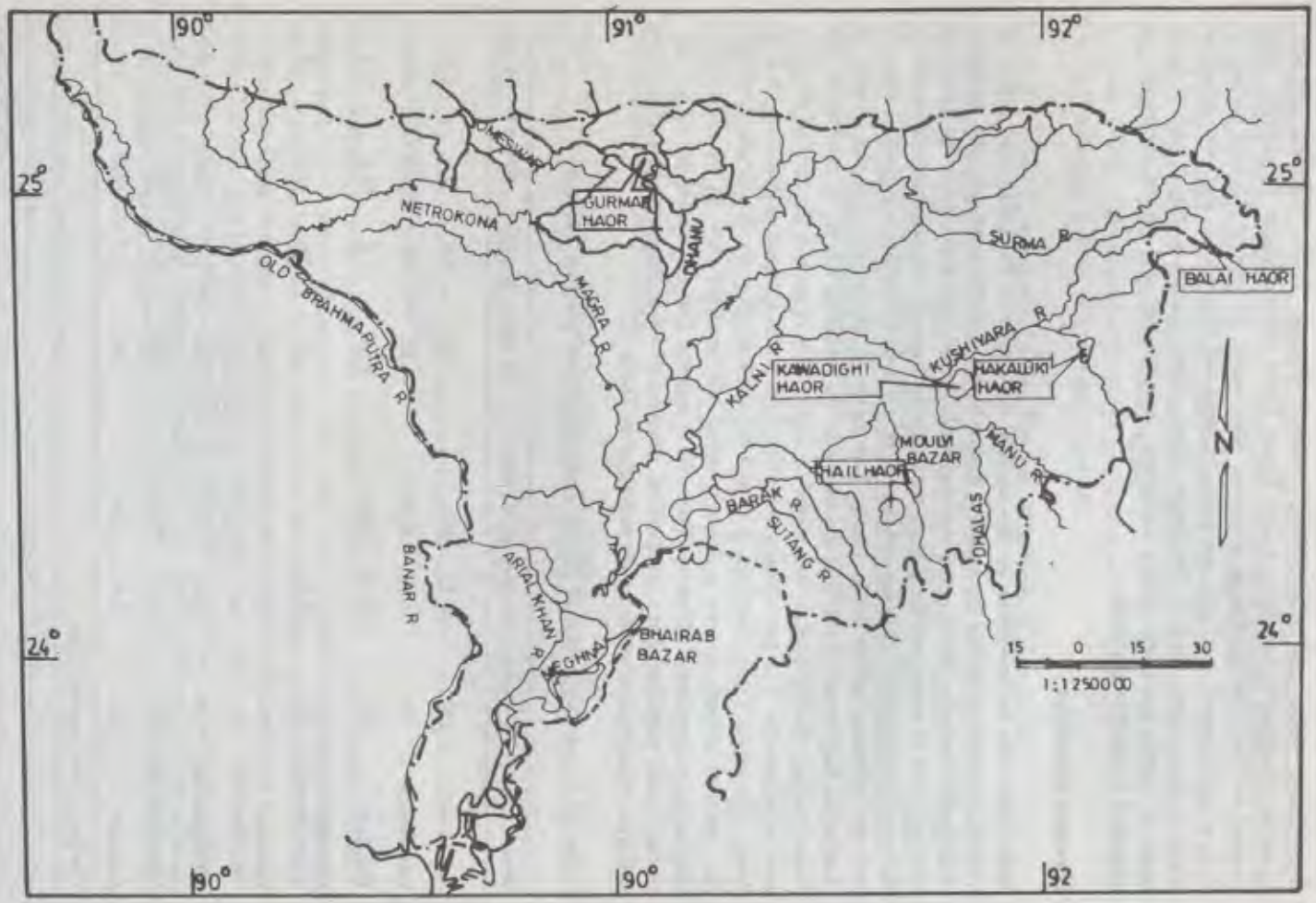


Figure 5: **Wetland Areas of Sylhet Basin**

Table 10: **A few Characteristics of Soils and Water from Various Wetlands of Bangladesh**

Samples from Rangpur area (1-Big lake: 2-traditionally managed pond)

Sample No.	pH		O.M.		NH_4-N ppm		NO_3-N ppm		Total N		Total P ppm	
	a	b	a(%)	b(ppm)	a	b	a	b	a(%)	b(ppm)	a	b
1	6.0	6.2	4.8	44	26.0	2.0	29.5	6.8	0.8	21.9	1040	5.2
2	6.1	6.3	3.8	35	34.0	3.9	19.2	6.9	0.5	33.5	678	3.7

Samples from Noakhali (1-Fulgazi; 2-Raipur)

Sample No.	pH		O.M(%)	Na ppm		K ppm	
	a	b	a	a	b	a	b
1	5.45	6.3	0.712	21	6.5	10.5	3
2	6.00	6.9	0.731	31	16.0	11.0	7

Samples from Noakhali (1- managed pond, 2- traditional pond)

Sample No.	pH		O.M.	Na ppm		NO_3-N ppm	PO_4-P ppm	K ppm	
	a	b	a(%)	a	b	a	a	a	b
1	8.8	7.5	0.67	135	490	1.5	250	7.8	18
2	7.8	7.2	1.06	105	110	1.7	321	12.0	7.0

a=soil, b=water

Table 11 describes the analytical results on some basic properties of the soils collected at different locations of the Hail Haor, Kawadighi Haor and soils outside the Monu project. The pH (wet condition) of both the *haors* is near neutral, though the relatively drier part of the *haors* have pH in the acidic side which is evident from the pH of the soils from outside the project (Table 12). The organic matter content is around 3 percent in both cases while it is much lower for soils outside the Monu project. It is interesting to note that the organic matter contents were higher where the soils were more wet. Similar is the case with other nutrients. These results are from the surface soils.

Alam *et al* (1987) reported the analyses of subsurface soils (45- 150 cm) of three sites from *haor* areas of Sylhet viz., Nayakhara, Ratla-1 and Ratla-2. Some of these properties are shown in Table 13.

It is apparent from these values that some nutrients are moved vertically when the soils are submerged. This vertical movement of nutrients could further be appreciated from Table 14. It indicates the downward movement of a few important nutrients when the soil is submerged for 15 days. This was an F_3 type soil.

Table 11: **Soil Characteristics of two Haors at Various Locations**

	Hail Haor						Kawadighi Haor					
Locations	pH	N_T %	O.M %	P ppm	K ppm	Fe %	pH	N_T %	O.M %	P ppm	K ppm	Fe %
1	5.74	0.14	1.3	36.4	45	0.05	6.35	0.23	1.9	71.7	51	0.11
2	6.12	0.44	3.8	46.4	257	0.14	6.15	0.39	3.5	43.8	160	0.13
3	6.24	0.50	4.6	124.9	261	0.24	5.82	0.39	3.7	30.9	216	0.14
4	–	–	–	–	–	–	6.02	0.37	2.7	181.8	85	0.17
Average	6.03	0.36	3.2	69.2	188	0.14	6.08	0.35	2.9	82.05	128	0.14

Table 12: **Soil Characteristics of Monu Project**

pH	% N_T	% O.M	P ppm	K ppm	% Fe
5.42	0.22	1.21	33.6	84	0.06

From Tables 13 and 14 it can be summarized that submergence causes changes in the nutrient status of the surface soils. So the nutrient dynamics in wetland soils and wetlands are in a complicated situation. There is not only a vertical and lateral redistribution of various nutrient species including organic matter but a change in the forms of the individual nutrients as well, which greatly affect the culture that is practiced on these soils. So far as the cultivation of lowland or wetland rice is concerned, there have not been much problems due to (1) the special physiological nature of rice plants to withstand the anaerobic conditions of wet soils and (2) maintenance of a natural fertility level by the blue-green algae - which add both biomass and nitrogen plus some nutrient elements to the system. However, in some cases adverse effects of submergence do occur. On the other hand, very little information is in hand as to the effects of the differential nutrient status of the soils and water in wetlands used for cultures other than rice.

Pollution of Wetlands

It is estimated that about 30% of the nitrogen fertilizers added to soil is lost through drainage. Of the drainage component about 10% is lost through lateral drainage and 20% is likely to be carried with the percolating water which implies that about 1,35,000 tons of N (current use of 6,75,000 tons of N from urea) might end up in the groundwater reservoirs and in the ponded environments causing eutrophication of

surfacewater bodies due to increased accumulation of NO_3-N (Habibullah and Imamul Huq, 1992). Table 15 shows the levels of NO_3-N in some waterbodies from different areas of the country.

Table 13: **Some physico-chemical and chemical properties of the sub-surface soils (90-150 cm) of Nayakhra, Ratla-1 and Ratla-2 areas**

	Nayakhra	Ratla-1	Ratla-2
pH	4.5	6.5	6.5
% Sand	10	7	8
% Silt	85	90	80
% Clay	5	3	4
% Organic C	0.16	0.10	0.14
% Total N	0.046	0.051	0.058
CEC meg/100g	5.46	6.07	3.78
% NH^+4-N	0.0178	0.0185	0.0172
% NO_3-N	0.0023	0.0040	0.0023
% Total P	0.178	0.250	0.300
% Total K	0.60	0.66	0.92
% Total Ca	2.3	2.7	2.6
% Tot. Mg	0.42	0.44	0.42
% Soluble SO_4^-	0.081	0.100	0.065
% Soluble Cl	0.334	0.449	0.261

Table 14: **Leaching loss of a few nutrients through submergence for 15 days**

	pH	% O.M	NH_4-N (ppm)	NO_3-N (ppm)	Ca (ppm)	Mg (ppm)
Initial Soil Character	4.0	0.84	0.029	0.199	250	200
After 15 days of submergence: the leachate	7.53	-	0.0035	0.0081	16	17

The amount of triple superphosphate currently used in agriculture equals 1,00,000 tons of P. The pollution of surface waterbodies from P-fertilizers may assume significance in some places like the open waterbodies near the residence of farmers or in the depressions/basin areas. The open waterbodies receive P not only from the fertilizers added to the ricefields but also from use of soaps, detergents, organophospho pesticides etc. The levels of P in some open waterbodies are shown in table 16.

High accumulation of nutrients, particularly NO_3 and PO_4 leads to eutrophication, at times even to hypertrophication of these waterbodies, reduction in the O_2 content, thus rendering the waterbodies unsuitable for aquatic fauna. All spots are surfacewater from lakes, ponds or *beels*.

Table 15: **Amount of NO_3-N in Waterbodies from Different Locations in Bangladesh**

Location	Spot	NO_3-N, mg/L
Rangpur,1987	1	6.7 - 19.3
,,	2	6.7 - 18.1
,,	3	7.7 - 22.5
,,	4	6.9 - 19.2
,,	5	6.8 - 29.5
Noakhali,1991-92	1	1.8 - 2.4
,,	2	2.8 - 6.2
,,	3	0.9 - 3.8
,,	4	trace - 8.5
,,	5	trace - 6.8
Mymensingh,1992	1	2.6 - 3.4
Comilla, 1992	1	2.0 - 13.8

Table 16: **Amount of PO_4 in Open Waterbodies in some Locations of Bangladesh**

Location	Spots	O-PO_4, mg/L
Rangpur, 1987	1	0.6 - 20
,,	2	0.3 - 14
,,	3	0.4 - 15
,,	4	0.4 - 24
,,	5	0.3 - 13
Noakhali, 1991 - 92	1	232 -253
,,	2	202 -255
,,	3	321 -391
,,	4	10 -238
,,	5	10 -234

River water contamination is assuming significance because of careless discharge of the industrial wastes into the rivers which then is carried to the various wetland environments. For example, Altaf *et al* (1991) found that the arsenic level was 9.3 ppm in and around the Ghorasal Fertilizer Factory which has caused an accumulation of the element in the nearby soil to as high as 3778 ppm. In fact, wetlands likely to receive water discharges from rivers passing through industrial enclaves are more susceptible to this type of pollution. The pollution of water can also arise from pollution of soil and

air with pesticides (Habibullah and Imamul Huq, 1992). Pesticide use has increased from none in 1955 to 6,000 tons in 1991. Non-standardization of agrochemicals (type and quantity) at farm levels has given rise to frequent incidences of casualties to both human and aquatic population. This affects fish culture in open waterbodies and in ricefields (Habibullah and Imamul Huq, 1992).

The discussion so far has centred around nutrient and other materials at microlevel. The dynamics of various materials - nutrients or contaminants - at a macrolevel are not known. The quanta of nutrients and other materials (toxic or non-toxic, pollutants or debris) received by the important waterbodies or the wetlands and the quanta effluxed need to be assessed for an overall evaluation of the whole wetland systems of the country. It is definite that the nature and quantity of deposits will be determined by the source of the water, volume of the water, volume of the water received and the volume of water leaving the system as well as the basic soil characteristics of the ecosystem. The agricultural practice of the environment around the wetlands will also be a determining factor.

FUTURE PERSPECTIVES

It needs to be emphasized that the future prospect of the country lies in better management of its wetland soils and wetlands. The wetland soils are principally used for rice cultivation. Its production level per hectare is one of the lowest (1.5 t/ha) when compared to Asian standards. Fertility level of the wetland soils in the country is low to moderate and is believed to be enriched by siltation during flooding . The land use in wetland soils is basically traditional depending on the timing and duration of flooding. However, new technology is making its way gradually. Although two rice crops are usually grown in the shallowly flooded wetland soils, *boro* is the only crop grown during the dry season (subject to the availability of irrigation facility) in the low and very low wetland soils.In the semi-perennial freshwater wetlands (deeply flooded for more than five months) floating or deepwater rice is the only crop. In other areas of wetlands , the landuse is non-existent. Pisciculture is not a common practice in most of the wetlands. Natural fisheries are the only use. Some hydrophytes (both macro and micro), the use of which is yet uncertain, grow in these areas.

Water management in most wetland soils/wetlands is either weak or non-existent especially during the rainy season . On the other hand, extraction of groundwater during dry season for *boro* cultivation is also not systematic. The exploitive nature of cultivation (rice-rice-rice/rice-rice-fallow) with little addition of organic manure is the reason behind low organic matter in most mineral wetland soils of the country. The depressions/basins that act as the sink likewise receive very little organic matter as run-off from their surrounding soils.

Many of the wetlands are on non-calcareous alluvium. These soils become acidic when dry; so are the organic wetlands. The peats in the country accumulate silts during

flooding season. As a result, instead of becoming typical peats they are mainly mucky clay or clayey muck.

The following strategies and research plans are envisaged for a better understanding and consequently better use of the wetlands:

a) a thorough inventory of the various types of freshwater wetlands under different agro-ecological regions; these should include the F_3 and F_4 land types;
b) thorough physical, physico-chemical and chemical analyses of water, soil and vegetation of the wetland eco-system; this has to be done initially every month for three consecutive years and then to be continued periodically as a monitoring work; this will help make a balance-sheet of various parameters at micro level;
c) quantify the total loads brought in by the major rivers and their tributaries to the various catchment areas and the quanta leaving the system; this will help assess the dynamics in a macro level;
d) evolve water management programmes efficient for both rainy season and dry periods; creating dams around the basin areas might help protect lands from flooding but not allowing water to be stored will create adverse effect, like soils becoming acids, in non-calcareous floodplains and organic wetlands; however, in calcareous floodplains where the waterbodies become dry during the dry season, the wetlands could be reclaimed by creating dams etc. so that the cropping intensity could be increased;
e) diversification of the use of waterbodies needs to be attempted through an efficient water management programme;
f) survey and monitoring for various pollutants in the wetlands, particularly in areas where intensive agriculture is practised or near the industrial and urban periphery;
g) assess the possibility of using the mucky clay or clayey muck for various soil amendments other than its use as fuel; and
h) develop personnel and manpower trained in the wetland systems of the country.

REFERENCES

Alam, Didarul, S.M.Imamul Huq and K. Anam. 1987. Some properties of a few sub-surface soils from *haor* areas of Sylhet. *Dhaka Univ. Stud.* part E,2(1) pp. 61-63.

Altaf Hossain, M.A., A.I. Mustafa, M. Ahamed and Israil Ahamed. 1991. Arsenic pollution in and around Ghorasal Urea Fertilizer Factory. Paper presented at the 15th annual conference of Bangladesh Chemical Society, held 13-15,Dec. 1991, Dhaka (Abstract No. AEC 11.pp.40).

Dudal, R. 1992. Introductory Address: Wet soils. *Proc. Eighth International Soil Correlation Meeting (VIII ISCOM): Characterization, Classfication and Utilization of Wet Soil.* Louisana and Texas, Oct. 6-12,1990, USDA, 1992 pp. 1-4.

FAO. 1971. *Bangladesh Soil Resources*. AGL: SF/PAK6, Tech. Rep.3, FAO, Rome, pp. 209.

FAO. 1988. Land Resources Appraisal of Bangladesh for Agricultural development. Report No 2, *Agroecological Regions of Bangladesh*. FAO, Rome, pp570.

FAO-UNESCO. 1988. FAO-UNESCO soil map of the world. Revised legend. FAO, Rome.

Habibullah, A.K.M. and S.M.Imamul Huq. 1992. Impact of Intensive Agriculture, Agro-Chemicals and Population on the Quality of Environment in Bangladesh. Paper presented at the Int. seminar on Environmental Soil Science, 8-15 August, 1992 Edmonton, Alberta, Canada, organized by CLRA, CSSS & ISSS.

Hassan, M. M. 1992. *M. Sc. Thesis*. Dept. of Soil Science, Dhaka University.

Kyuma, K., 1985. Fundamental characteristics of wetland soils. pp191-206. In: *Wetland Soils: Characterization, Classification, and Utilization*. IRRI, Los Banos, Philippines.

Khan, F.H. 1991. *Geology of Bangladesh*. University Press Limited, Dhaka.

Morgan, J.P. and W.C. McIntire. 1959. Quaternary geology of the Bengal Basin, East Pakistan and India. pp 319-342. *Bull. Geol. Soc. Amer.*, 70.

Neue, H.U. 1985. Organic matter dynamics in wetland soil. pp 109-122. *Wetland Soils: Characterization, Classification and Utilization*. IRRI, Los Banos, Philippines.

Ponnamperuma, F.N., 1985. Chemical kinetics of wetland rice soils relative to soil fertility. pp 71-89. *Wetland Soils: Characterization, Classification and Utilization*. IRRI, Los Banos, Philippines.

Saheed, S.M. 1984. Soils of Bangladesh. pp 107-129. *Proc. Int. Symp. Soil Test Crop Response Correlation Studies*. BARC and SSSB, Dhaka, Bangladesh.

Saheed, S.M. and M.S. Hussain. 1992. Wetland soil of Bangladesh. pp 220-229. *Proc. Eighth International Soil Correlation Meeting (VIII ISCOM): Characterization, Classification, and Utilization of Wet Soils*. Louisana and Texas, Oct.6-21, 1990. USDA, 1992. pp. 220-229.

Soil Resources Development Institute Staff (SRDI Staff). 1965-1987. *Reconnaissance Soil Survey Reports*. 34 volumes,Govt. of Bangladesh, Dhaka.

Annexure

Distribution of Various Land Types in Different AERs

Region	Location and Extent	Medium low land	low land	Very low land	Homesteads/ water	Settlement/ water
Region-1 Old Himalayan Piedmont plain	Most of Panchagarh and Thakurgaon districts, and north-western parts of Dinajpur District. 4008 km2 (1549 sq miles).	1	0	0	7	-
Region-2 Active Tista Floodplain	The region occupies narrow belts within and adjoining the channels of the Tista, Dharla and Dudhkumar rivers in Nilphamari, Rangpur, Lalmanirhat, Kurigram and Gaibandha Districts. 836 sq. km (323 sq. miles)	0	0	0	26	-
Region-3 Tista Meander Floodplain	This region extends over several Districts : Most of greater Rangpur; eastern part of Panchagarh and Dinajpur; northern Bogra; and parts of Jaipurhat Naogaon and Rajshahi Districts 9468 sq. km (3658 sq. miles)	4	1	0	9	-
Region-4 Karatoya - Bangali Floodplain	Eastern half of Bogra Districts and most of Sirajganj District. 2572 sq. km (994 sq. miles)	14	4	1	14	-
Region-5 Lower Atrai Basin	Most of this region lies in Naogaon and Natore Districts, Small areas extend into Rajshahi, Bogra and Sirajganj Districts. 851 sq. km. (329 sq. miles)	21	65	0	4	-
Region-6 Lower Punarbhaba Floodplain	Extreme western part of Naogaon District and the extreme northern part of Chapai Nawabganj District. 129 sq. km (50 sq. miles)	10	60	0	-	30

Region	Location and Extent	Medium low land	low land	Very low land	Homesteads/ water	Settlement/ water
Region-7 Active Brahmaputra-Jamuna floodplain	Eastern parts of Kurigram, Gaibandha, Bogra, Sirajganj and Pabna Districts and westetn parts of Sherpur, Jamalpur, Tangail and Manikganj Districts. Minor areas also occur in Dhaka, Munshiganj, Narayanganj and Chandpur Districts. The region's boundaries are liable to change with time due to bank erosion (Mostly on the west bank of the Brahmaputra-Jamuna river) and due to top soil development on stable alluvial formations (mainly on the eastern side). 3190 sq. km. (1233 sq. miles)	20	8	0	30	-
Region-8 Young Brahmaputra and Jamuna Floodplains	Western parts of Sherpur, Jamalpur and Tangail Districts; parts of Manikganj, Dhaka, Munshiganj, Narayanganj and Gajipur Districts; and the belt adjoining the Old Brahmaputra channel through Mymensingh, Kishoreganj and Narsingdi Districts. 5924 sq. km. (2289 sq. miles)	19	9	0	12	-
Region-9 Old Brahmaputra Floodplains	Large areas in Sherpur, Jamalpur, Tangail, Mymensingh Netrakona, Kishoreganj, Narsingdi and Narayanganj Districts. Small areas in the east of Dhaka Gajipur Districts 7230 sq. Km. (2794 sq. miles)	20	7	<1	10	-
Region-10 Active Ganges Floodplain	The region extends along the Ganges and lower Meghna rivers channels from the Indian border in Chapai Nawabganj and Rajshahi Districts to the mouth of the Meghna estuary in Lakshmipur and Barisal Districts. 3334 sq. km. (1288 sq. miles)	18	4	0	-	33

Region	Location and Extent	Medium low land	low land	Very low land	Homesteads/ water	Settlement/ water
Region-11 High Ganges River Floodplain	Chapai Nawabganj, Rajshahi, Southern Pabna, Kushtia, Meherpur, Chuadanga, Jhenaida, Magura, Jessore and northern parts of Satkhira and Khulna Districts, together with minor areas in Naogaon and Narail Districts. 13205 sq. km (5103 sq. miles)	12	2	0	11	-
Region-12 Low Ganges River Floodplain	Natore, Pabna, Goalundo, Faridpur, Madaripur, Gopalganj and Sariatpur; eastern parts of Kushtia, Magura and Narail; north-eastern parts of Khulna and Bagerhat; northern Barisal; and south-western parts of Manikganj, Dhaka and Munshiganj districts. 7968 sq. km. (3079 sq. miles)	31	14	2	11	-
Region-13 Ganges Tidal Floodplain	The region occupies all or most of Barisal, Jhalakati, Pirojpur, Patuakhali, Barguna, Bagerhat, Khulna and Satkhira Districts. It includes the Khulna and Bagerhat Sunderbans Reserved Forests. 17066 sq. km. (6594 sq. miles)	2	<1	0	18	-
Region-14 Gopalganj-Khulna Beels	The region occupies a number of separate basin areas in Madaripur, Gopalganj, Narail, Jessore, Bagerhat and Khulna districts. 2247 sq. km. (867 sq. miles)	41	28	11	4	-
Region-15 Arial Beel	Munshiganj and Dhaka Districts. 144 sq. km. (56 sq. miles)	13	73	0	14	-
Region-16 Middle Meghna River Floodplain	Region 16 occurs between the Southern part of the Sylhet Basin and the confluence of the Meghna river which the covers parts of several Districts: Kishoreganj; Brahmanbaria; Comilla; Chandpur; Narsingdi; Narayanganj 1555 sq. km (600 sq. miles)	29	25	11	27	-

Region	Location and Extent	Medium low land	low land	Very low land	Homesteads/ water	Settlement/ water
Region-17 Lower Meghna River Floodplain	Chandpur, Lakshmipur and Noakhali districts. 909 sq. km. (351 sq. miles)	31	<1	0	27	-
Region-18 Young Meghna Estuarine Floodplain	Chittagong, Feni, Noakhali, Lakshmipur, Bhola, Barisal, Patuakhali, Barguna districts. 9269 sq. km. (3581 sq. miles)	7 (12)	0	0	47(12)	-
Region-19 Old Meghna Esturaine Floodplain	Kishorganj, Habiganj, Brahmanbaria, Comilla, Chandpur, Feni, Noakhali, Lakshmipur, Narsingdi, Narayanganj, Dhaka, Sariatpur, Madaripur, Gopalganj, Barisal districts. 7740 sq. km. (2991 sq. miles)	33	21	3	17	-
Region-20 Eastern Surma-Kusiyara Floodplain	Sylhet, Moulvi Bazar, Sunamganj, Habiganj districts. 4622 sq. km. (1786 sq. miles)	20	36	<1	14	-
Region-21 Sylhet Basin	This region extends over large parts of Sunamganj, Habiganj, Netrakona, Kishoreganj and Brahmanbaria districts. 4573 sq. km. (1767 sq. miles)	19	43	23	11	-
Region-22 Northern and Eastern Piedmont plains	Sherpur, Netrakona, Sunamganj, Sylhet, Moulvi Bazar, Habiganj, Brahmanbaria and Comilla districts. 4038 sq. km. (1560 sq. miles)	16	9	1	10	-
Region-23 Chittagong Coastal Plain	Feni, Chittagong and Cox's Bazar districts. 3720 sq. km. (1437 sq. miles)	13	<1	0	27	-

Region	Location and Extent	Medium low land	low land	Very low land	Homesteads/ water	Settlement/ water
Region-24 St. Martin's Coastal Island.	St. Martin's Island. 8 sq. Km. (3 sq. miles)	2	0	0	2	-
Region-25 Level Barind Tract	Dinajpur, Gaibandha, Jaipurhat, Bogra, Naogaon, Natore and Sirajganj districts. 5049 sq. km. (1951 sq. miles)	4	2	0	9	-
Region-26 High Barind Tract	Rajshahi, Nawabganj and Naogaon districts. 1600 sq. km. (618 sq. miles)	<1	<1	0	6	-
Region-27 North-Eastern Barind Tract	Dinajpur, Gaibandha, Jaipurhat, Bogra, Rangpur districts. 1079 sq. km. (417 sq. miles)	1	0	0	7	-
Region-28 Madhupur Tract	Dhaka, Gazipur, Narsingdi, Narayanganj, Tangail, Jamalpur, Mymensingh and Kishoreganj districts. 4244 sq. km. (1640 sq. miles)	7	9	0	10	-
Region-29 Northern and Eastern Hills	Mainly in Khagrachhari, Rangamati, Bandarban Chittagong, Cox's Bazar, Habiganj and Moulvi Bazar districts. Small areas occur along the northern border of Sherpur, Mymensingh, Sumamganj and Sylhet districts, in central and south-eastern Sylhet and in the east of Brahmanbaria, Comilla and Feni districts. 18171 sq. km. (7021 sq. miles)	<1	<1	<1	5	-
Region-30 Akhaura Terrace	Brahmanbaria districts and minor area in Habiganj district. 113 sq. km. (44 sq. miles)	10	15	3	6	-

Source: FAO - UNDP (1988).

ECOLOGICAL CHARACTERISTICS OF FRESHWATER WETLANDS

A. K. M. Nazrul-Islam

ABSTRACT: The paper presents a conceptual framework of the role of hydrology on wetland ecosystem and a classification of wetland systems based on a hydrodynamic energy gradient. Physical parameters of three different ecological systems of freshwater wetlands viz. marshes, *baors* and *haors* have been evaluated.

INTRODUCTION

Freshwater wetlands mean different things to different people. To some, the vitality and beauty of marshes is evident, while to others, wetlands represent wastelands which could be drained and then utilized. To the aquatic ecologists, freshwater wetlands are complex systems and generally represent extremely important resources. The conditions of wetlands change markedly and rapidly in response to fluctuations in climate and precipitation. Many responses are cyclical in long-term periodicity.

Baors, *haors* and *beels* are inland marshes. Wet meadows, mudflats, bogs, wood swamps and fens are examples of freshwater wetlands. These are precious ecological resources that nurture wildlife, purify polluted water, check the destructive power of floods and storms and provide ground for a variety of recreational activities.

There exists abundant literature concerning the ecology of wetland habitats. Gorham (1953, 1956) has studied the acidity and base status of bogs and also analysed some natural aquatic habitats. In a previous work, vegetation, water and soil of some marshes were described (Nazrul-Islam and Kader 1988) and also the environmental conditions and biomass production of wetland habitat were discussed. In addition, growth, chemical composition of an aquatic fern *Azolla* was also evaluated (Nazrul-Islam 1993). The aim of this paper is to summarise information available on the ecological characteristics of freshwater wetlands of Bangladesh.

A CONCEPTUAL MODEL OF ROLE OF HYDROLOGY IN WETLAND ECOSYSTEM

Figure 1 shows a simple model, which allows us to set bounds to the discussion. Climatic influences such as temperature and radiation may have an overriding influence on the type of species that develop in a wetland (Gosselink and Turner, 1978).

Hydrologic Parameters

The following attributes of the hydrologic regime (numbered 1 in Figure 1) seem to be the most important to the biota. The 'source' determines ionic composition, oxygen saturation and toxicity of land. The 'velocity' affects turbulence and the ability of the

water to carry suspended particulate matter. The 'renewal rate' describes the frequency of replacement of the water. It depends on water depth (volume), frequency of inundation, and velocity, and it is one of the most difficult hydrodynamic parameters to measure. The 'timing', that is, the frequency of inundation (daily, seasonal) and its regularity or predictability, influences the potential for system succession and maturation (Margalef, 1968).

Inland waters are remarkably varied in their ionic composition. Although the variation in ionic composition is so great, four cations (sodium, postassium, magnesium and calcium) and three anions (chloride, sulphate and bicarbonate) account for all. The compositions of world averge freshwater (river water) and water from different selected wetlands of Bangladesh, are given in Table 1.

Table 1: **Ionic Composition of World Average Freshwater and of Wetlands of Bangladesh**

Ionic composition	World* average mg/l	Wetlands of Bangladesh mg/l
Cations		
Na^+	8	1.3 - 4.0
K^+	3	1.0 - 2.0
Mg^{++}	5	0.1 - 1.0
Ca^{++}	30	3.0 -12.0
Anions		
Cl^-	8	50.0 -90.0
HCO_3^-	105	Not done

* Bayly and Williams, 1973

CLASSIFICATION OF WETLAND SYSTEMS ON A HYDRODYNAMIC ENERGY GRADIENT

The classification of wetlands along a hydrodynamic energy gradient could be a useful approach to understanding functional relationships. Figure 2 (Gosselink and Turner, 1978) catalogues freshwater wetlands into 6 classes based on source and velocity of water flow. In general flow rate or other indications of hydrologic energy, such as renewal time or frequency of flooding, increases from raised convex wetlands to lentic and tidal wetlands. The major sources of water and types of flow are given in Table 2. If a classification of wetlands on a hydrodynamic energy gradient is of functional value, it should correspond with gradients in ecosystem attributes. During successional processes hydrologic flows are diverted and reduced by the developing biota. According to ecosystem theory (e.g Odum, 1971 and Margaef, 1968), diversity should increase with maturity. This means that diversity should be highest in perched bogs and lowest in high energy wetlands.

Table 2: **Major Hydrodynamic Characteristics of Different Marsh Types (Shown in Figure 2)**

	Water input to marsh			Types of water flow			Outputs from marsh			
Marsh type	Cap.	Ppt.	Upstream	Cap.	SS	OBF	Pcl.	Evt.	DSR	Hp.
1. Raised convex	-	+		+			++	+		S
2. Meadow	+	+	VL				+	+	VL	S
3. Sunken convex		+			VL					S
4. Lotic		+	+		+	+		+		S
5. Tidal		+	+		+	+		+		T
6. Lentic		+	++		+	+		+		V
										S

Cap = Capillary, Ppt = Precipitation, SS = Surface sheet, OBF = Overbank flooding, Pcl = Percolation, Evt = Evapotranspiration, DSR = Downstream run-off, Hp = Hydropulse, S = Seasonal, VL = Very little, T = Tidal and V = Variable

Source : Gosselink and Turner, 1978.

STUDY OF ECOLOGICAL CHARACTERISTICS OF SELECTED WETLANDS

Ecological characteristics of three marshes near Dhaka, *baors* of Jessore district and Halir Haor of Sunamganj district have been studied and reported. Water and plant samples were collected from the wetland habitats. Total alkalinity, chloride and disssolved oxygen (DO) were analysed according to the standard methods of APHA (1977); total hardness with the method of Vogel (1961); conductivity was measured with a conductivity bridge (Nazrul-Islam, 1985); exchangeable cations in soils were extracted with normal ammonium acetate (Nazrul-Islam and Rorison, 1978); potassium(K) was analysed by Flame Photometry; calcium(Ca), magnesium(Mg), manganese(Mn) and iron(Fe) were analysed by atomic absorption spectrophotometer.

Freshwater wetlands are found in many kinds of physical regimes and include such diverse ecosystems as the *haor* basins of Sylhet and Mymensingh districts, the *baors* of Jessore, Khulna and Faridpur districts and natural depressions known as *beels* spread all over the country. In addition, artificial reservoirs such as ponds are very common. All these wetland habitats have at least one thing in common: they are flooded enough so that the roots of the emergent vegetation exist in an anaerobic environment.

Solid quantitative information about the hydrodynamic characteristics of different wetlands is surprisingly difficult to find. Several attributes of the hydrologic regime seem to be important variables which directly influence or modify a range of secondary abiotic parameters (pH, dissolved oxygen, conductivity, etc) which, in turn, determine biotic response.

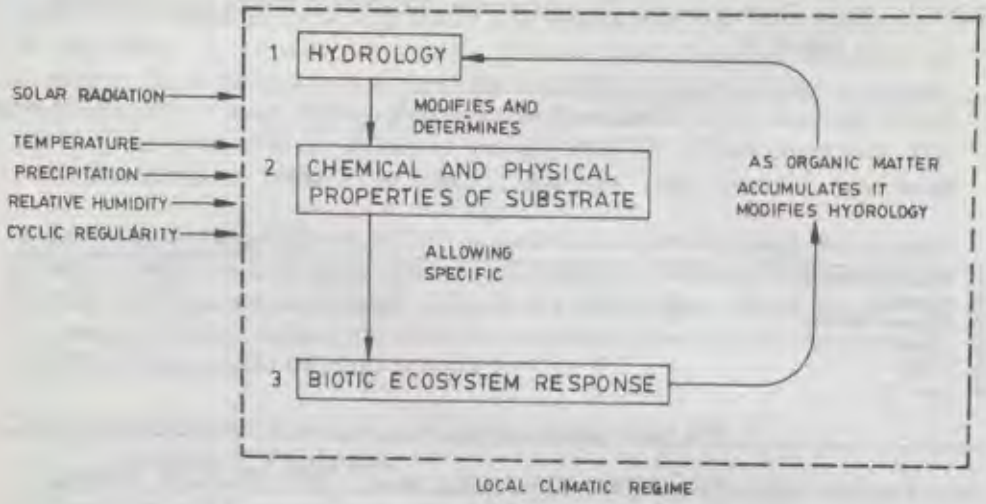


Figure 1: **General Conceptual Model of the Role of Hydrology in Wetland Ecosystems**

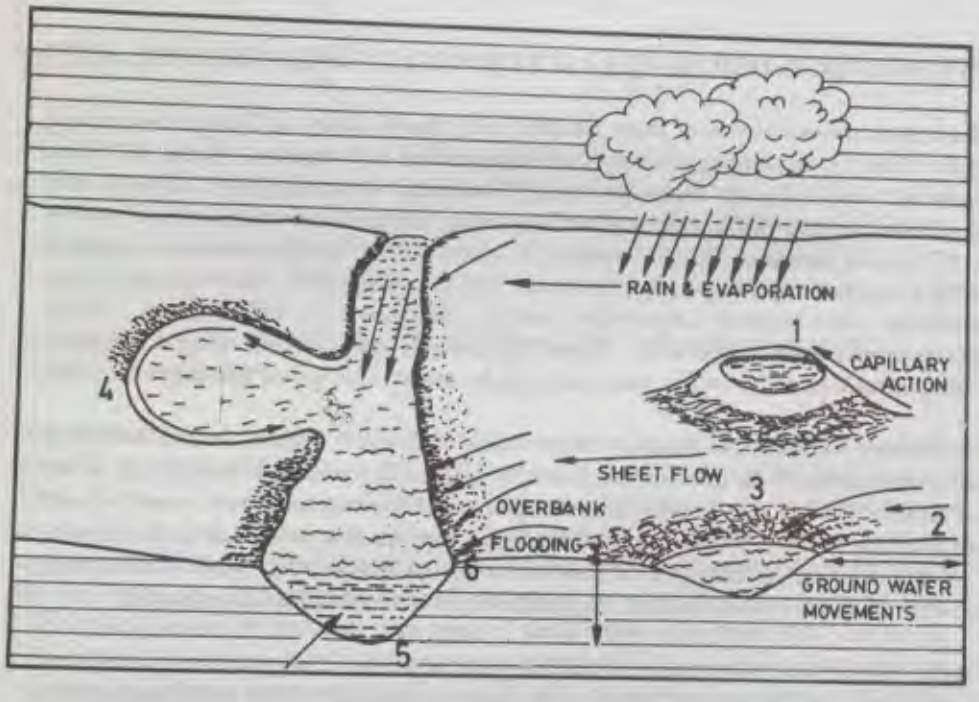


Figure 2: **A Schematic Representation of 6 Types of Freshwater Marsh Environments and their Hydrologic Regime (The Numbers Correspond to the Description of Each in Table - 2)**

Baors of Jessore Area

The *baors* and *beels* of Sharsha *thana* were studied. These are in the Sonamukhi-Banmander Drainage Project. The river Betna passes through the centre of the project. There are a large number of *beels* and *baors* in the project area. The areas of *baors* and *beels* are given in Table 3. After the project, the fish resource has sharply declined. The only source of traditional fish stock is from the central part of the Sunamukhi Beel area where during the lean period some areas remain as marshes.

Table 3: **Areas of Baors and Beels of Sunamukhi-Banmander Drainage Project, Sharsha Thana (Jessore District)**

Areas	Number	Total Area (acre)
A. Baors		
Less than 20 acres	5	53.88
20 to 60 acres	3	121.03
Less than 120 acres	4	411.12
300 acres	1	299.12
		885.15
B. Beels		
Less than 20 acres	1	27.36
More than 20 acres	17	3,000.00
		3,027.36

In the pre-project period, flooding depth was very high. As a result of improved drainage, the surface water area has decreased significantly and encouraged broadcasting *aman* cultivation. For proper drainage, newly excavated canals were connected through *baors* which changed into lotic conditions from lentic, particularly during the monsoon season. As a result of improved drainage, the marshy area of the Sunamukhi Beel has decreased. This has reduced fish production and stock size particularly in the winter season. It is, therefore, argued that a further encroachment of *beel* area for B. *aman* cultivation should not be allowed.

Marshes of Dhaka Area

The vegetation of marshes consists of emergent, submerged and free floating forms of intermingled mats. The main plant communities of these marshes are given in Table 4. In a number of sites *Nymphoides indica, N. cristata, Hygroryza aristata* formed consociation.

Water Characteristics: Water chemistry of these marshes is given in Table 5. The variation in pH ranged from 6.3 to 7.5; since pH of the marshes was less than 8.0 it is possible that the photosynthetic activity also was low in these marshes; calicum was

the dominant cation followed by sodium and potassium. The measurement of dissolved oxygen at different times from the morning to evening showed that the values were lowest in the morning (0.9 mg/l) and highest in the evening (12.5 mg/l). (Nazrul-Islam and Kadir 1988)

Table 4: **List of Macrophytes Occuring in Temporary Marshes**

	Species	Family
1	**Hydrophytes Attached to Substratum**	
	a) Floating leaved hydrophytes:	
	Aponogeton appendiculatus	Aponogetonaceae
	Nymphaea nouchali	Nymphaceae
	Nymphoides indica	Gentianaceae
	N. cristata	Gentianaceae
	Alternanthera sessilis	Amaranthaceae
	Potamogeton mucronatus	Potamogetonaceae
	Telanthera philoxyroides	Amaranthaceae
	b) Submerged hydrophytes:	
	Ottelia alismoides	Hydrocharitaceae
	Limnophila heterophylla	Scrophulariaceae
	Nechamandra alternifolia	Hydrocharitaceae
	Najas graminea	Najadacea
2	**Free Floating Forms:**	
	Lindernia roundifolia	Scrophulariaceae
	Eichhornia crassipes	Pontederiaceae
	Utricularia stellaris	Lentibulariaceae
	U. flexousa	Lentibulariaceae
	Hydrilla verticillata	Hydrocharitaceae
	Trapa bispinosa	Trapaceae
	Hygrorryza aristata	Gramineae

Haor of Sylhet Area

Halir Haor is bounded by the river Surma in the east and by the Bouli to the south, west and north. The *haor* areas have been formed by gradual deposition of sediments. The northern part of the Halir Haor is relatively higher than the south and south western parts. The whole *haor* area is low-lying and is a depressed basin generally inundated by 1.5 m (5 ft) to 6m (20 ft) floodwater in the monsoon. The hydrology of the *haor* area is controlled by three rivers (Surma, Boulai and Paikertalla) receiving floodwater from the Khasi and Jainta hills.

The *haor* area remains under water from May to November- December. Much of the land was and still is under cultivation, but agriculture is limited to *boro* cultivation which starts from January and continues up to the first week of May. The water level in the river rises rapidly in April or early May overtopping river banks and causing

damage to the crops. The data were collected in May 1991 through a Rapid Rural Appraisal (RRA) and personal observations on the ecology and environment of the *haor* area.

Table 5: **Chemical Composition of Water of Selected Marshes (July to November, 1988; values are in range)**

Name of the Marsh	pH	Conductivity µs cm^{-1}	µg/mg				Total hardness mgl^{-1}
			Na	K	Ca	Mg	
Konapara	6.3 + 0.2	151-181	41-50	2.82	1.20	7.5	0.06
	7.1 + 0.8			3.50	1.50	9.5	0.08
Rajendrapur	6.6 + 0.2	161-210	33-40	1.70	2.0	4.0	0.9
	7.5 + 0.3			4.80	5.0	5.8	1.4
Sonargaon	6.5 + 0.2	140-170	45-70	1.30	1.00	3.5	0.01
	7.4 + 0.2			1.90	1.20	5.5	0.02

Source : Nazrul-Islam and Kadir, 1988.

Human Environment: The human-made highlands for houses are very limited. However, people appear to be well adjusted to living in these conditions and are living in a cordial atmosphere. The houses are highly congested and close together. The density of the population living on village mounds during the monsoon is exceptionally high (Table 6), and the human environment is not hygienic. Open highlands for recreational purposes and also for keeping livestock are lacking.

Table 6: **Population Density of Different Villages of Haor**

Location	Name of Village	Length (ft)	Width (ft)	Area (sqft)	No.of families	Population	sq ft/ Person
North West	Harinakandi	200	70	14,000	150	780	17.9
North West	Rajdarpur	200	50	10,000	30	250	40.0
North East	Haor Alipur	150	50	7,500	22	150	50.0
North	Beheli Alipur	300	60	18,000	60	400	45.0
South West	Insanpur	125	40	5,000	35	180	27.8
South East	Gopalpur	400	40	16,000	75	620	25.8

The crowding of human and livestock population into very confined areas for over six months in a year and lack of sanitary facilities pose a health risk, particularly since *haor* is the only source of readily available water. The availability of safe drinking water is unsatisfactory and setting up a tubewell is very expensive, because boring to a minimum of 300-350 feet is needed to reach potable groundwater.

Natural Environment: Field work took place when the *haor* was already virtually full of water. Hence direct observation was limited and the assessment is partial, particularly since the winter season, when water levels are low, is the critical period for assessing the importance and status of the *haor* ecology and environment. The area of fallow land has declined and with it the area of marsh and grassland, with associated

changes in species composition. The importance of this *haor* for wildfowl is not known. It is not listed as such in the National Conservation Strategy, Bangladesh IUCN (1989), but decline in the number of wintering ducks has been reported by local people. However, some 400 lesser Whistling Ducks (*Dendrocygna javanica*) were observed over the *haor*. So it may retain some importance for wildfowl population.

Impacts of Submersible Embankment on the Environment: The embankment has both positive and negative impacts. Among the positive ones are that the embankment provides a pathway during the dry season for pedestrians. In addition, farmers temporarily (2-4 weeks) use the embankment tops for stacking paddy and straw for final processing in the month of May when flood water inundates all the *haor* areas except embankments and houses. A few people have used highland for planting *hijal (Barringtonia acutangula)*. Groundnut and chillis are also cultivated in the raised areas as cash crops.

Before the embankment there were substantial areas of wetland and fallow wet grassland, supporting the heavy and dense vegetation of two grasses, *chailla* and *dud chailla*. These grasses are used as fodder, thatching material and are especially used around the homestead for protection against erosion from wave action, a common natural hazard in the *haor*, during the flood season. As a result of the embankment, the habitat areas of these grasses have significantly decreased. *Ikor* grass *(Sclerostachya fusca* 1.2-1.8m long) was common in some localised wetlands in the *haor* area. This grass was one of the best thatching materials available. The improved and controlled drainage system has strongly disturbed the growth of this grass, and thereby dislocated the shelter of wildlife such as migrant wildfowl. At present, this grass is restricted to areas in and around the homesteads and lowlying land areas.

Soil Environment: The soils of the Halir Haor are dark grey in colour, with a pH 6.0 and piedmont in origin, being derived from sediments from the Jainta and Khasi Hills. Considerable peat deposits are found at a depth of 3m or more and are collected by local people to use as fuel. This peat deposition indicates that possibly the area was once dominated by bog vegetation. Floodwater enters the area every year, siltation occurs, and the soil environment is fertile. Floodwater allows the growth of various euhalophytic plants and with the recedance of floodwater the aquatic plants decompose and add substantial amounts of detritus and organic matter to the soil environment maintaining soil fertility. Present intensive fishing activity does not allow heavy growth of euhalophytes. Therefore, the addition of organic matter from the decomposition of aquatic plants to the soil environment has decreased and this has already shown a tendency to reduce organic matter in the soils. If the present rate of fishing activity continues it is possible that the soil condition will deteriorate further.

REFERENCES

APHA 1977. *Standard Methods for the Examination of Water and Wastewater*, 14th ed APHA, Washington, D.C.

Bayly, A.E. and Williams, W.D. 1973. *Inland Waters and their Ecology*, Longman, Chesire.

IUCN 1989. *The National Conservation Strategy of Bangladesh*. Ministry of Environment and Forest, Government of Bangladesh.

Gorham, E. 1953. A note on the acidity and base status of raised and blanket bogs. *J.Ecol.* 41:153-156.

Gorham, E. 1956. Tionic composition of some bog and fen waters in the English Lake District. *J. Ecol.* 44:142-1

Gosselink, J. G. and R.E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. In: R.E. Good, D.F. Whigham and R.L. Simpson. *Freshwater Wetlands*. Academic Press, Page 63-77.

Margalef, R. 1968. *Perspectives of Ecological Theory*. University of Chicago Press, Chicago, Illinois.

Nazrul-Islam, A.K.M. 1985. The ecology of bay and some edaphic features of coastal soils. *J. NOAMI* 2:23-25.

Nazrul-Islam, A.K.M. 1993. Growth, acidity and water content of *Azolla*. *Bangladesh* J. Bot. 22:55-59

Nazrul-Islam, A.K.M. and I.H. Rorison. 1978. Field investigation of seasonal oxidation-reduction conditions in soil and of changes in the mineral contents of shoots associated species. *Dhaka University Studies* 26:57-65.

Nazrul-Islam, A.K.M. and A.F.M. Kadir. 1988. Vegetation, water and soil of some temporary marshes near Dhaka. *Int. J. Ecol. Environ. Sci.* 14:67-73.

Odum, E.P. 1971. *Fundamentals of Ecology*. 3rd ed. W.B. Saunders Co. Philadelphia.

Vogel, A.I. 1961. *Text book of Inorganic Analysis Including Elementary Instrumental Analysis*. Lowe and Brydone Printers Ltd. London.

PLANT DIVERSITY AND THEIR CONSERVATION IN FRESHWATER WETLANDS

Ansarul Karim

ABSTRACT: In this paper plant diversity of freshwater wetlands and their conservation in Bangladesh, diversity of freshwater wetlands species, life form and community have been discussed and distribution of plants in six ecological zones has been documented. About 158 species belonging to 49 families have been identified. Changing condition of the landscape due to geotectonic change within a very short period of time and increasing human intervention disrupt the pattern and process of vegetation development. Human uses and protective functions of these wetlands have been highlighted. *Aldrovanda vesiculosa* and *Rosa involucrata* have been identified as locally threatened species while freshwater swamp forest consisting of *Barringtonia acutangula, Pongamia glabra* and *Crataeva nurvala* has been considered to be the most threatened vegetation due to over-exploitation and sedimentation. Deep tillage for cultivating HYV in the wetlands have been considered to cause disturbance to the natural seed bank of these wetlands leading to loss of plant diversity. Conservation goal and priority consideration for the freshwater wetland plants have been recommended as criteria for identification of priority sites for conservation. Based on this Tanguar Haor system and Bara Haor in the northeast region have been recommended for immediate protection. Adoption of policy and legal framework, integrated conservation management and research have been identified for restoration of threatened plants and communities.

INTRODUCTION

Wetlands are components of the landscape ecosystems the formation of which has been dominated by water and the processes and characteristics of which are largely controlled by water. The presence of excessive water causes wetlands to become hostile to the normal plant life. There are nevertheless a vast assemblage of specialized plant species which have adapted themselves to such extreme environment. A considerable number of these plant species present man with valuable products such as food, fuel, medicine and housing materials. The plants provide forage for domestic animals. These plants are the genetic reserve which man has exploited since millennium for crops.

Ecological value of these wetland plants is also being increasingly recognized because it provides habitat to a large number of wild animals and act as escape cover and flood -safe nesting sites for many birds and other wild animals. Marsh plants and their associated habitat provide important breeding areas for a wide variety of water fowls and important staging areas for a large number of resident and migratory birds. Plants also contribute to the biological cycling and mobilization of chemical elements. The dry matter and nutrients in wetland plants and other food chain of the ecosystem directly support a wealth of fisheries resource. Aquatic vegetation beds act as spawning grounds and shelter juveniles of a large variety of fishes and prawns. Dense vegetation and hydrologic regime of the wetlands provide vital nutrient elements not only within but beyond their immediate boundary downstream.

Due to increasing over exploitation of the resources and lack of perception of the value of the plant resources of this unique ecosystem, the resources are declining at an alarming rate. This paper intends to focus on the documentation of the non-agricultural plant resources of the historical past and their present status in natural wetlands of Bangladesh. An attempt has also been made to suggest conservation measures to protect the dwindling plant resources of these wetlands.

PLANT DIVERSITY

Biodiversity is a widely misunderstood term and often recognizes the genetic and taxonomic aspect of plants and animals only. Recent convention on "Biological Diversity" (UNCED 1992) clearly defines the term and broadens its scope. The term means variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. The convention also defines the term "Ecosystem" as meaning a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit. Following these definitions, the plant diversity of wetlands will be discussed at different levels.

Wetlands are a highly dynamic ecosystem that are influenced by recent and past alterations in landuse of wetlands, terraces that border them and the adjoining landscapes including the whole catchment areas. Freshwater wetlands of Bangladesh are highly complex due to their location at the geotectonically active part at the confluence of three great rivers of the world, the Brahmaputra-Jamuna, the Ganges and the Meghna and their numerous tributaries and distributaries. The physiographic features together with the intricate network of these river systems divide the country into regions which have distinct drainage and flooding regimes. Superimposed on this landscape variation, the climatic regime (rainfall, temperature etc.) and the human interventions cause significant variation on the ecological characteristics of the wetlands that support different flora and the vegetation types. Plant diversity has been considered in this paper under such broad ecological regions as shown in the map (Fig.1).

Plants in the Past

Earliest records of systematic collection of this country's botanical materials do not go beyond Roxburgh's *Hortous Bengalensis* of 1814. The previous floral records and other records of the British administration indicated the wetlands as marsh and swamps consisting of impenetrable jungles with a large variety of plants and equally diverse fauna. Though not systematic records they provide an overview of the past vegetation characteristics of the wetlands of different districts.

a) Region I represents the Sylhet basin. Kanjilal in his account of Flora of Assam (Kanjilal, 1934) indicated that "Swamps and Beels abound in the plains of Sylhet and Cachar some of the latter being so large as to deserve to be called lakes". He mentions the plants in three habitats. Vegetation along the border

of the larger *beels*, especially of those situated in hilly tracts, are *Crataeva, Eugenia, Duabanga, Terminalia, Lagerstroemia, Hyptianthera, Symplocos, Pealii, Ardisia, Rhabdia, Litsaea, Homonoia, Antidesma, Bunius, Trewia, Ficus, Cunia, Engelhardia, Dracaena, Clinogyune etc.*
Grasses - *Hygrorhiza, Vossia, Panicum, Myurus, Crusgali, Phragmitis, Arunds, Arundonella, Thysanolana.*
Aquatic plants belonging to families are *Nymphaeaceae, Araceae, Lemnaceae, Alismaceae, Majadaceae, Eriocaulaceae* and *Cyperaceae*. The river banks were extensively covered with grasses of enormous size consisting of reeds (*Phragmitis, Saccharm, Anthisteria, Erianthus* and *Arundo).*

b) In regions II and III that represent the northwest regions of Bangladesh forest formation do not cover the wetland areas in the recent past. Usually the higher grounds are covered with bamboos and grass. *Imperata arundinacea* and *Andropogon ociculatus* are among them. The banyan, pipal and semul may also be seen. The char areas of Rajshahi used to be covered with thick reeds, bushes, *tamarix* bushes and heavy jungles where wild buffaloes used to be seen. Old river beds, ponds, marshes and streams with sluggish current have a copious vegetation of *vallisnaria* and other plants. Lands subjected to inundation have usually a covering of *tamarix* and reedy grass. In the district of Bogra it is reported that in some parts where the ground is more or less marshy *rosa involucrata* was plentiful.

c) The region IV that represents the moribund part of the Gangetic delta consisted of numerous ponds and ditches filled with submersed and floating water plants. Remarkable among these for its rarity and interesting on account of its distribution to Europe on the one hand and Australia on the other is the floating *aldrovanda vesiculosa*. The edges of sluggish creeks are lined with large sedges and bulrushes, and the banks of rivers have a hedge-like scrub jungle.

d) The region V that represents the *beel* areas of the greater Faridpur district and greater Bakerganj district also consisted of similar types of marsh vegetation. In these areas the banks of the canals are thickly wooded with canes and trees so as to appear to be remnant of some primeval forest.However from the old records it is clear that the east of the districts contained extensive stretches of jungle, which were the habitat of tigers and buffaloes. In 1792, rewards were paid for killing tigers in Madaripur and even as late as 1875 wild buffaloes were common in the winter season. Leopards of the small variety were found in the north of the district and occasionally a tiger from the Sundarbans used to take refuge in the southern marshes. Wild pigs were so numerous that the then collector expressed his opinion that "unless prompt measures are taken for their destruction, many of the villages of the district will be given back to the jungle".

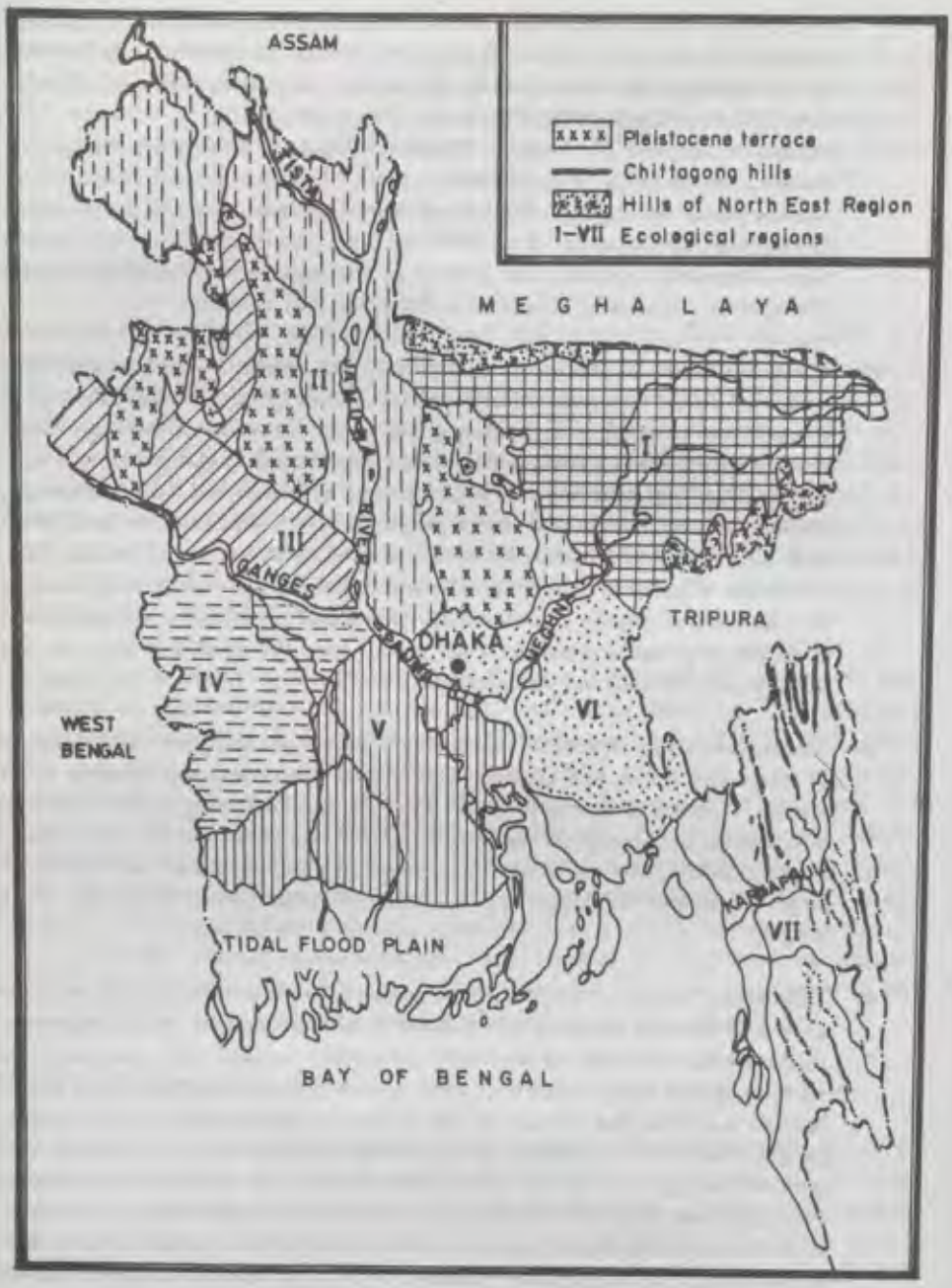


Figure 1: Ecological Regions of Bangladesh

e) In region VI that represents the east of the Madhupur jungle and the lower Meghna the surface of the marshes were covered with huge stretches of inundated rice or were covered by matted floating islets of sedges and grasses and waterlilies, the most being of *makna* (*Euryale ferox*) while on the levees or raised lands scrubby jungles with bamboo and a few trees of *jiyal* (*Odina wodier*) and red cotton trees (*Bombax cieba*) could be seen.

Present Plant Diversity

Floral Diversity: Khan and Halim (1976) reported 123 aquatic angiospermic plant species which also include *Nymphaea amazonica* and *Nymphaea capensis*. These two ornamental species were introduced from other parts of the world but are not found in their natural habitats. Aquatic plants here are covered by the definition of Cook *et al* (1974).The natural freshwater wetland vegetation which remains fully or partly submerged during the wet season also include other terrestrial macrophytic plants. The important species to be added to the lists are *Azolla, Salvinia* and *Marsilea. Ficus heterophylla, Lippia javanica, Rosa involucrata, Phyllanthus disticha* are the shrubs; and *Barringtonia acutangula, Crataeva nurvala, Trewia nudiflora, Pongamia glabra, Salix tetrasperma and Tamarix* are trees which occur naturally in the freshwater wetlands of Bangladesh. The list of plants and their taxonomic position is given in Table 1 in annexure.

All these plants belong to 48 families. The families *Ceratophyllaceae, Najadaceae, Lythraceae, Mersileaceae, Amaranthaceae, Pontadariaceae, Liliaceae, Moraceae, Verbenaceae, Rosaceae, Lechythiadaceae, Lapparidaceae, Papilionoideae, Salicaceae* and Asclepidiaceae are represented by single genus with only one species in each genus. The family *Graminae* is represented by highest number of species (16 genus with 18 species). The members of the *families Aponogetonaceae, Hydrocharitaceae, Ceratophyllaceae, Haloraceae, Najadaceae, Potamogetonaceae, Lythraceae, Alistamaceae, Salniniaceae, Araceae, Lemnacae, Lentibulariaceae* and *Nymphaeceae* are restricted to open water habitat.

Life Form Diversity

Earlier classification (Weaver and Clements, 1929) arranged aquatic plants into three fairly natural groups with respect to their relation to water and air. These are submerged, floating and amphibious plants. However, due to diverse condition of life form categories of wetland plants of Bangladesh have been considered under six headings following Mirashi (1957) with further modification.

a) Floating hydrophytes: These are in contact with water and air only.
b) Suspended hydrophytes: These are rootless submerged hydrophytes that are in contact with water only.
c) Anchored submerged hydrophytes: These are entirely, or for the most part, in contact with soil and water only.
d) Anchored hydrophytes with floating leaves : These are in contact with the soil as well as with water and air.

e) Emergent amphibious hydrophytes: The root, the lower part of the stem and, in some cases, even the lower leaves of these hydrophytes are usually submerged under water.
f) Facultative hydrophytes: These are rooted in soil that is usually saturated with water, at least in the early part of their life. Some of them continue to thrive even after the substratum has dried up considerably.

Table 3 in annexure provides the diversity of the life form categories and the species in different categories. This list includes 40 species of perennial plants found in open water aquatic habitat. The swamp forest is represented by 5 tree species and 2 woody climbers.

Plant Distribution

Table 2 in annexure shows the distribution of macrophytic plants in the various wetland zones of Bangladesh. On the basis of information so far obtained the maximum number of plant species have been encountered in zone I, III and IV represented by 93 species each, zone V and VII represented by 89 species each and zone II and VI represented by 87 and 85 species respectively. It also reveals that distribution of *Ludwigia repens*, *Cryptocoryne spiralis* and *Rosa involucrata* are restricted to the zone I, *Limnophyton obtusifolium*, *Cryptocoryne ciliata*, *Cyperus tegeteforenis* restricted to zone II, *Hygrophylla deformis*, *Aldrovenda vesiculosa*, *Limnophila cana*, *Polygonum bruniana* restricted to zone III, *Zannichellia palustris*, *Utricularia inflexa*, *Wolffia microscopica* in zone IV only, *Eriocaulon setaceum* restricted in zone VI and *Nymphoides purvifolium*, *Polygonum tomentosum*, *Mimotus orbicularis*, *Pseudoraphis spinescens* in zone VII only.

COMMUNITY DIVERSITY AND ECOLOGY

Wetlands are viewed as a single functional unit but their vegetation may show considerable differences in species composition and structure in different spots usually forming mosaic patterns. In other cases transitional changes often shows zonation as a common feature. A specific vegetation type may be seen as a subsystem and may be divided into smaller secondary subsystems. Since detailed floristics of the vegetation of freshwater wetland and their ecology in Bangladesh are yet to be undertaken, the vegetation types here have been recognized on the basis of physiognomic and habitat criteria.

Zonation

In Bangladesh complete pattern of zonation of natural vegetation is a rare sight due to the destruction of wetland habitat. However, scheme of vegetation zonation has been drawn from the relatively pristine wetland areas of Sunamganj. Fig.2 shows the schematic presentation of vegetation types based on the findings of the author and his co-workers (Karim *et al*, 1992) in the Passua Beel of Tanguar Haor system. The area is located at 25°02 North Latitude and 91°05 East Longitude. The study reveals that

vegetation in this wetland consists of diverse physiognomic types. Major ecological determinant for the diversity of the plant communities has been attributed to the variation in hydrological regime along with the variation in the geomorphological characteristics which are discussed below.

Open-Water Aquatic Vegetation

This type of vegetation consists of rooted and free-floating aquatic plants comprising a large number of unrelated families as shown in Table 2. These plants are highly sensitive to seasonal fluctuations of water level. It was observed that composition of species in this vegetation differs considerably in different wetlands. Location of this vegetation changes with the fluctuation of seasonal water level. During dry season this vegetation types occur in the deep depressions or *beels*. During monsoon,with the rise of the water level and violent waves caused by the stormy winds, the floating vegetation is torn away. The plants appear again during post-monsoon when the wave action reduces and the water in the *haor* system remains calm. The type of vegetation which were found in the deep depressions of the perennial *beels* during dry season reappear along the relatively shallow water areas during post-monsoon. The land in this zone is usually cultivated with *boro* or *aman* paddies during dry season.

Emergent Vegetation

This vegetation type includes amphibious plants or geophytes of emergent plants consisting mostly of *Cyperaceae* and *Polygonaceae*. The root of these plants remain under water while the leaves are exposed to the air. Generally this vegetation type occupies the water margin of the perennial waterbodies during the dry season. With the rise in water level during the wet season this vegetation type remains submerged in water. Under submerged condition the shoot of the plants dies out and slowly decomposes into the water and enriches the water with organic matter.

Reed Swamps

The elevated areas with gentle slope are occupied by tall grasses or reeds. This type of vegetation is locally known as *Pajuban* and consists of *Phragmitis karka* (Nal), *Arundo donax*, *Saccharum spontaneum*, *Vertiveria* and *Sclerostachya fusca*. It is reported that a good growth of reed attains the height of about 6-7m and used to be an ideal hideout for the now extinct single-horn rhinos, *barashinga*, tigers and elephants. The reeds also occur in the deeply flooded channel deposit locally known as *Kanda*. The area remains submerged under 3-5m water during flood season and dries out during lean period. In the past this type of vegetation occupied extensive areas throughout the region. The total area of the reedland for commercial exploitation before 1977 was estimated to be more than 20,000 ha. Biomass production of the reedland was calculated to be 4.5 MT/ha (air-dry basis). *Rosa involucrata* which finds natural sanctuary in the pristine reedland is a threatened plant in Bangladesh. Over-exploitation of the reeds for lime burning and conversion of land to agriculture are the threats to the conservation of these vegetations.

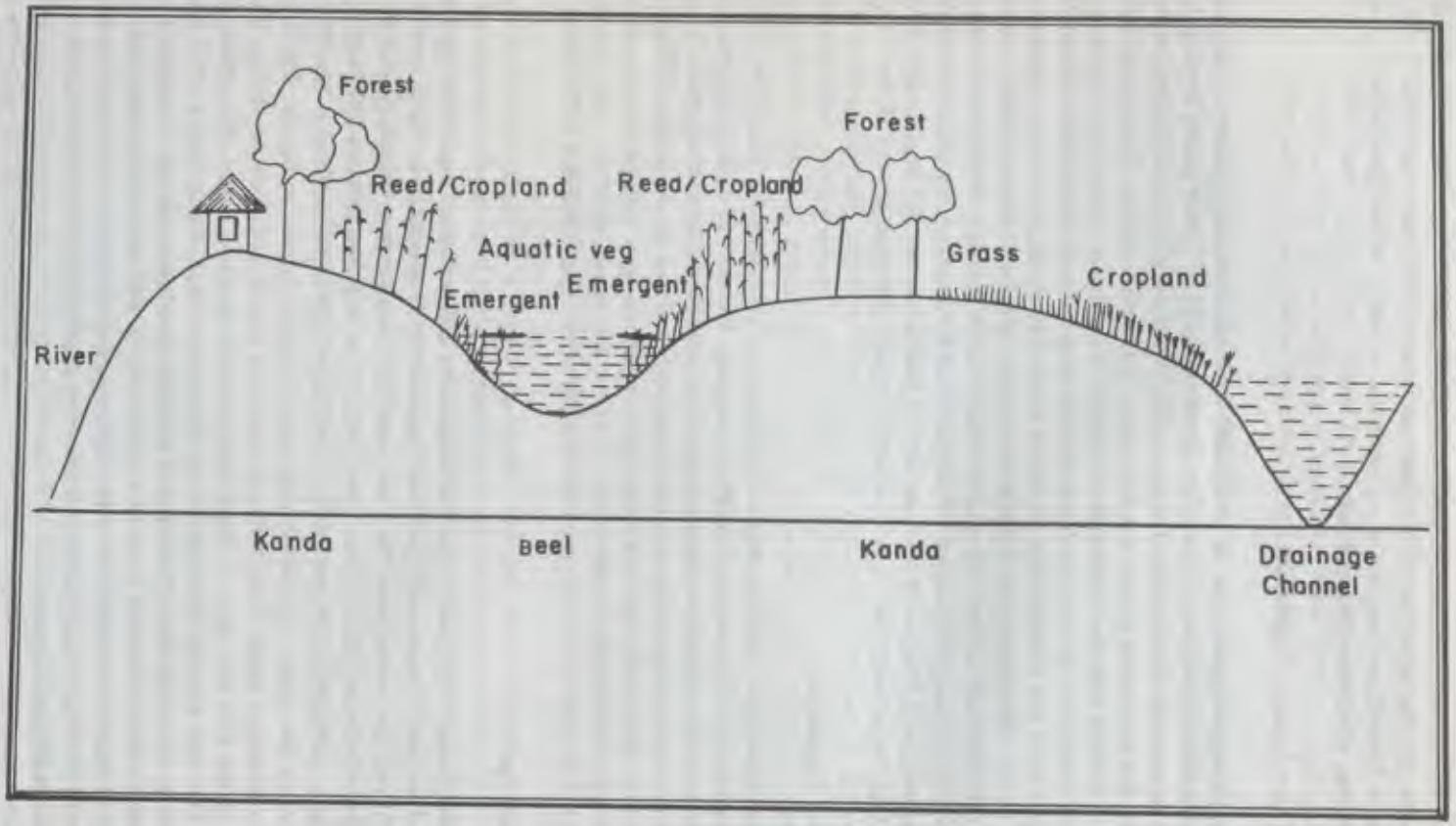


Figure 2: Schematic Presentation of Vegetation Zones in a Haor System

Freshwater Swamp Forests

This type of vegetation consists of evergreen trees forming a closed canopy. The trees are 10-12 m at top height. *Barringtonia acutangula* (*Hizal*) and *Pongamia pinnata* (*Karach*) occur in varying proportions to form this vegetation type. *Crataeva nurvela* and *Ficus heterophylla* also frequently form this vegetation type. Besides the trees, *Phyllanthus niruri* and an Asclepiad climber were found to occur in this forest. A large number of orchids on those trees could also be seen.

These forests occur on the elevated ridges between the *beels* or levees of the streams. It can also be seen on the raised flat plains sheltering the village homesteads sloping towards *haor* proper. The area of single patch of these forests at present varies from a few plants to several hectares. The lower part of the trees remain submerged in 2-2.5m deep water for 3-4 months during the monsoon. The luxuriance of the vegetation varies greatly with conditions and extent of human interference from a very open crop of low trees with undergrowth grasses to a dense closed canopy with poor undergrowth.

Estimation of a sample forest type at a village known as Ranchi within the Tanguar Haor system showed that the forest consists of 300 tree/ha with an average girth at breast height of 110 cm/tree. Principal trees of these forests *Barringtonia* and *Pongamia* coppices very well. Traditionally the forests were being managed under a community ownership as protection from the ravages of violent waves of the *haor*. The coppices are harvested at three-year rotation for fuel wood, housing posts and fish entrenchment.

So far there is no account on the status and distribution of these forest types with the government agencies. The forest is felled by vested interest groups in connivance with the local officials of the land revenue department. The lack of an objective forest management policy and the conflicting land tenure systems are the major administrative constraints that threaten the existence of these forests.

Dynamics of Vegetation

Information so far obtained on the dynamic changes is indicative of the complexities of pattern only. The details of the underlying causes is yet to be worked out. Recent studies (Karim *et al*, 1992) indicate that composition of vegetation and their dominance change continuously and are attributable to the land form characteristics and seasonal fluctuation of water level. The intensity of tillage is an important factor that disturbs the seed bank of the geophytes and determines the trends of change in species composition of the wetlands.

Zonal sequence of the wetland communities are considered as seral stages of hydrosere succession (Weaver and Clement, 1929). Each seral stage is replaced by the next higher stage due to gradual shallowing of water depth and accumulation of organic matter. Thus zonation represents a spatial model of the succession series which has an autogenous character. This situation is perceivable in a stable land form.

In a tectonically active area like Bangladesh where channel pattern is rapidly changing over a short period of time and human interventions are very high, only fragmentary zonation may develop and in more extreme cases zonation is lacking. But often succession does not proceed along more than a few stages or does not develop at all. The ultimate stage of succession is determined by the extreme degree of one or more of the factors including human disturbance. This necessitates the different management systems and interventions based on the distinct pattern and complexities of the prevailing plant communities.

USE OF WETLAND PLANT

The first people to populate wetlands in prehistoric times probably found these areas suitable for abundant food. The floodplains of the major streams were also ideal for living and represented prime agricultural land when agriculture later became important. This man - and - wetland interaction in Bangladesh has been explicitly illustrated by Hunter (1875):

> "There with great perseverance and toil they raised in the center of the swamps large hillocks from twelve to twenty feet in height, whereon they built their homesteads in the dry weather in order to preserve their cattle and goods during the high inundation. In this place they are located to the present day, cultivating the swamps with rice and jute and carrying on the occupations of fishing and bird catching, varied with mat and basket weaving, and the cutting of grass for thatching purposes and for the consumption of their cattle".

Food

Many wetland plants are economically important, some are food staples. In Bangladesh about 2,929 varieties of rice have been used in different regions of the country (NCS 1991). The root stock of all the four species of *Aponogeton* locally known as *ghechu* was used as food during scarcity. *Hygroryza aristata* grains are also eaten by the local people during such scarcity. Grains of *Oryza rufipogon* are used as substitute for rice. Fruits of *Ottellia alismoides* (*Pani Kala*) are eaten as food. From *Typha angustata* a flour is made which is eaten in Faridpur-Barisal region. The seeds of *Euryale ferox* (*Makna*) are eaten raw or roasted. The seeds of *Trapa bispinosa* and *T. maximowiczii* produce nuts. These are being commercially exploited for local market. Fruits of *T. bispinosa* are sold at Tk 10 per kg of air-dry weight in the market in Dhaka city. Seeds of *Nymphaea nouchali* are made into puffed grain by frying the green seeds. The puffed seeds are eaten as such or prepared into home-made confectionery.

Vegetables

Stems and leaves of *Amaranthus aquatica, Alternanthera philoxeroides, Ipomoea aquatica, Nymphaea nouchali* (*shapla, shaluk*) are used as vegetables. The rhizomes and pedicels are eaten raw and later used as vegetables. Seeds of *Nymphaea stellata* are also eaten raw. The petioles and blade of *Ottelia alismoides* are used as vegetables.

Limnocharis flava leaves are eaten as alternative to spinach. It is cultivated in India for commercial purposes. *Monocharia hastata* stems and leaves are eaten as green vegetable.

Fodder

Coix aquatica is used as fodder for buffaloes. *Hygroryza aristata, Leersia hexandra, Oryza rufipogon, Panicum paludosum, Paspalidium punctatum, Limnocharis flava, Eichhornia crassipes, Typha elephantina* are used as fodder grass. *Hydrolea zeylanica* is often eaten by cattle.

Medicine

Hydrophila auriculata is a diuretic in case of hepatic obstruction, dropsy, rheumatism and diseases of the genito-urinary tracts. The seeds are demulcent, diuretic and perhaps used as tonic. The leaves of *Hydrolea zeylanica* are considered to possess antiseptic properties, and are used as poultice for obstinate ulcers. *Nymphoides indicum* (*Panchuli*) plants are used for fever and jaundice. *Nelumbo nucifera* is recommended as cardiac tonic, diuretic and in fever. The seeds are also used as cooling balm in skin disease. They are also prescribed for piles, and its paste is used for elimination of ring worm. The red flowers of *Nymphaea nouchali* are used in blood dysentery and in gynecological complaints, and the powdered rhizome in piles, dysentery and dyspepsia. The flowers of *Nymphaea stellata* (*Nilpadma*) are used for preparing cardiac tonic. Most members of the *Polygonum* are known to have antibacterial properties. *Limnophila indica* (*Karpur*) is used as an antiseptic. It is made into a liniment with coconut oil and used in *elephantiasis*. In pestilent fever, the juice of the plant is rubbed over the body of the patient. It is also used in dysentery. *Cyperus articulatus* tubers are regarded as tonic and stimulant.

Thatching and Mat Making

Typha elephantina (*hogla*) is used for making mats and screens in the southern districts. A large number of people depend on it. *Cyperus corymbosus* (*golnethi*), *C. platystylis* and *Elecocharis dulcis* are locally used as thatching material for huts and as protective screen in homesteads. So also are *Belerostachya fusca* (*ikor*) and *Veteveria zizanioides* (*binna*). The later species is also a very good soil binder. An excellent mat known as *sithalpati* is made from *Clinogyne dichotoma* (*pati pata* or *Murta*). Sometimes one 1.5 m × 2 m size of mat is sold at Tk 15,000 a piece. This supports a good cottage industry in the northeast region of Bangladesh.

Fuelwood

The trees of *Barringtonia* and *Pongamia* species are exploited locally in construction of homestead and as fuelwood. All the grasses are dried and used as fuel.

Protection

Barringtonia and *Pongamia* forest is considered very effective in shielding homesteads from wave actions, erosion and storm damage which are characteristic features of the *haor* system during the monsoon. Local villagers have now developed a community system of management for protecting these forests from the ravages of destruction.

Fisheries

The fisheries resources of Bangladesh are among the richest in the world with over 500 fish species inhabiting Bangladesh's inland, estuarine and coastal waters. These fisheries resources have developed as an integral part of the wetland ecosystem where vegetation plays a pivotal role as shelter for the juveniles. Extensive development of periphyton on the stems and leaves of submerged vegetaton provides food to the fishes. Decomposition of plant material also enriches the food chain.The branches of *Baringtonia* are considered by the local fishing folks as essential for increase in fish production. These are also used extensively as fish entrenchments by the local lease holders for sustaining their fisheries projects.

Industry

The reed (*Phragmites karka, Saccharum spontaneum*) locally known as *pajubans* is an important constituent of raw materials for paper pulp used by the Sylhet paper and pulp mill. More than 90% of the lime requirement of the country comes from the north – eastern region. This lime burning industry was completely dependent on the reeds for burning. This has led to the extensive destruction of the reeds. The industry now uses natural gas for lime burning. About 100-350 bundles/ha of reed can be produced in one growth season.

Fertilizer

Azolla is used as an important bio-fertilizer in the Pearl river delta region of China. *Eichhornia crassipes*, water hyacinth once considered to be a pest, is now being used as compost fertilizer in the NE region of Bangladesh. The ash of the plant, which contains 30% potash, 7% phosphoric acid and 13% lime, makes an excellent fertilizer. Its value has been proven in Sudan, where it has increased peanut production by over 30% (Maltby, 1986). In India also compost from water hyacinth is used as fertilizer. Other possible uses for the species and *Lemna* include conversion to biogass (upto 40 litres of gas can be produced from 90 kg weight of fresh plant), animal feed and various paper and board products.

Pollution Abatement

Aquatic plants are proving an asset in the treatment of sewage and polluted water. *Lemna* can remove half of nitrogen, 67% of the phosphorus and nearly all the heavy metals. Calcutta's sewage has undergone natural purification in the complex of wetlands east of the city for at least 50 years. It supports a rich fishery in the country. In India

Eichhornia crassipes is being used to clean tannery effluents which are damaging groundwater resources in Madras. In Malaysia, the aquatic plant *Azolla* is being used to treat wastewater both from sugar refineries and from a rubber processing plant. The marsh vegetation *Phragmites australis* (reeds), *Arundo donax* (giant reed grass) and *Salix tetrasperma* (willow) proved to filter sedimentload from the dredged material in USA (Maltby, 1986).

ENDANGERED SPECIES

Aldrovanda vesiculosa, an insectivorous plant, is a locally threatened species. *Barringtonia acutangula*, *Pongamia glabra* and *Crataeva nurvala*, which used to from the natural freshwater swamp forests have disappeared from all over the country excepting northeast region where small patches of remnant forest can be seen in natural condition. These trees can now be seen only in the homesteads in the rest of the country. *Typha* which once supported the livelihood of rural people through mat making in the southern districts has become rare due to conversion of the natural land area for paddy cultivation. *Rosa involucrata* which is a wild relative of the garden roses was abundant in the wetlands of Bangladesh. It was abundant in the northern districts even in the last part of the nineteenth century. Due to habitat destruction the plant has become rare. It is now restricted to the undisturbed *haors* of Sunamganj only.

A major cause of decline of these plants is conversion of wetlands for paddy cultivation. In the past local people used to maintain rotation of crops. They used to plant deepwater rice with minimum tillage during the dry season in the elevated areas. The low-lying areas were used for fish cultivation. With the increase in demand for food agricultural areas extended further down. The *beels* are being drained and embankments are being built to save the crops from flashflood. To raise HYV intensive cultivation induced intensive tillage disturbing the seed banks of the aquatic vegetation.

These vegetations are facing the threat from over-exploitation, sedimentation or shallowing of water depth. Deep tillage due to cultivation of HYV rice disturbs the seed bank of natural vegetation and affects species regeneration.

CONSERVATION

The major goal of the world conservation strategy launched in 1980 by IUCN, WWF and UNEP is the integration of conservation and development to ensure that modifications to the environment secure the survival and wellbeing of people while maintaining sufficient natural areas for survival of the existing natural diversity. The goal of conservation is not to stop wetland development, but to ensure that it is done in a way which minimizes the environmental costs. In achieving these goals every country should concentrate on the priority requirements and on the main obstacles for which a strategy can be formulated.

The wetlands of Bangladesh is blessed with enormous diversity of plants and animal resources which provide food, housing material and fodder and perform functions which have national and global dimensions. Many of the wild animals have become extinct and many others are now considered vulnerable due to habitat loss. Removal of vegetation cover produces an open expanse which is unattractive to waterfowls' migrating pattern. For production of paddy these wetlands are being converted to agricultural land. Age-old indigenous protective management system has been destroyed to allow short-run benefits for vested groups. It has brought the once extensively distributed swamp forests to the verge of extermination. Unless adequate conservation measures are taken the loss of wetland plants' values and functions will be irreplaceable.

There are two ways of protecting plants. One is 'in-situ' conservation or protecting plants in natural habitat condition and the other is 'ex-situ' conservation protecting plants outside their natural habitat.

In-situ Conservation

This is accomplished through maintenance of plants and animals within their natural ecosystem. The noble way of doing so is to declare a network of protected areas that include the maximum number of threatened species and representative areas of ecosystem types. IUCN has recognized through its Commission on National Parks and Protected Areas ten categories of conservation areas representing different levels of protection (from strict nature reserves to multiple-use areas) and varying degrees of local, regional and global importance. Each category is designed to meet different objectives. However, it is considered that a country may not need to develop all the categories listed but through a mix of several different categories can design a system that reflects its own objectives and constraints (IUCN 1984).

In Bangladesh three types of protected areas are defined under Wildlife (Preservation Amendment) Act of 1974. The types of protected areas are presented in Table 1. This shows the limitation of the national protected-area management.None of these areas include any representative area of freshwater wetlands that has plant protection value in their natural condition. A Directory of Asian Wetlands (Scott, 1989) indicated that a conservation programme covering fiftyone wetland areas were drawn up during the first five year plan, but economic constraints severely hampered its implementation, and the wetlands remain poorly protected. A National Conservation Strategy now awaiting approval by the Government recognizes the enormous economic importance of the wetland resources of Bangladesh (Government of Bangladesh and IUCN, 1991). This draft plan runs short of including areas that require priority protection from the plant diversity point of view.

Ex-situ Conservation

There could be two approaches to this aspect: (1) perpetuating sample species outside the natural habitats i.e, in the botanical gardens, harbarium etc. (2) genetic storage in germ plasma banks. In Bangladesh the responsibility of preservation of the germ plasma

belonging to the numerous crops rests with the agricultural research organizations (BARRI, BRRI, BJRI, BTRI, BFRI etc). Scientists in the University of Chittagong maintain a large number of germ plasma of wild plants and wild relatives of crop plants in the botanical garden of the university.

Table 1: **Protected Areas in Bangladesh**

Name	Type	Area in ha	Type of Vegetation
Bhawal	National Park	5,022	Moist deciduous
Himchari	"	1,729	Rain forest
Madhupur	"	8,436	Moist deciduous
Ramsagar	"	50	Large pond and plantation on embankment
Char Kukri-Mukri	Wildlife Sanctuary	40	Mangrove
Chunati	"	7,764	Rain forest
Pablakhali	"	42,087	Rain forest
Rema-Klenga	"	1,095	Rain forest
Sunderbans East	"	5,439	Mangrove
Sunderbans South	"	17,878	Mangrove
Sunderbans West	"	9,069	Mangrove
Teknaf	Game Reserve	11,615	Rain forest

Constraint to Conservation

Being a signatory to the Ramsar Convention and a number of other international plant protection conventions Bangladesh is highly committed to the wise use of wetland resources. The high appreciation of plant resources to halt the environmental degradation has been reflected in various government forestry programmes. Despite increasing efforts to stop environmental degradation through tree planting many of the wetlands will be lost due to the existence of policies that favour exploiting wetlands, nonexistence of institutions responsible for managing wetlands and also lack of resources to maintain such institutions and lack of information on the status and values of plant resource of wetlands.

Policy

There is no specific policy regarding conservation of plant genetic resources excepting the National Forest Policy adopted in 1979. It aims at maintenance and conservation of forest resources to promote economic development and also to maintain ecological balance for sustenance of development. The other sectoral policies also envisage achieving self-sufficiency in agriculture by cultivating high-yielding varieties. Water-resource development plans are oriented towards achieving that goal. The government

policy with regard to water resource and flood control is embodied in the Fourth Five Year Plan (1990-95), the central strategy of which is:

> "..... the expansion of irrigation and water control to increase area under effective cultivation for improvements in long term productivity and employment....."

This indicates the contradiction between the perception of conservation and policy guidelines of the government.Legal framework for conservation of species is also very limited in scope. So far conservation of biodiversity in the country has been used as synonym to the conservation of wildlife which again is very narrowly defined in the Wildlife Preservation Act of 1974. As per this act wildlife has been defined as "the mammals, amphibians and birds". A large number of animals and the flora remain out of protection under this law. This situation put the government and the international agencies to make plan and institutions for conservation of narrowly defined wildlife animals only. Plant conservation has been assumed to be of secondary benefit out of the project activities.

Institution

Effective conservation requires a clear commitment backed by appropriate administrative agency and adequate budget to carry out its programme. In Bangladesh there are several government agencies involved in management of wetland resources. These are the Forest Department, Agriculture Department, Fisheries Department and Water Development Board. Bangladesh Council for Scientific and Industrial Research, Bangladesh Agricultural Research Council, Bangladesh Rice Research Institute, Forest Research Institute, Fisheries Research Institute and various universities are involved in research pertaining to the wetland resources. Bangladesh National Harbarium was established in 1975. As per its mandate this organization is engaged in exploration of plants and preserve the dried specimen for identification purposes only. The Harbarium is a rich depository of the dried samples for use by the conservation scientists. No attempt has ever been made in this country to explore the potentials of wetland plant resources which can be utilized for human benefit with adequate management intervention. All other institutions as mentioned earlier are meant for specific sectoral resource development and as a result have a limited perspective on the conservation management of the wetlands.

Future Strategy

In a country with poor resources the conservation efforts need to be guided on the principle of minimum cost and maximum benefit. It is not feasible to protect all plants occurring in the country. All species in the ecosystem are not considered of equal value to the society. So every country is to take a strategy to protect those species and the ecosystems under imminent threat which may lead to the irretrievable loss to the society. This requires a pragmatic conservation strategy to be supplemented with equally feasible action plans.

The country must prioritize the indigenous species to be protected on the basis of their economic importance, identify the habitat requirements of such species, survey the availability of alternative habitats and ecosystem areas that perform critical functions. The sites should also be relatively free from development impacts which can alter water quality, plant and animal species composition and other environmental attributes. This insures long term preservation, especially when the conservation plan aims to protect not only wetland plants but also entire functional unit of the wetland ecosystem. Management plans then need to be developed along with the institutional arrangements and funding.

As discussed earlier, priority of selecting wetland conservation sites should be based on criteria defined by the conservation goals. Under the prevailing socio-economic conditions of Bangladesh priority for conservation should be based on the following criteria :

a) Area that supports the maximum number of species/threatened species;
b) Maximum habitat diversity/threatened vegetable types;
c) High flood storage and nutrient cycling function;
d) Least population pressure;
e) Minimum other development potential; and
f) Minimum maintenance cost.

Identification of such priority sites requires detailed inventory of the existing wetlands. However, information so far available (NERP, 1992) indicates that Tanguar Haor system still supports some areas of relatively pristine wetland forests and reedland. It is the last remaining natural habitat for the threatened plant species *Rosa involucrata*. A few of the natural freshwater swamps persist in the low population density area of Bara Haor. From plant diversity conservation point of view these areas deserve priority consideration.

RECOMMENDATIONS

Policy and Legal Framework

Legal framework needs to be developed to protect all significant wetland values from a wide range of likely impacts particularly from direct and indirect hydrological changes due to flood control and drainage works, road construction and housing settlement schemes. Local development schemes, particularly smallscale drainage canals and construction of roads under Food for Works Progrmme, need to be assessed for their cumulative impacts on the wetlands. Regulation of forestry practices is also necessary to prevent downstream wetlands from sedimentation. The guiding principles of IUCN (Dugan, 1990) could be a basis for such legal framework. The existing wildlife regulation should also be amended to protect all endangered plants and animals and their natural habitats.

Conservation Management

An appropriate instrument for effective conservation of wetland plants should be viewed in the light of the integrated management plan. Land and water management needs to be undertaken at a catchment level. Such integrated management must be based on sound knowledge and understanding of the wetland process, ecological links and socio-economic realities. Decisive action must be taken to develop a network of protected areas of representative wetlands to preserve endangered plant species and communities. Management mechanism that ensures participation of the local people, meets the requirement of the local community and broadens the resource base need to be developed. Efforts towards creation of awareness and concern among local people are necessary.

Research Need

The management, maintenance and preservation of wetlands can only succeed if built on a strong scientific research base. Pious ideas not to overexploit the wetland resource shall carry little value to the government which has to plan for three million new mouths every year and to the people who consume less than 2,000 calories per capita per day. The most effective conservation strategy needs to plan on expanding the resource base on ecological principle. This requires effective use of existing plant resources and discover plants the economical potentials of which are not yet recognized. Research on these plants could provide valuable information needed to ensure their long-term survival.It is hoped that if management activities include detailed scientific involvement early in the planning process, management will be able to avoid critical mistakes during implementation. As a first step towards achieving this goal the following activities are suggested:

a) detailed inventory of wetlands should be prepared with description of species, abundance, seasonality, population dynamics, habitat requirement, sediment and changes in hydrologic regime;
b) research for more effective implementation and restoration of threatened wetland plants and communities;
c) identification and development of a monitoring network for the plants that influences in the health of the wetlands;
d) investigation about the use of wetlands to treat wastewater; and
e) studies of pollutant flows in wetland ecosystem.

International Cooperation

Largescale destruction of high elevation rainforest of Meghalaya/Manipur in India is causing severe erosion leading to loss of wetland habitats downstream and a potential threat to the regional climate. Efforts need to be made to seek effective cooperation to conserve the wetlands that form a landscape continuum between the two countries, particularly in the northeast and northwest regions of Bangladesh.

Activities of the international organizations on conservation are less known in this country. This knowledge is generally confined within government programmes and therefore does not promote wider participation. Effective steps for dissemination of international experience and approaches in wetland management may lead to quicker response in Bangladesh. For this, collaboration with international organizations may be strengthened.

ACKNOWLEDGEMENTS

The author acknowledges with thanks the help rendered by Mr Ishtiaq Sobhan, Mr Anisuzzaman Khan, Mr S.M.A. Rashid and Mr A. Sayeed of NACOM in the field work for this paper. Thanks are due to Prof M. Salar Khan and other officers of the Bangladesh National Herbarium for identification of plants. The author is indebted to Ms S.L. Bennete, Environment Consultant, FAP 6, for her encouragement and for sponsoring part of the field work.

REFERENCES

Cook, C.D.K., B.J. Gut, E.M. Rix, J. Schneller and M. Seith. 1974. *Water Plants of the World*. Dr.W.Junk Publishers, The Hague, The Netherlands.

Dugan, P.J.(ed). 1990. *Wetland Conservation: A Review of Current Issues and Required Action*. IUCN, Gland, Switzerland. pp 96.

Government of Bangladesh and IUCN. 1991. *Towards Sustainable Development: The National Conservation Strategy of Bangladesh*. First Draft. Dhaka.

Hunter, W. 1875. *Statistical Account of Bengal*, Vol-I and II. Trubner and Co, London.

Kanjilal, P.C. 1934. *Flora of Assam*. Prabashi Press, Calcutta.

Karim, A., I. Sobhan and S. Khan, 1992. Field studies. North East Regional Water Managament Project(FAP 6). Shawinigan Lavalin Inc., Nature Conservation Movement, CIDA and FPCO, Government of Bangladesh. *Interim Report*. Dhaka.

Khan, S. and M. Halim. 1987. *Aquatic Angiosperms of Bangladesh*. Bangladesh Agricultural Research Council, Dhaka. pp 120.

Maltby, E. 1986. *Waterlogged Wealth*. Earthscan, International Institute for Environment and Development. London and Washington D.C.

Mirashi, M.V. 1954. Studies in the hydrophytes of Nagpur. pp 299-308. *J. Indian Bot. Soc.*, 33.

Scott, D.A.(ed.). 1989. *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge, UK. pp 1181.

UNCED. 1992. Convention on Biological Diversity; United Nations Commission for Environment and Development, Rio De Janeiro, Brazil.

Weaver, J.E. and F.E. Clement. 1929. *Plant Ecology*. Tata McGraw Hill Publishing Company Ltd, New Delhi. pp 610.

Annexure

Table:1 List of macrophytic plants of natural freshwater wetlands of Bangladesh and the taxonomic position

	Family		Species	REGIONS						
				1	2	3	4	5	6	7
1.	*Acanthaceae*	1	*Hygrophila difformis*			+				
		2	*H. auriculata*	+	+	+	+	+	+	+
2.	*Amaranthaceae*	1.	*Achyranthes aquatica*				+	+		
		2	*Alternanthera philoxeroides*	+	+	+	+	+	+	+
		3	*A. sessilis*	+	-	-	-	-	-	-
3.	*Asclepiadaceae*	1	*Asclepias sp.*	+	-	-	-	-	-	-
4.	*Balsaminaceae*	1	*Hydrocera triflora*	-	-	-	-	-	-	-
5.	*Capparidaceae*	1	*Cleome hassleriana*	+	-	-	-	-	-	-
		2.	*Crataeva nurvala*	+	-	-	-	-	-	-
6.	*Ceratophyllaceae*	1	*Ceratophyllum demersum*	+	+	+	+	+	+	+
		2	*C. submersum*	+		+				
7.	*Compositae*	1	*Enhydra fluctuans*	+	+	+	+	+	+	+
		2.	*Eclipta alba*	+	+	+	+	+	+	+
		3	*Spilanthes acmella*	+	+	+	+	+	+	+
		4	*Xanthium indicum*	+	+		+	+	+	
8.	*Convolvulaceae*	1	*Ipomoea aquatica*	+	+	+	+	+	+	+
		2	*I. fistulosa*	+	+	+	+	+	+	+
9.	*Droseraceae*	1	*Aldrovanda vesiculosa*			+				
10.	*Elatinaceae*	1	*Elatine triandra*			+	+	+		
		2	*Bergia capensis*			+	+	+		
11.	*Euphorbiaceae*	1	*Phyllanthus disticha*	+	-	-	-	-	-	-
		2	*Trewia nudiflora*	+	-	-	-	-	-	-
12.	*Haloragaceae*	1	*Myriophyllum tuberculatum*	+	+	+	+	+	+	+
		2	*M. tetrandrum*	+	+	+	+	+	+	+
13	*Hydrophyllaceae*	1	*Hydrolea zeylanica*	+	+	+	+	+	+	+

+: Present -: Status Unknown

Annexure: Table 1 (Contd.)

14.	*Lecythidaceae*	1	*Barringtonia acutangula*	+	-	-	-	-	-	-
15.	*Lentibulariaceae*	1	*Utricularia exoleata*	+	+	+	+	+	+	+
		2	*U. aurea*	+	+	+	+	+	+	+
		3	*U. inflexa*				+			
		4	*U. stellaris*	+	+	+	+	+	+	+
16	*Lythraceae*	1	*Rotala wallichii*	+					+	
17.	*Menyanthaceae*	1	*Nymphoides aurantiacum*		+				+	
		2	*N. parvifolium*							+
		3.	*N. cristatum*	+	+	+	+	+	+	+
		4	*N. indicum*	+	+	+	+	+	+	+
18.	*Mimosaceae*	1	*Neptunia natans*	+	+	+	+	+	+	+
		2	*N. plena*	-	-	-	-	-	-	-
19.	*Moraceae*	1	*Ficus heterophylla var. heterophylla*	+	-	-	-	-	-	-
20.	*Nymphaeaceae*	1	*Euryale ferax*	+	+			+		
		2	*Nelumbo nucifera*	+	+	+	+	+	+	+
		3	*Nuphar luteum*	+	+	+	+	+	+	+
		4	*Nymphaea stellata*	+	+	+	+	+	+	+
		5	*N. nouchali*	+	+	+	+	+	+	+
		6	*Victoria amazonica*	-	-	-	-	-	-	-
21.	*Onagraceae*	1	*Ludwigia repens*	+						
		2	*L. adscendens*	+	+	+	+	+	+	+
22.	*Papilionaceae*	1	*Aeschynomene aspera*	+	+	+	+	+	+	+
		2	*A. indica*	+	+	+	+	+	+	+
		3	*Sesbania roxburghii*	+	+	+	+	+	+	+
		4	*Pongamia pinnata*	+	-	-	-	-	-	-
23.	*Polygonaceae*	1	*Polygonum pedunculare*	+						+
		2	*P. stagninum*	+						+
		3	*P. barbatum*	+	+	+	+	+	+	+
		4	*P. lanatum*	+	+	+	+	+	+	+

		5	*P. glabrum*	+	+	+	+	+	+	+
		6	*P. tomentasum*							+
		7	*P. limbatum*	+	+	+	+	+	+	+
		8	*Rumex maritimus*	+	-	-	-	-	-	-
24.	*Rosaceae*	1	*Rosa involucrata*	+	-	-	-	-	-	-
25.	*Salicaceae*	1	*Salix tetrasperma*	+						
26.	*Scrophulariaceae*	1	*Dopatrium junceum*							+
		2	*Limnophila indica*	+	+	+	+	+	+	+
		3	*L. cana*			+				
		4	*L. sessiliflora*	+	+	+	+	+	+	+
		5	*L. heterophylla*	+	+	+	+	+	+	+
		6	*Mimulus orbicularis*							+
27.	*Trapaceae*	1	*Trapa bispinosa*	-	-	-	-	-	-	-
		2	*T. maximowiczii*	+	-	-	-	-	-	-
28.	*Verbenaceae*	1	*Lippia javanica*	+	-	-	-	-	-	-
29.	*Alismataceae*	1	*Alisma plantago*	-	-	-	-	-	-	-
		2	*Caldesia oligococca*	-	-	-	-	-	-	-
		3	*C. parnassifolia*	-	-	-	-	-	-	-
		4	*Limnophyton obtusifolium*		+					
		5	*Sagittaria sagittifolia*	+	+	+	+	+	+	+
		6	*S. guayanensis ssp. lappula*	+	+	+	+	+	+	+
30.	*Aponogetonaceae*	1	*Aponogeton undulatus*	+		+	+	+		
		2	*A. appendiculatus*	+	+	+	+	+	+	+
		3	*A. natans*	+	+	+	+	+	+	+
		4	*A. echinatus*	+	+	+	+	+	+	+
31.	*Araceae*	1	*Colocasia esculenta*	+	+	+	+	+	+	+
		2	*Cryptocoryne spiralis*				+	+		
		3	*C. gomezii*	+						
		4	*C. retrospiralis*		+					
		5	*C. ciliata*		+					

		6	*Lasia spinosa*			+	+	+	+	+
		7	*Pistia stratiotes*	+	+	+	+	+	+	+
32	*Cyperaceae*	1	*Cyperus cephalotes*	+	+					
		2	*C. platystylis*	+	+	+	+	+	+	+
		3	*C. corymbosus*			+	+	+	+	+
		4	*C. tegetiformis*		+					
		5	*C. articulatus*	+	+				+	
		6	*Eleocharis dulcis*	+	+	+	+	+	+	+
		7	*Fimbristylis dichotoma*	+	-	-	-	-	-	-
		8	*F. squarrosa*	+	-	-	-	-	-	-
		9	*F. milliaceae*	+	-	-	-	-	-	-
		10	*Mariscus compactus*	+	+	+	+	+	+	+
		11	*Schoenoplectus grossus*	-	-	-	-	-	-	-
		12	*S. articulatus*	+	+	+	+	+	+	+
		13	*Scirpus juncoides*	+	-	-	-	-	-	-
33.	*Eriocaulaceae*	1	*Eriocaulon setaceum*						+	
34.	*Gramineae*	1	*Coix aquatica*	+			+	+		
		2	*Arundo donax*	+	-	-	-	-	-	-
		3	*Echinochloa colonum*	+	-	-	-	-	-	-
		4	*Hemarthria protensa*	+	-	-	-	-	-	-
		5	*Sateria pallidefusca*	+	-	-	-	-	-	-
		6	*S. glauca*	+	-	-	-	-	-	-
		7	*Phragmites karka*	+	-	-	-	-	-	-
		8	*Saccharum spontaneum*	+	-	-	-	-	-	-
		9	*Sclerostachya fusca*	+	-	-	-	-	-	-
		10	*Vetiveria zizanioides*	+	-	-	-	-	-	-
		11	*Hygroryza aristata*	+	+	+	+	+	+	+
		12	*Leersia hexandra*	+	+	+	+	+	+	+
		13	*Oryza rufipogon*	+	+	+	+	+	+	+
		14	*Panicum paludosum*	+	+	+	+	+	+	+
		15	*Paspalidium punctatum*	+	+	+	+	+	+	+

		16	*Pseudoraphis minuta*	+		+				
		17	*P. spinescens*							+
		18	*P. brunoniana*			+				
35	*Hydrocharitaceae*	1	*Blyxa auberti*	+	+	+	+	+	+	+
		2	*B. echinosperma*	+	+	+	+	+	+	+
		3	*B. japonica*			+	+	+		
		4	*B. octandra*			+	+	+		
		5	*Hydrilla verticillata*	+	+	+	+	+	+	+
		6	*Hydrocharis dubia*	+	+	+	+	+	+	+
		7	*Nechamandra alternifolia*	+	+	+	+	+	+	+
		8	*Ottelia alismoides*	+	+	+	+	+	+	+
		9	*Vallisneria spiralis*	+	+	+	+	+	+	+
36.	*Lemnaceae*	1	*Lemna perpusilla*	+	+	+	+	+	+	+
		2	*L. trisulca*	+	+	+	+	+	+	+
		3	*Spirodela polyrrhiza*	+	+	+	+	+	+	+
		4	*S. punctata*	+	-	+	+	+	+	+
		5	*Wolffia arrhiza*	+	-	+	+	+	+	+
		6	*W. microscopica*				+			
37	*Limnocharitaceae*	1	*Limnocharis flava*							+
		2	*Tenagocharis latifolia*	+	+	+	+	+	+	+
38	*Marantaceae*	1	*Clinogyne dichotoma*	+	-	-	-	-	-	-
39	*Najadaceae*	1	*Najas graminea*	+	+	+	+	+	+	+
		2	*N. indica*	+	+	+	+	+	+	+
		3	*N. minor*	+	+	+	+	+	+	+
		4	*N. lacerata*	+	+	+	+	+	+	+
		5	*N. falciculata*	+	+	+	+	+	+	+
40.	*Pontederiaceae*	1	*Eichhornia crassipes*	+	+	+	+	+	+	+
		2	*Monochoria hastata*	+	+	+	+	+	+	+
		3	*M. aginalis*	+	+	+	+	+	+	+
41	*Potamotegonaceae*	1	*Potamogeton pectinatus*	+	+	+	+	+	+	+
		2	*P. crispus*	+	+	+	+	+	+	+

		3	*P. mucronatus*	+	+	+	+	+	+	+
		4	*P. nodosus*			+	+			
		5	*P. octandrus*	+	+	+	+	+	+	+
42.	*Ruppiaceae*	1	*Ruppia maritima*				+			+
43.	*Typhaceae*	1	*Typha elephantina*	+	+	+	+	+	+	+
		2	*T. angustata*	+	+	+	+	+	+	+
44.	*Zannichelliaceae*	1	*Zannichellia palustris ssp. pedicellata*			+				
45	*Salviniaceae*	1	*Azolla pinnata*	+	+	+	+	+	+	+
		2	*Salvinia cuculata*	+	+	+	+	+	+	+
		3	*S. natans*	+	+	+	+	+	+	+
46	*Marsileaceae*	1	*Wersllea quadrifolia*	+	+	+	+	+	+	+
47	*Polypodiaceae*	1	*Ceratopteris thalictroides*	+	-	-	-	-	-	-

Annexure

Table 2: List of Plants in Different Life Form Categories

Scientific Name/Life form	Local Name	Habit
Free Floating:		
Azolla pinnata	Kutipana	H,Pe
Eichhornia crassipes	Kochuripana	H,Pe
Lemna perpusilla	Khudipana	H,Pe
Lemna trisulca	Khudipana	H,Pe
Pistia stratiotes	Kuripana, Indurkan	H,Pe
Salvinia cucullata	Tetulapana	H,Pe
Salvinia natans	Tetulapana	H,Pe
Spirodela punctata	Khudipana	H,Pe
Spirodela polyrrhiza	Khudipana	H,Pe
Wolffia arrhiza	Guripana	H,Pe
Wolffia microscopica	Guripana	H,Pe
Suspended:		
Aldrovanda vesiculosa	–	H,A
Ceratophyllum demersum	Jhangi, Katajhangi	H,Pe
Ceratophyllum submersum	Chhotojhangi	H,A
Utricularia exoleata	Chhotojhangi	H,A
Utricularia siellaris	Chhotoihangi	H,A
Utricularia inflexa	Chhotojhangi	H,A
Anchored:		
Alisma plantago	–	H,A
Aponogeton echinatus	Ghechu	H,Pe
Aponogeton undulatus	Ghechu	H,Pe
Aponogeton natans	Ghechu	H,Pe
Aponogeton appendiculatus	Ghechu	H,Pe
Bergia capensis	–	H,A
Blyxa octandra	Shayala	H,A
Blyxa nuberti	Shayala	H,A
Blyxa echinosperma	Shayala	H,A
Blyxa japonica	Shayala	H,A
Caldesia parnassifolia	–	H,A
Caldesia oligococca	–	H,A
Elatina triandra	–	H,A
Hydrilla verticillata	Kureli, Jhangi	H,Pe
Hydrocera triflora	–	H,A
Hydrocharis dubia	–	H,A
Hydrolea zeylanica	–	H,A

Annexure: Table 2 (contd.)

Hygrophila auriculata	–	H,A
Hygrophila difformis	–	H,A
Limnocharis flava	–	H,A
Limonphyton obtusifolium	–	H,A
Myriophyllum tuberculatum	–	H,A
Myriophyllum tetrandrum	–	H,A
Najas graminea	Goisa	H,A
Najas falciculata	Goisa,Shayalaghas	H,A
Najas lacorata	Katagoisa	H,A
Najas minor	Goisa,Shayalaghas	H,A
Nechamandra alternifolia	–	H,A
Ottelia alismoides	Panikola,Kaorali	H,A/Pe
Potamogeton crispus	Keorali	H,Pe
Potamogeton octandra	Keorali	H,Pe
Potamogeton mucronatus	Keorali	H,Pe
Potamogeton nodosus	Keorali	H,Pe
Potamogeton pectinatus	Keorali	H,Pe
Rotala wallichii	–	H,A
Sagittaria guayanensis ssp. lappula	Muamia,Kaowathukri	H,Pe
Sagittaria sagittifolia	Chhotokul	H,Pe
Tenagocharis latifolium	–	H,A
Vallisnaria spiralis	Pataseola,Bicha	H,A/Pe

Rooted Floating:

Euryale ferox	Makhana	H,A/Pe
Hygroryza aristata	Phutki	H,Pe
Limnophila heterophylla	Karpur	H,A
Limnophila cana	Karpur	H,A
Limnophila sessiliflora	Bijatighash	H,A
Limnophila indica	Karpur	H,A
Marsilea quadrifoliata	Sushnisak	H,A/Pe
Nelumbo nucifera	Padma	H,Pe
Nuphar luteum	–	H,Pe
Nymphaea stellata	Nilshapla	H,Pe
Nymphaea nouchali	Sada, raktoshapla	H,Pe
Nymphoides parvifolium	Chotto panchuli	H,Pe
Nymphoides aurantiacum	–	H,Pe
Nymphoides indicum	Panchuli	H,Pe
Nymphoides cristatum	Chandmala	H,Pe
Trapa maximowiczii	Singra,Paniphal	H,Pe
Victoria amazonica	Amazon lily	H,Pe

Annexure: Table 2 (contd.)

Emergent amphibious hydrophytes:

Achyranthes aquatica	–	H,A
Aeschynomene indica	Katshola,Bhatshola	S,A
Aeschynomene aspera	Shola,Banda	S,A
Alternanthera philoxeroides	Helencha	H,A
Alternanthera sessilis	Malencha	H,A
Arundo donax	Baranal, Gobanal	H,A
Asparagus racemosus	Satamuli,Hilum	S,Pe
Cleome hasslerana	Nunirleta,Chakutha	H,A
Clinogyne dichotoma	Sital-pati	S,Pe
Coix aquatica	–	H,A
Colocasia esculenta	Kachu	H,Pe
Cryptocoryne gomezii	–	H,Pe
Cryptocoryne spiralis	–	H,Pe
Cryptocoryne retrospiralis	–	H,Pe
Cryptocoryne ciliata	–	H,Pe
Cyperus corymbosus	Mutha	H,A
Cyperus platystylis	Mutha	H,A
Cyperus cephalotes	Mutha	H,A
Cyperus articulatus	Mutha	H,A
Cyperus tegetiformis	Mutha	H,A
Dopatrium junceum	–	H,A
Echinochloa colonum	Parua	H,A
Eclipta alba	Kalokeshi,Kalohuza	H,A/Pe
Eleocharis dulcis	Panichaise	H,A
Enhydra fluctuans	Helencha, Harhach	H,Pe
Eriocaulon setaceum	–	H,Pe
Ficus heterophylla var. heterophylla	Bonolat,Baladumur	S,Pe
Fimbristylis miliacea	Joina,Chatkighsh	H,A
Fimbristylis dichotoma	Joina chaise	H,Pe
Fimbristylis squarrosa	Jumka chaich	H,A
Hemarthria protensa	Chailla	H,A
Ipomoea aquatica	Kalmi shak	H,Pe
Ipomoea fistulosa	Dhol kalmi	S,Pe
Lasia spinosa	–	H,Pe
Leersia hexandra	–	H,A
Lippia javanica	Bhuiokra	S,Pe
Ludwigia abscendens	Kesardam,Mulcha	H,A
Ludwigia repens	Panidoga	H,A
Mariscus compactus	–	H,A
Mimulus orbicularis	–	H,A
Monochoria hastata	Baranukha,Kechur	H,Pe
Neptunia natans	–	H,A
Neptunia plena	–	H,A
Oryza ruftpogon	–	H,A
Panicum paludosum	–	H,A/Pe
Paspalidium punctatum	–	H,A
Phragmites karka	Khagra,Nol	S,Pe
Polygonum tomentosum	Kukra	H,A

Annexure: Table 2 (contd.)

Polygonum glabrum	Bishkatali,Kukra	H,A
Polygonum stagninum	Bishkatali,Kukra	H,A
Polygonum pedunculare	Kukra	H,A
Polygonum lanatum	Kukra	H,A
Polygonum barbatum	Bishkatali	H,A
Pseudoraphis minuta	--	H,Pe
Pseudoraphis brunoniana	--	H,Pe
Pseudoraphis spinescens	Erali	H,Pe
Rosa involucrata	Gunja kata	S,Pe
Rumex maritimus	Bonpalong	H,A
Ruppia maritima	--	H,A
Saccharum spontaneum	Khag,aisha	S,Pe
Schoenoplectus articulatus	--	H,A
Schoenoplectus grossus	--	H,A
Scirpus articulatus	Chisra	H,Pe
Sclerostachya fusca	Khuri	H,A
Sesbania roxburghii	Huli,Phuli	S,A
Setaria glauca	Kulkulle,Kauni	H,A
Seteria pallidefusca	Pinginatchi	H,A
Spilanthus acmella	--	H,Pe
Typha elephantina	Hogla	H,Pe
Typha angustata	Hogla	H,Pe
Vetiveria zizanioides	Binna, Gandhabena	H,Pe
Xanthium indicum	Ghagra, Khagra	H,A
Zannichellia palustris ssp. pedicellata	--	H,A
Swamp Forest:		
Asclepias ssp.	--	
Barringtonia acutangula	Hijal	S,Pe
Crataeva nurvala	Barun	T,Pe
Phyllanthus disticha	Chitki	T,Pe
Pongamia pinnata	Karanch	S,Pe
Salix tetrasperma	Bias,Panihijal	T,Pe
Trewia nudiflora	Gotagamar,Panidumur	T,Pe
		T,Pe

H: Herb; S: Shrub; T: Tree; Tl: Treelet; Cl: Climber
A: Annual; Pe: Perennial

FAUNAL DIVERSITY AND THEIR CONSERVATION IN FRESHWATER WETLANDS

Sohrab Uddin Sarker

ABSTRACT: The paper discusses status, distribution and conservation of wetland fauna of Bangladesh. Of the avifauna listed, 78 species are migratory and 129 are resident waterbirds that frequent the wetlands in Bangladesh. Among the ducks, lapwings, plovers, cormorants, herons, gulls and terns are important. Twenty-five species of resident and migratory waterbirds are endangered and threatened and the rest are vulnerable. Ducks in each roosting site vary between 2000 - 5000 and there are about a hundred of such sites in and near the wetlands. Thousands of waders and other waterfowls also visit the wetlands every winter. Seasonal distribution shows that migrants begin to arrive between mid-August and mid-November, reach optimum in December-January and begin to return between February and May. Resident waterfowls breed in wetlands and nearby woodlands in small groups. Large breeding colonies are rare even in the Sundarbans. Breeding success is very low owing to human disturbances and habitat destruction.

Ever increasing human population, hunting, trapping, lack of awareness and absence of wetland sanctuary and agrochemical residues are the main problems in conserving wetlands and waterfowls in Bangladesh. In spite of a ban on trapping and hunting of waterfowls, such activities are found to happen frequently owing to lack of agencies to enforce the law. The paper suggests undertaking a detailed survey of wetland fauna and a conservation and management plan for the ecologically significant wetlands. Hakaluki, Hail and Tanguar Haors and some suitable areas of the Jamuna river have been suggested to be declared as wetland sanctuaries for protection of wetland fauna.

INTRODUCTION

Bangladesh is rich in faunal diversity (Amphibia to Mammalia). About 932 species of wildlife fauna have been reported by different authors (Sarker & Sarker 1988). About 231 species of wetland wildlife and 11 species of other fauna excluding fishes have been reported for the first time from Hakaluki Haor (Sarker and Husain 1990a and 1990b and Husain *et al* 1990-91).

Water is a very important limiting factor for sustaining wetland fauna and other microbes. Any kind of change of this factor would drastically affect the abiotic and biotic environment. Recycling of food energy in the foodchain is obligatory for survival of the biotic components in a stable ecosystem. Natural environment has been undergoing almost radical changes everywhere in Bangladesh. Population pressure is the principal factor behind this. More and more wetlands are converted into dryland for urbanization. In addition, agriculture, irrigation, drainage, construction of highways and technological developmental activities also cause further shrinkage of wetland habitats. Most of the affected fauna of Bangladesh are associated with wetland and forest. The status of each of these species and their environmental impacts are poorly known. The present paper provides a review of the available information on the diversity, distribution, sustainable conservation and management of wildlife in the freshwater wetlands in Bangladesh.

FAUNAL DIVERSITY

Bangladesh is rich in fauna and flora. About 932 species of wildlife have so far been reported by different workers (Smith 1943, Ali and Ripley 1983, Daniel 1983, Hussain et al 1990-91, Sarker 1991, 1992a, 1992b and 1992c, Sarker *et al* 1984, Sarker and Hussain 1990a and 1990b). Out of these about 650 species have been observed in the field showing about 350 as resident and the rest as migratory. About 282 (43.5%) out of 650 species of wildlife are known as freshwater wetland species. There are about 207 species of birds, 33 species of reptiles, 18 species of mammals and 10 species of frogs and toads. A specieswise status of wetland fauna (birds, amphibians, reptiles, mammals and invertebrates) is incorporated in the annexure.

Birds

Among the birds, 62 (30%) are waterfowls, 55 (26.5%) waders, 42 (20%) bush and herbland birds and the rest are grassland, air hawking birds and birds of prey (11.5%). (For a detailed list see annexure). Of these freshwater birds 129 (62.3%) species are resident and the others are migratory.

Waterfowl

In this group, there are 27 species of geese and ducks, 12 species of herons, egrets and bitterns, 7 species of storks and ibises, 6 species of rails and the rest are grebes, cormorants and others. Among them 25 species have been reported from Hakaluki and Hail *haors* (Sarker 1992c and Sarker and Hussain 1990) and 30 from the Jamuna and the Padma (Hussain et al 1990-91). Among the waterfowls nearly 35.5% are migratory.

Geese and Ducks

In this group, Lesser Whistling teals are common, while Gargeney, Pintail and Scoters are fairly common and the rest are few in number. Barheaded goose and Greylag goose were fairly common in recent past but now they are rare. Scoters are larger in size than ducks. They are regular winter migrants in Bangladesh. Unfortunately these ducks were not reported earlier due to identification problems. The author identified White-winged Scoter and Surf Scoter in November 1992 from the markets in Dhaka. Ruddy shelduck is the biggest migratory duck in Bangladesh, fairly common in the Jamuna and Pintail is a medium-size one, also fairly common in Mirpur Zoo lake and Pilkhana lake in Dhaka. A number of shovellers were found in a fish pond at Hail Haor. Among the six resident ducks, Lesser Whistling Teals are the commonest ones found in large flock in isolated big ponds in and around Dhaka City (Dhaka Zoo and Pilkhana Bangladesh Rifles Headquarter, the President's House and Jahangir Nagar University). Comb duck is the resident one. A few individuals were found in zoo lake in winter in 1990 and 1991. These ducks are not found in other regions in Bangladesh.

About 100 Spotbill ducks live in the Jamuna river throughout the year and breed there between February and July. These ducks are also observed in other non-breeding areas but only in the winter season. The only known breeding duck population of the country

are severely disturbed in both breeding and non-breeding period by working people and poachers. If they are not protected and managed scientifically they are likely to be extinct in the near future.

White-winged Wood duck is an endangered species in Bangladesh. Only 30 individuals were reported and studied from Pablakhali Wildlife Sanctuary in Chittagong Hill Tracts. The present condition is not known. The habitats of these ducks are heavily disturbed by human settlement in recent years.

Breeding status of Lesser Whistling Teal is very limited. A few pairs are found to breed in segregated places. No breeding colony is known. Cotton Teal which breeds in hilly areas and occasionally in the plains is fewer in number.

Grebes

Little grebe was a common wetland bird even 20 years ago. It was used to be seen in *beel, jheel,* ditch, and *haor.* It feeds on seeds, floating and submerged vegetation and frequently dives under water for catching small fishes. Now it is endangered owing to drying up of wetland areas for cultivation and random trapping by local people during dry season. A bag of 50-60 grebes were seized from the centre of Dhaka city (Baitul Mukarram area) by officials of the Forest Department and were released in Mirpur Zoo lake. Two pairs of birds with three young ones were seen in a depression at Bhuapur ferry ghat in Tangail between October and November 1990. In December none was seen there due to drying up of water. Only a male grebe was seen in the river Jamuna. In October 1992 a pair was noted in a small canal along the roadside near the Ishwardi Railway Junction in Pabna and a dozen in the Hail Haor. Crested grebe is a winter migrant; only one individual was found in Chatler Beel in Hakaluki Haor in 1990. It is one of the rare birds of Bangladesh.

Cormorants and Darters

Little cormorant is a fairly common diving bird and is seen at *beel, jheel, dighee, haor,* pond, river, etc, both in shallow and deep water. More than 400 birds were observed in Nikrail areas near the Jamuna river. These waterfowls preferably feed in stagnant water like marshes and come back to the running water of the Jamuna and other rivers when the previous habitats dry up. A pair was seen in mating condition in winter and their copulation took place after diving several times under water. No permanent breeding colony is known in Bangladesh. Snake bird or darter is the biggest one in this group but is now rare and endangered. A bird was collected from Kachiar Beel in Sirajgonj in 1969 from a flock of 11 birds. But this bird is no more seen there. One bird was reported to have been shot in January/February 1992 in Kaptai Lake. This aquatic bird will soon be extinct from Bangladesh unless protective measures are taken. Other birds of this group are rare and less known.

Herons, Egrets and Bitterns

Grey and purple herons and large egret are the biggest waterfowls of this group though they are less in number. A purple heron was collected from Kachiar Beel in 1969 and the last one from Chalna Port in 1982. Some 50-100 grey herons are observed in the Jamuna River during winter months between Bhuapur-Sirajgonj and Aricha Nagarbari. This heron is also found in *haors* in lesser number. No breeding information is available in the country. Pond heron including other egrets are fairly common. Though they were all under pressure due to shortage of wetland in the recent past but modern IRRI cultivation and irrigation have created new habitats for them, to frequent and feed throughout the year. But they do not breed well due to shortage of suitable breeding habitats and due to human disturbances. They usually breed in a small colony or solitary pair in and around the wetlands.

Night heron is the only nocturnal bird in this group, frequenting in flocks near the wetlands. A big colony was found at Ruhitpur, a few kilometers south of Dhaka City. There were about 500 birds in 1982 but their number came down to one hundred within a few years due to hunting and trapping. A colony of nearly a hundred individuals was seen in Mirpur Zoo. These birds usually roost in leafy trees in daytime and disperse for feeding in the evening. Their population is now greatly reduced. Bittern, a comparatively shy bird, frequents, feeds and breeds in an isolated solitary area near water source.

Cattle egret is a common field bird which usually frequents around the grazing cattle. About 4,000 birds were counted in an evening of May 1989 between Kasiar Beel and Kachiar Beel in Sirajganj.

A group of 300 cattle egrets were noted in the growing *boro* ricefield in May 1990 in Hakaluki Haor and another group of 100 were also seen moving behind the cattle in Hail Haor in October 1992. Most of these birds seem to come from neighbouring countries in winter months. They are also found in summer but less in number and rare in flood season. They breed in the country but very few in number due to lack of breeding habitats and human disturbances. Some cattle egrets are trapped and hunted each year.

Storks, Ibises and Spoonbills

In this group, openbill stork is now endangered. They are fewer in number than earlier due to hunting, trapping and shortage of water areas. About 20 birds were found at Gonglir Beel near Bhuapur, Tangail, in November and December 1990 and a flock of 100 birds were found flying back to their night roost in Sitakundu hill at 6.30 pm from a nearby wetland in May 1991. No breeding record is available in the country - not even in the Sundarbans. These birds frequent *haors* and *beels* in winter months coming from Southeast Asia, where there are big breeding colonies.

Lesser adjutant is mostly confined in the Sundarbans, and is occasionally found in freshwater wetland in rainy season and winter months. Greater adjutant has become

extinct recently from Bangladesh and even from India except 60-80 breeding pairs reported from Assam by Hancock and Brouwer (1990). Blacknecked stork is a rare bird which occasionally visits Bangladesh. One bird was seen in the river Jamuna in January 1990. White Ibis is a migrant which occasionally frequents wetlands in small groups of 3 to 5 birds. Other species of this group are very rare.

Rail, Waterhen, Watercock, Moorhen and Jacana

This group of birds are local winter visitors in the country. In rainy and monsoon periods they usually disperse in low wetland areas where water is partly covered with thick floating vegetation like wild grasses, reeds, paddy, jute, etc. They frequent and breed there and return to hilly wetland and *haor* areas in dry season. Among them watercock is an endangered one due to random killing and trapping of wild adult males. Others are also victims of hunting and netting. A large number of these birds are captured and trapped in winter months for sale.

Waders

About 55 species of wader birds are known to occur in Bangladesh. Most of the species are migratory and a few are resident (Table 2). Among resident birds, pratincoles, terns, kingfishers and martins are fairly common and the rest are migratory, e.g. plovers, sandpipers, snipes, wagtails, etc.

Waders are smaller in size feeding mostly along the edge of the water or little above the water surface. They are less aquatic than waterfowls. Plovers, snipes, sandpipers, wagtails, whimbrels, curlews, stilts, etc. frequent the muddy surface. Snipe usually feeds in grassy muddy surface whereas gulls, terns, swallows, etc. more or less hawk in the air and sometimes touch or dive into water for food. Terns, pratincoles and plovers are fairly common in river water and few in marshes but other waders are fairly common in marshes and few in the rivers. Among the resident waders, terns, pratincoles, painted snipes, red wattle lapwing breed in colonies in the Jamuna river and *haors* in summer months but most of them are disturbed by local people. All waders are in great pressure of hunting and trapping all over the country, particularly during winter months when migratory ones arrive.

Other Birds

a) **Grassland birds:** About 14 species of birds frequent the grassland area in and around the wetlands. Among them 12 species are resident and the rest migrants. All passerine resident birds mostly feed and breed there in summer months. Pigeon and doves are granivorous birds in grasslands and footpaths. Short toed sand larks prefer sandy river banks and the rest are widely distributed in the wetland areas.

b) **Bush and Herb Land Birds:** About 42 species of such birds frequent bushes and herbs in wetland. Baya, parakeets, cuckoos, shrikes, drongo, crows, babblers, warblers, etc.occur in good number. Among them doves, babblers and warblers breed there.

c) **Birds of Prey:** This is also an important group of birds in the wetland ecosystem. About 24 species of raptors occur in the wetland areas. Vultures are scavengers; they usually live and breed in the wood and forest lands and feed on carcasses which are available in the wetlands. In Hakaluki Haor, there are about 150 Whitebacked vultures and about 200 in the Hail Haor including griffin one. Kites and harriers are common air hawking raptors. They fly over the floating vegetation particularly in Hail Haor and surrounding cultivated lands of other wetlands and prey on rats, fishes, insects, birds, etc. Pallas's fishing eagle and Shaheen falcon are endangered in Hakaluki Haor and the Jamuna river respectively and upland eagle is a rare one in the latter.

d) **Air Hawking Birds:** Some smaller air hawking birds like shallows and swifts are found over the wetland areas.

e) **Migratory Wetland Birds:** About 200 species of migratory birds arrive in Bangladesh during winter months. Among them 50% are wetland ones and the rest are terrestrial. Most of the migrants arrive in the country in November and December and return in February and March. But the initial arrival starts in mid-August and last departure is at the end of May. Usually smaller migrants arrive first and then the larger ones but reverse is not uncommon.

Amphibia

Frogs and toads play a vital role in the freshwater wetland ecosystem. About 11 species have been recorded from *haor* and other wetland areas. Among them the skipper frogs are more abundant in Hail Haor than other large wetlands due to presence of numerous floating vegetation like nymphia, lotus, trapa, wild grasses,etc. Even the toad is found in the floating vegetation in this *haor*. The density of skipper frogs in Hail Haor was estimated at $0.87/m^2$ in 900 samples in October 1992.

Reptiles

About 33 species of reptiles are found in and around the wetland areas(see annexure). Among them turtles, monitors, aquatic snakes are important ones. Peacock and Gangetic soft shell turtles are more common in the river Jamuna, the Padma, and the Meghna and their tributaries and the other turtles prefer ponds, lakes, canals, and ditches. Soft shell turtles are listed in the schedules of CITES Convention but they are caught and exported mainly in the winter when most of the gravid females come to lay their eggs in shallow water areas in the rivers. Many of the turtles are now endangered. Yellow water monitors sometimes are angled by fishing baited hooks and are killed by villagers. Aquatic snakes are more common in ditches and canals than in larger waterbodies such as marshes and rivers. Reptilian species particularly the olive keel backwater snakes are more in number in Hail Haor than Hakaluki Haor owing to more vegetation and small fishes in the former.

Mammals

In mammals, otters are aquatic. In Hail Haor, the large Bandicoot lives mainly in floating vegetation on water where it frequents and breeds all the year. It swims easily

among floating supports and sometimes becomes the victim of predators like raptors, snakes, jackals, cats, civets and large carnivore fishes e.g. *Wallago attu* and *Channa striatus*, and *C. marulius*. About 18 species of mammals feed on frogs and toads, fishes, insects and other animals in all wetland areas. Jackals, civets and cats are fairly common in *haors* (See annexure).

Invertebrate Fauna

a) **Insects:** Insects both terrestrial and aquatic are abundant in Hail Haor due to the presence of uniform vegetation on land and in water. They are considered as pests in agriculture. Density of grasshoppers in Hail Haor in 100 samples was 27.13/m^2. Other insects are also found there.

b) **Molluscs:** Large and small snails occur in all wetlands. Smaller and younger ones are used as food for ducks and waders.

Extinct and Endangered Fauna

a) Two species of reptiles, 7 birds and 5 mammalian species have become extinct from freshwater wetlands of Bangladesh (Table-1). Pinheaded duck became extinct long before in this subcontinent. King vulture and greater adjutant have become extinct in recent decades. The rhino and water buffalo are extinct due to hunting and destruction of their habitats in wetland areas.

Table 1: **Extinct Wetland Fauna**

Reptiles	
Marsh Crocodile	*Crocodilus palustris*
Rock Python	*Python molurus*
Birds	
Spotbill Pelican	*Pelecanus Philippensis*
Pelican	*P. onocrotalus*
Scavenger Vulture	*Neophron percropterus*
Bengal Florican	*Eupodotis bengalensis*
Pinkheaded Duck	*Rhodonessa caryophylacea*
Greater Adjutant	*Leptoptilos dubius*
King Vulture	*Sarcogyps calvus*
Mammals	
Lesser one horned Rhinoceros	*Rhinoceros sondaicus*
Greater One horned Rhinoceros	*Rhinoceros unicornis*
Asian Twohorned Rhinoceros	*Didermocerus sumatrensis*
Swamp Deer	*Cervus duvauceli*
Water Buffalo	*Bubalus bubalis*

b) About 35 wildlife species of wetland are endangered (Table-2). Among them are 3 reptiles, 25 birds and 7 mammals.

Table 2: **Endangered Wetland Fauna**

Turtles	
Lissemys punctata	*Trionyx gangeticus*
T. hurum	
Birds	
Podiceps cristatus	*Podiceps ruficollis*
Phalacrocorax carbo	*Phalacrocorax fuscicollis*
Anhinga rufa	*Ardea cinerea*
Neophron percnopterus	*Anastomus oscitans*
Leptoptilos javanicus	*Threskiornis melanocephala*
Plegadis falcinellus	*Platalea leucorodia*
A. anser	*Anser indicus*
Cairina scutulata	*Sarkidornis melanotos*
Haliaeetus leucoryphus	*Ichthyophaga ichthyaetus*
Anthropoidis virgo	*Rallus aquaticus*
Rostratula bengalensis	*Burhinus oedicnemus*
Esacus magnirostris	*Rynchops albicollis*
Pelargopsis capensis	
Mammals	
Lutra parspicillata	*Aonyx cinerea*
Viverricula indica	*Viverra zibetha*
Felis chaus	*Felis viverrina*
Vulpes bengalensis	

CAUSES OF LOSS OF WETLAND FAUNA OF BANGLADESH

Human Action

a) **Direct Causes:** killing, trapping, shooting of waterfowl and waders particularly the migratory ones.

Habitat Destruction:

- Drainage and irrigation for agriculture;
- Accumulation of insecticides, pesticides, rodenticides from agricultural fields, city, town, drainage, etc.;
- Filling by solid waste disposal, roads and highways and industrial development;
- Discharge of agrochemicals;
- Abstraction of groundwater;

- Discharge of chemical wastes from industries directly into rivers;
- Construction of dikes, dams and embankments for flood control and irrigation;
- Dredging and canalization for navigation, ferry and housing society, etc.;
- Cutting of woodland and village jungles for domestic fuel which removes about 50% of wetland habitat in rural areas; and
- Continuous fishing throughout the year and drying up of wetlands by drainage or pump for fishing which kill all other fauna.

Indirect Causes

- Illiteracy; about 80% of people lack even primary education;
- Lack of awareness about the value of wetland and wetland fauna;
- Siltation due to deposition of sediments from hills, city, towns, roads, etc.;
- Hydrological changes e. g. the river Dhaleshwari will be filled up by river training work for the Jamuna bridge near Bhuapur in Tangail;
- Introduction of exotic predatory fishes; and
- Over-exploitation of wetland resources.

Natural Causes

- Cyclonic storm and tidal surge kill occasionally take a heavy toll of wetland fauna;
- Virus diseases of fishes cause shortage of food both for human being and faunal communities all over the country;
- Traditional prejudice causes killing of snakes, monitor, owls, vulture and wild mammals like jackal, otter, fishing cats, etc.;
- Environmental degradation;
- Cultivation in the wetlands causes destruction of faunal habitats and disturbances of their feeding and breeding activities;
- Lack of National wetland Inventory and Conservation policy for development and preservation of wetland fauna; and
- Absence of an institution for management of wetlands.

SUSTAINABLE CONSERVATION AND MANAGEMENT

The Ramsar Convention recommended in July 1987 that each country should develop a national policy for wise use of the country's wetland resources. A comprehensive policy as well as planning and management guidelines should be developed for flood plain wetland fauna with field projects aimed at highest priority sites (Navid, 1990).

Guidelines for Action Plan

- Wetlands are extremely complex ecosystems involving hundreds of species of plants, microbes,invertebrate, amphibia and other wildlife and have developed as part of a larger landscape that took hundreds of years to establish a diversity of ecosystems and functions;

- Preparation of national wetland faunal inventory for such a project should be started with the cooperation of specialists;
- Identification of natural, scientific, aesthetic, and educational values and benefits of these wetland fauna and wetland;
- Assessment of impacts on wildlife before implementation of any development project for wetlands;
- Wetland management should take into account the need of local communities;
- Immediate control of trapping, killing and selling of vertebrate fauna like waterfowl and waders;
- Training of staff in the disciplines which will help in preparation of such policy;
- Pursuit of legislation and policy which will assist the conservation of wetland fauna;
- Need of establishment of wetland fauna sanctuaries like Hakaluki, Hail or Tanguar *haors* and some area in the river Jamuna; and
- Manage the wetlands as multiple-use resource.

RECOMMENDATIONS

For sustainable conservation, management and development the following recommendations are made:

- Detailed survey of wetland fauna should be done by experts for preparation of national wetland and wetland faunal inventories on which conservation and management plan may be prepared;
- A national committee for conservation of wetland fauna should be constituted involving government representatives, specialists and NGOs;
- Hunting, killing and trapping of wetland fauna must be stopped immediately;
- Hakaluki, Hail and Tanguar Haors and some suitable areas of the Jamuna river should be declared as protected areas for fauna;
- Public awareness programme should be undertaken in earnest;
- Existing Wildlife Preservation Order should be strictly applied for wetland fauna; and
- Local community should be involved in all conservation and management activities.

REFERENCES

Akonda, A. W. 1989. Bangladesh. pp 541-581. In: D. A. Scott (ed.). *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge UK.

Ali. S. and D. S. Ripley. 1983. *Birds of India and Pakistan*. Composite edition. Bombay. Nat. Hist. Soc. Bombay.

Anon. 1990. Wetland Management Group IWRB News, Mo. 3.

Blandford, W.T. 1888. *Fauna of British India, Ceylon and Burma*, Taylor and Francis, London.

Brouwer, K. 1990. Greater Adjutants hold on in Assam. *World Birdwatch, Newsletter*, ICBP., 12 (1-2): 3.

Daniel, J. C. 1983. *The Book of Indian Reptiles*, Bombay Nat. His. Soc. Bombay.

Hancock, J. A. 1989. Extinction stalks the storks of Asia. *World Birdwatch Newsletter*, ICBP. 11 (1): 1.

Husain, K. Z., S.U. Sarker, M.K. Rahman and A. Islam. 1990- 91. *Report of the Wildlife Study Group, Jamuna Multipurpose Bridge Area*. Jamuna Bridge Authority, Dhaka, Bangladesh. pp 1-39.

Matasui, S., T. Suzuki, E.P. Swift, A. Hibi, N. Ichida, Y. Tsukamoto, and K. Sonobe. 1982. *A Field Guide to the Birds of Japan*, Wild Bird Society of Japan, New York.

King, B. F, and E. C. Dickinson. 1975. *A Field Guide to the Birds of South East Asia*. William Collins Sons & Co Ltd. Glasgow.

Navid. D. 1990. Regional Cooperation *Ramsar Newsletter*, No.6, pp 1.

Sarker, S.U. 1991. Wildlife. pp9 & 47-49. In: Raana Haider, A. Atiq Rahman and Saleemul Huq (eds.). Cyclone '91: An Environmental and Perceptional Study. Bangladesh Centre for Advanced Studies. Dhaka.

Sarker, S. U. 1992. *Ecology of Wildlife*. UNDP/FAO BGD/85/011 Field Document No. 50. IFCU. pp 1-251.

Sarker, S. U. 1992a. *Parks and Wildlife Management*. UNDP/FAO BGD/85/011, Document No. 52, IFCU, pp1-200.

Sarker, S. U. 1992b. *Environmental Impact Assessment. Study in the Greater Dhaka City Flood Protection Plan. FAP 8A*, Aqua Consultant, JAICA, Japan.

Sarker, S. U. 1992c. Conservation of Faunal Resources of Hail Haor, with iovolvement of local community. WWF, Biodiversity Programme.

Sarker, S. U., M.A.R. Khan and S.M.A. Rashid. 1984. Stork, Ibises, and Spoonbill Status of Bangladesh. A status report, WWG of SIS ; *Zum Fliegen*. No. 2, pp17.

Sarker, S. U. and K.Z. Husain. 1990a. Wetland Wildlife of Bangladesh and their Conservation. Paper presented in workshop on Environmental Impacts on the Surface Water Systems of Bangladesh. *Proc*. University Press limited, Dhaka. 1990.

Sarker, S. U. and K.Z. Husain. 1990b. Wetland Wildlife of Hakaluki Haor: A Case Study. Bangladesh Center for Advanced Studies. Dhaka.

Sarker, S. U. and N.J. Sarker. 1988. *Wildlife of Bangladesh: A Systematic List*. Ricko Printer, Dhaka.

Scott., D. A. and C.M. Poole. 1989. *A Status Overview of Asian Wetlands*. IWRB, Malaysia.

Smith, M. A. 1943. *Fauna of British India (Amphibia and Reptiles)* Vol. 1-3. Taylor Francis, London.

Annexure : Status of Wetland Fauna in Bangladesh

1. Birds

English Name	Scientific Name	Status
A. Waterfowl		
Order : *Podicipediformes*		
Family: *Podicipedidae*		
Crested Grebe	*Podiceps cristatus*	M O
Little Grebe	*P.ruficollis*	R F
Order : *Pelecaniformes*		
Family: *Phalacrocoracidae*		
Cormorant	*Phalacrocorax carbo*	R F
Shag	*P. fuscicollis*	R O
Little Cormorant	*P. niger*	R FC
Darter	*Anhinga rufa*	R O
Order : *Ciconiformes*		
Family: *Ardeidae*		
Grey Heron	*Ardea cinerea*	R F
Purple Heron	*A. purpurea*	R O
Little Green Heron	*Butorides striatus*	R F
Pond Heron	*Ardeola grayii*	R C
Night Heron	*N. nycticorax*	R F
Cattle Egret	*Bubulcus ibis*	R C
Large Egret	*Egretta alba*	R O
Intermediate Egret	*E. intermedia*	R FC
Little Egret	*E. garzetta*	R FC
Chestnut Bittern	*Ixobrychus cinnamomeus*	R F
Bittern	*Botaurus stellaris*	R O
Black Bittern	*Dupetor flavicollis*	R O
Family: *Ciconiidae*		
Painted Stork	*Ibis leucocephalus*	R O
Open bill Stork	*Anastomus oscitans*	R F
Blacknecked Stork	*Xenorhynchus asiaticus*	R O
Lesser Adjutant	*Leptoptilos javanicus*	R O
Family: *Threskiornithidae*		
White Ibis	*Threskiornis melanocephala*	R O
Glossy Ibis	*Plegadis falcinellus*	R O
Spoonbill	*Platalea leucorodia*	R O
Order : *Anseriformes*		
Family: *Anatidae*		
Tundra Bean Goose	*Anser fabalis*	M O
Greylag Goose	*A. anser*	M F
Barheaded Goose	*A. indicus*	M O
Brahminy Duck/Ruddy Shelduck	*Tadorna ferruginea*	M F
Common Shelduck	*T. tadorna*	M F
Pintail	*Anas acuta*	M F
Common Teal	*A. crecca*	M F
Mallard	*A. platyrhynchos*	M FC
Gadwall	*A. strepera*	M F
Falcated Teal	*A. falcata*	M F
Wigeon	*A. penelope*	M F
Garganey	*A. querquedula*	M FC
Shoveller	*A. clypeata*	M FC
Greater Scaup	*Aythya marila*	M F
Common Pochard	*A. ferina*	M F
Baer's Pochard	*A. baeri*	M O
Tufted Duck	*A. fuligula*	M F
White-eyed Pochard	*A. Nyroca*	M F
Crested Pochard	*Netta rufina*	M F

M = Migratory, R = Resident, C = Common, VC = Very Common, FC = Fairly Common, F = Few and O = Occasional.

English Name	Scientific Name	Status
White-winged Scoter	*Melanitta fusca*	M FC
Surf Scoter	*M. perspicilata*	M FC
Lesser Whistling Teal	*Dendrocygna javanica*	R C
Large Whistling Teal	*D. bicolor*	R C
Cotton Teal	*Nettapus coromandelianus*	R FC
Spotbill Duck	*Anas poeciolorhyncha*	R FC
Whitewinged Woodduck	*Cairina scutulata*	R F
Comb Duck/Nakhta	*Sarkidiornis melanotos*	R O
Order : *Gruifoyrmes*		
Family: *Gruidae*		
Sarus Crane	*Grus antigone*	R F
Demoisells Crane	*Anthropoides virgo*	R O
Family: *Rallidae*		
Water Rail	*Rallus aquaticus*	R FC
Ruddy Crake	*Amaurornis fuscus*	R FC
Whitebreast Waterhen	*A. phoenicurus*	R FC
Water Cock	*Gallicrex cinerea*	R FC
Purple Moorhen	*Porphyrio porphyrio*	R FC
Indian Moorhen	*Gallinula chloropus*	R FC
Coot	*Fulica atra*	R F
Order : *Charadriiformes*		
Family: *Jacanidae*		
Pheasant tailed Jacana	*Hydrophasianus chirurgus*	R F
Bronzed winged Jacana	*Metapidius indicus*	R F
B. Waders		
Order : *Charadriiformes*		
Family : *Charadriidae*		
Sociable Lapwing	*Vanellus gregarius*	M FC
Greyheaded Lawpwing	*V. cinereus*	M FC
Redwattled Lapwing	*V. indicus*	R FC
Yellowwattled Lapwing	*V. malabaricus*	R F
Spurwinged Lapwing	*V. spinosus*	R FC
Eastern Golden Plover	*Pluvialis dominica*	M F
Lesser Sand Plover	*Charadrius mongolus*	M F
Little Ringed Plover	*C. dubius*	M C
Plover	*C. hiaticus*	M F
Eastern Whimbrel	*Numenius phaeopus*	M F
Curlew	*N. arquata*	M F
Blacktailed Godwit	*Limosa limosa*	M F
Common Red Shank	*Tringa totanus*	M F
Green Shank	*T. nebularia*	M F
Common Sandpiper	*T. hyypoleucos*	M FC
Wood Sandpiper	*T. glareola*	M F
Green Sandpiper	*T. ochropus*	M F
Terek Sandpiper	*T.terek*	M F
Nordmann's Greenshank	*T. guttifer*	M F
Marsh Sandpiper	*T. stagnatilis*	M FC
Solitary Snipe	*Gallinago solitaria*	M FC
Pintailed Snipe	*G. stenura*	M FC
Fantail Snipe	*G. gallinago*	M FC
Little Stint	*Calidris minutus*	M C
Temminck's Stint	*C. temmincki*	M F
Longtoed Stint	*C. subminutus*	M O
Turnstone	*Arenaria interpres*	M O
Family: *Rostratulidae*		
Painted Snipe	*Rostratula bengalensis*	R F
Family: *Recurvirostridae*		
Blackwinged Stilt	*Himantopus himantopus*	R F
Avocet	*Recurvirostra avoseta*	M F
Family: *Burhinidae*		
Stone Curlew	*Burhinus oedicnemus*	R F
Great Stone Plover	*Esacus magnirostris*	R F

English Name	Scientific Name	Status
Family: *Glareolidae*		
Courser	*Cursorius coromandelicus*	R F
Small Pratincole	*Glareola lactea*	R C
Family: *Laridae*		
Herring Gull	*Larus argentatus*	M F
Brownheaded Gull	*L. brunicephalus*	M FC
Blackheaded Gull	*L. rudibundus*	M F
Whiskered Tern	*Chlidonias hybrida*	R FC
Whitewinged Black Tern	*C. leucoptera*	M F
Gullbilled Tern	*Gelochelidon nilotica*	R F
Caspian Tern	*Hydroprogone caspia*	R F
River Tern	*Sterna aurantia*	R FC
Common Tern	*S. hirundo*	M F
Little Tern	*S. albifrons*	R F
Blackbellied Tern	*S. acuticauda*	R FC
Skimmer	*Rynchops albicollis*	R O
Order : *Coraciiformes*		
Family: *Alcedinidae*		
Lesser Pied Kingfisher	*Ceryle rudis*	R F
Common Kingfisher	*Alcedo aithis*	R C
Storkbilled Kingfisher	*Pelargopsis capensis*	R O
Whitebreasted Kingfisher	*Halcyon smyrnensis*	R FC
Order : *Passeriformes*		
Family: *Motacillidae*		
Grey Wagtail	*Motacilla flava*	M FC
Yellow Wagtail	*M. citreola*	M FC
Forest Wagtail	*M. caspica*	M FC
Pied Wagtail	*M. alba*	M C
Large Pied Wagtail	*M. madagascarensis*	M F
C. Grassland Birds		
Order : *Columbiformes*		
Family: *Columbidae*		
Rock Pigeon	*Columba livia*	R FC
Ring Dove	*Streptopelia decaocto*	R FC
Red Turtle Dove	*S. tranquebarica*	R FC
Spotted Dove	*S. chinensis*	R F
Order :*Passeriformes*		
Family:*Motacillidae*		
Tree Pipit	*Anthus hodgsoni*	M FC
Paddyfield Pipit]	*Anthus novaeseelandae*	M FC
Family: *Alaudidae*		
Eastern Skylark	*Alauda gulgula*	R FC
Sand Lark	*Calandrella cinerea*	R FC
Assam Bush Lark	*Mirafra assamica*	R FC
Ashycrowned Finch Lark	*Erymopteryx grisea*	R FC
Family: *Sturnidae*		
Common Myna	*Acridotheres tristis*	R FC
Jungle Myna	*A. fuscus*	R FC
Pied Myna	*Sturnus contra*	R C
Order : *Coraciiformes*		
Family: *Upupidae*		
Hoopoe	*Upupa epops*	R F
D. Bushland Birds		
Order : *Psittaciformes*		
Family: *Psittacidae*		
Roseringed Parakeet	*Psittacula krameri*	R F
Redbreasted Parakeet	*P. alexandri*	R F
Slatyheaded Parakeet	*P. himalayana*	R F

English Name	Scientific Name	Status
Order : *Cuculiformes*		
Family: *Cuculidae*		
Common Hawk Cuckoo	*Cuculus varius*	R F
Plaintive Cudckoo	*Cacomantis marulinus*	R F
Crow Pheasant	*Centropus sinensis*	R F
Order : *Strigiformes*		
Family: *Strigidae*		
Brown Fish Owl	*Bubo zeylonensis*	R F
Order : *Caprimulgiformes*		
Family: *Caprimulgidae*		
Longtailed Nightjar	*Caprimulgus macrurus*	R F
Order : *Coraciformes*		
Family: *Meropidae*		
Blue tailed Bee-eater	*Merops philippinus*	R FC
Green Bee-eater	*M. orientalis*	R F
Family: *Coracidae*		
Blue Jay	*Coracias benghalensis*	R F
Order : *Passeriformes*		
Family: *Laniidae*		
Blackheaded Shrike	*Lanius schach*	R F
Brown Shrike	*L. cristatus*	M FC
Family: *Dicruridae*		
Black Drongo	*Dicrurus adsimilis*	R VC
Ashy Drongo	*D. leucophaeus*	R F
Family: *Corvidae*		
House Crow	*Corvus splendens*	R F
Jungle Crow	*C. macrorhynchos*	R FC
Family: *Pycnonotidae*		
Redvented Bulbul	*Pycnonotus cafer*	R F
Family: *Muscicapidae*		
Marsh Spotted Babbler	*Pellorneum palustre*	R F
Abbott's Babbler	*Trichastoma abbotti*	R F
Common Babbler	*Turdoides caudatus*	R O
Striated Babbler	*T. carilei*	R O
Jungle Babbler	*T. striatus*	R F
Nepal Quaker Babbler	*Alcippe nipalensis*	R F
Streaked Fantail Warbler	*Cisticola juncidis*	R F
Streaked Longtailed Warbler	*Prinia gracilis*	R F
Tawnyflanked Longtailed Warbler	*P. subflava*	R F
Ashy Wren Warbler	*P. socialis*	R F
Redbreasted Flycatcher	*Muscicapa parva*	M F
Ruby Throat	*Erithacus calliope*	M F
Blue Throat	*E. svecicus*	M F
Tailor Bird	*Orthotomus sutorius*	R F
Magpie Robin	*Copsychus saularis*	R F
Black Redstart	*Phoenicurus ochruros*	M F
Collared Bush Chat	*Saxicolla torquata*	M FC
Pied Bush Chat	*S. caprata*	M F
Family: *Ploceidae*		
Baya	*Ploceus philippinus*	R C
House Sparrow	*Passer domesticus*	R F
Spotted Munia	*Lonchura punctulata*	R FC
Chestnut Munia	*L. malacca*	R C
Whitethroated Munia	*L. malabarica*	R F
Red Munia	*Estrilda amandava*	R F
E. Birds of Prey		
Order : *Falconiformes*		
Family: *Accipetridae*		
Blackwinged Kite	*Elanus caeruleus*	R FC
Pariah Kite	*Milvus migrans*	R FC

English Name	Scientific Name	Status
Large Pariah Kite	*Milvus migran lineatus*	M C
Brahminy Kite	*Haliastur indus*	R FC
Shikra	*Accipiter badius*	R F
Changeable Hawk Eagle	*Spizaetetus cirrhatus*	M F
Booted Hawk Eagle	*Hieraaetus pennatus*	R F
Upland Eagle	*Buteo hemilasius*	M O
Tawny Eagle	*Aquila rapax*	R F
Steppe Eagle	*A. nipalensis*	M F
Large Spotted Eagle	*A. clanga*	R O
Lesser Spotted Eagle	*A. pomarina*	R F
Pallah's Fish Eagle	*Haliaeetus leucoryphus*	R O
Greyheaded Fish Eagle	*Ichthyophaga ichthyaetus*	R F
Whitebacked Vulture	*Gyps bengalensis*	R FC
Grifton Vulture	*G. fulvus*	R O
Pale Harrier	*Circus macrourus*	M O
Pied Harrier	*C. melenoleucos*	M FC
Montagu Harrier	*C. pygargus*	M O
Marsh Harrier	*C. aeruginosus*	M F
Crested Serpent Eagle	*Spilornis cheela*	R FC
Family: *Pandionidae*		
Osprey	*Pandion haliatus*	M O
Family: *Falconidae*		
Shaheen Falcon	*Falco peregrinus*	R O
European Kestrel	*Falco tinnunculus*	M FC
F. Air Hawking Birds in Wetland Areas		
Order :*Apodiformes*		
Family:*Apodidae*		
Crested Tree Swift	*Hemiprocne coronata*	R F
Spinetailed Swift	*Chaetura caudacuta*	R F
Alpine Swift	*Apus melba*	R FC
Palm Swift	*Cypsiurus parvus*	R FC
Order :*Passeriformes*		
Family:*Hirundinidae*		
Plain Sand Martin	*Riparia paludicola*	R F
Collared Sand Martin	*R. riparia*	R FC
Nepal House Msrtin	*Delichon nipalensis*	R FC
Common Swallow	*Hirundo rustica*	M C
Wiretailed Swallow	*H. smithi*	M F
Family:*Artamidae*		
Asy Swallow Shrike	*Artamus fuscus*	R F
2. Amphibians		
Order :*Anura*		
Family:*Ranidae*		
Green Frog	*Rana hexadactyla*	O
Bull Frog	*R. tigrina*	FC
Skipper Frog	*R. cyanophlyctis*	VC
Cricket Frog	*R. limnocharis*	F
Tree Frog	*R. tytleri*	F
Family:*Rhacophoridae*		
Tree Frog	*Rhacophorus maximum*	F
Tree Frog	*R. bimaculatus*	F
Family:*Microhylidae*		
Red Frog	*Microhyla rubra*	F
China Frog	*Microhyla ornata*	F
Baloon Frog	*Uperdon globosa*	O
Family:*Bufonidae*		
Toad	*Bufo melanostictus*	F

3. Reptiles

English Name	Scientific Name	Status
Turtles	-	-
Spotted Soft Shell Turtle	*Lissemys punctata*	FC
Peacock Soft Shell Turtle	*Trionyx hurum*	C
Gangetic Soft Shell Turtle	*T. gangeticus*	FC
Soft Shell Turtle	*Citra indica*	F
Three Keeled Tortoise	*Melanochelys tricarinata*	F
Pond Tortoise	*M. trijuga*	F
Black Pond Tortoise	*Geoclemys hamiltoni*	FC
Brahminy River Turtle	*Hardilla thurgii*	C
Roof Turtle	*K. tentoria*	F
Large Roof Turtle	*K. dhongoka*	F
Yellow Turtle	*Morenia petersi*	FC
Common Roof Turtle	*Kachuga tecta*	C
Sylhet Roof Turtle	*K. sylhetensis*	F
Roof Turtle	*K. smithi*	F
Lizards	-	-
Wall Lizard	*Hemiductylus frenatus*	F
House Lizard	*H. brooki*	F
Garden Lizard	*Calotes versicolor*	F
Stripped Skink	*Mabuya dissimilis*	FC
Common Skink	*M. carinata*	
Yellow Water Monitor	*Varanus flaviscens*	
Grey Land Monitor	*V. bengalensis*	FC
Snakes	-	
Common Blind Snake	*Typhlops braminus*	FC
Large Blind Snake	*T. diardi*	FC
Checkered Keelback Water Snake	*Xenochrophis piscator*	FC
Olive Keelback Water Snake	*Atretium schistosum*	FC
Stripped Keelback Water Snake	*Amphiesma stolata*	FC
Copper head	*Elaphe radiata*	F
Rat Snake	*Ptyas mucosus*	FC
Common Krait	*Bungarus caeruleus*	FC
Banded Krait	*B. fasciatus*	FC
Common Cobra	*N. naja*	FC
Russell's Viper	*Vipera russellii*	F

4. Mammals

English Name	Scientific Name	Status
Bats		
Yellow Bat	*Scotophilus luteus*	F
Pigmy Pipistrelle	*Pipistrellus mimus*	FC
Otters		
Common Otter	*L. lutra*	F
Smoothcoated Otter	*Lutra perspicillata*	F
Smallclawed Otter	*Aonyx cinerea*	F
Cats		
Small Civet	*Viverricula indica*	F
Large Civet	*Viverra zibetha*	F
Fishing Cat	*Felis viverrina*	FC
Jungle Cat	*Felis chaus*	FC
Rats		
Brown Rat	*Rattus norvegicus*	F
Black Rat	*Rattus rattus*	F
House Mouse	*Mus musculus*	F
Lesser Bandicoot	*Bandicota bengalensis*	FC
Large Bandicoot	*Bandicota indica*	FC
Jackal	*Canis aureus*	FC
Bengal Fox	*Vulpes bengalensis*	F
Grey Mongoose	*Herpestes edwardsi*	FC
Small Mongoose	*Herpestes auropunctatus*	FC
5. Invertebrate Fauna		
Grasshopper(green)		VC
Grasshopper(brown)		VC
Garris spp.		FC
	Neps cinerea	F
	Pila globosa	FC
	Planorbis albus	F
	Argenia aquatica	C
	Halipius spp.	F
	Hydroparus spp.	F
	Pelodytes edentulus	FC
	Bellamys sp.	F

Source : Author's observation and Sarker & Sarker, 1988.

LIMNOLOGY AND POLLUTION OF WETLANDS

A.K.M. Nurul Islam

ABSTRACT: The paper discusses the limnological characteristics of freshwater wetlands of Bangladesh. Reviewing the historical transformation of these wetlands it shows that a complex interaction of man and natural processes - riverbed evolution, extensive flood control and irrigation works and excessive pollutants - have been considered to have caused changes in the wetland features and rendered them ecologically fragile. Productivity and trophic status of freshwater wetlands of Bangladesh and its adjacent areas have been discussed from various case studies. Phytoplankton productivity of some *beels* was found to convert only 5-21% (or 15-30%) of energy and a major contributor was found to be macrophytes. Major pollution sources, both point and non-point, that cause environmental hazards in the wetlands have been identified. These are mainly chemical and biological in nature. These pollutants have been considered to cause as many as 32 waterborne diseases including cholera, dysentery, diarrhoea, typhoid and shigellosis. Many diseases of fish, waterfowl, cattle and other animals have been considered to be related to eutrophication and pollution of the wetlands. Freshwater wetlands of Bangladesh have been considered to exceed the limit of natural purification. To mitigate eutrophication and pollution problems a number of recommendations have been made. Population, poverty, pollution, productivity (biological), politics, progress and prejudices have been considered to be constraints in the conservation of the wetlands.

INTRODUCTION

Limnology on the whole is a multidisciplinary subject and its studies include physical, chemical and biological aspects of any aquatic habitat. In other words, it deals with the biology of productivity. The biological production is carried out by the phytoplankton, zooplankton, bottom fauna, macrophytes, nektons, etc. The primary productivity is carried out by all the chlorophyll-bearing green plants from unicellular phytoplankton to multicellular macrophytes. These primary producers, through photosynthesis, fix and convert the solar energy into chemical energy and start the food chain/web in the aquatic medium. Subsequent productions are all secondary or tertiary through consumer levels, i.e., through zooplankton, benthos, small fish, big fish, etc. Also included in different trophic levels of the food-chain are the birds, waterfowl, reptiles, insects, amphibians, mammals and man. At the bottom of the food-chain, micro-organisms are present as the decomposers breaking down the organic compounds into inorganic components to be used by the green plants to produce organic matter again. Besides the solar radiation, the atmospheric gases O_2, N_2, CO_2 and other essential and trace elements must be available in dissolved form in adequate amounts for the optimum organic production.

In limnological studies, attention should be given to the origin, location, basin shape, depth, precipitation, general topography, physiography, contours and geomorphology of the watershed and the catchment areas of the rivers, lakes and other wetlands habitats. The physical and chemical nature of the land surrounding the lakes and wetlands are also important as the runoff water over the land surface often carries different elements including the eroded soils into the waterbody.

CHANGES IN PHYSICAL SETTING OF FRESHWATER WETLANDS[1]

As Bangladesh is a deltaic flat country it is at the receiving end of all the materials carried by the rivers coming down from outside the country. Although no records or data have been kept, nor any study been made in the past centuries (say, more than a thousand years), it might be assumed that the limnological/hydrobiological conditions of the freshwater wetlands of Bangladesh might have developed to their present state having passed through the following stages:

a) During the formation of the *haors*, *baors*, *beels*, swamps and the floodplains centuries back no major chemical and hence biological changes took place, except for some physical changes in some rivers and their tributaries and distributaries. These changes were mainly in the direction of their waterflow, sedimentation, shoal formation, cutting of the bank, etc. The changing flow of the Ganges within Bangladesh, once through Gorai, then through Madhumati or Arial Khan and then through the present course is well-known. The flow of the Brahmaputra has also changed to south as Jamuna since 1787 as a result of unusual flooding, during which time the course of the Teesta also changed from a southerly direction to an easterly direction to join the Brahmaputra to create its present status. The Surma-Barak-Kushiyara-Meghna system also passed through various complex and tortuous courses to its present condition. Many of the small rivers, tributaries and channels have silted up gradually and have been converted to farmlands or human settlements.

b) The rivers, *haors*, *baors*, *jheels*, etc. were mostly deep and the water was crystal clear even in the near past. Through sedimentation the basins of these habitats gradually became shallower, and slowly the bottom flora started developing in the later phases. The phytoplankton and zooplankton phase was moderate enough to support moderate fish growth.

c) The bottom vegetation enhanced the process of sedimentation, which led to the formation of emergent vegetation like reeds, sedges, cattails and then other groups of plant species followed. All these made the wetlands biologically productive to provide enough food and shelter not only for fish and other aquatic vertebrate and invertebrate organisms but also attracted the migratory birds. The birds' excreta, in course of time, further added to the fertility of the water, which allowed luxuriant growth of the macrophytes and the phytoplankton, thereby increasing fish production.

d) Another aspect to be mentioned here is that several aquatic plants were introduced by humans to this part nearly 100 years ago, of which *Eichhornia crassipes* (water hyacinth) is the most notorious one. Such exotic plants became so adventive and dominant that not only did they change the ecosystems but also played a negative role in the economy and biology of this

[1]See Akonda (1989) for a description of the present-day wetlands of Bangladesh.

rice growing and fish producing area. Prior to the introduction of these exotic plants (till then no exotic fish or any aquatic animal was introduced) the wetlands and the riverine habitats maintained a well-balanced ecosystem and the optimum biological production was not disturbed, except perhaps by natural phenomena like flood, cyclone and drought conditions.

e) Although the human settlement along the Gangetic plains is very old, it did not affect the quality of water much in the past. Whatever pollution contaminated the river system could be purified through natural homeostasis. But, during the past couple of centuries, hundreds of towns and cities developed by the side of big rivers like the Ganges. Human populations started increasing with a resultant increase in municipal wastes and domestic garbages. Agriculture expanded with the use of fertilizers, pesticides and insecticides, all new to this whole ecosystem. Trees and forests gradually diminished (and are still being depleted), erosion in the catchment areas increased and, much later, industries of different kinds started developing. The industries, which even at the beginning of this century were negligible in the whole subcontinent, are now being developed and in some places the process of industrial development is rather rapid. The consequences of all these developments and human activities are increased chemical pollutants (not only in water but also on the land and in the air) and mild to serious eutrophication or hypertrophic condition of the surface waters.

f) During the last 50 years or so, besides pollutants, many river beds were silted up, shoal formation enhanced, many dams and embankments were constructed to control flood and to develop irrigation system. Not only the rivers, but many *beels*, *haors*, and marshes were filled up by natural processes as well as by humans. Many floodplains, *beels*, and marshy areas were reclaimed through extensive drainage for human settlements, farmland formation, construction of industries, roads and highways, and so on. The trees and bushes along the wetlands, which developed through centuries, have been depleted with the resultant harmful consequences and in some cases the damages are perhaps irreversible.

g) The transport systems in our waterways have changed during the past 200 years or so. For long distance journeys only a few steamers were introduced about a century ago. Today, thousands of big and small motor vessels are plying and the country boats/sail boats have been replaced largely by 'shallows'. Many types of country boats have already disappeared from the scene and become objects in museums. The launches and 'shallows' are not only polluting the waters but are also responsible for river bank erosion and sedimentation. In the floodplains tractors are gradually replacing old fashioned agricultural implements.

h) As a result of all this urbanization, industrialization and modernization in agriculture and in transport systems, the quality of the water within and outside the country has deteriorated to such an extent that the biological productivity has gone down, fisheries in natural bodies of water have been

affected, many species of plants, fish and other organisms have either become depleted (extinct) or are on their way to extinction. There is hardly any pond, lake, river or any wetland area in Bangladesh which is not polluted organically or inorganically through sewage contamination, agricultural wastes or industrial effluents. The water of the rivers or channels, particularly near the harbour, bazar, ferry, industries or close to any city or town appears dark or brown or tar-like in colour and human excreta are found floating. So, the water in the wetlands is either heavily loaded with the nitrogenous and phosphorus compounds, or together with these the toxic materials (biodegradable or non-biodegradable), hot waters, acids, heavy metals, etc, are mixed up. As a result, water from streams, rivers and other bodies have become unsuitable for drinking, bathing, washing and domestic uses or for any biological production. Depending on pollution load, Patrick (1951) classified water as (i) healthy, (ii) semi-healthy, (iii) polluted, and (iv) very polluted.

The water condition can also be saprobic, mesosaprobic or polysaprobic depending on the bacterial populations present, particularly in waters contaminated by sewage effluent.

The dynamics of water balance in the wetlands, as affected by the incursion of river water, varying degrees of precipitation and nature of catchment, are highly complex and the present contrasting features of the *beel* and *haor* areas, which represent a combination of lotic and lentic habitats, are becoming at times a natural lake ecosystem. *Beels* and *haors* are quite conspicuous and have a long history of development with the riparian settlement. These are complex natural aquatic habitats and to deal with them several geographical, biological, socio-economic variables, such as landscape, source of water, level of fluctuations and quality of flora and fauna, human use etc., surrounding settlement pattern and land use, should be taken into account for their conservation and optimum exploitation.

Thus, although the *beels* and *haors* are highly productive for fisheries and other uses, unfortunately, a combination of processes as mentioned above i.e., a) river-bed evolution, b) effects of extensive flood control, c) irrigation works in the river basins, and d) effects of excessive pollutions, has annihilated many of the original features and rendered them ecologically fragile.

With this general background of the condition of the surface water and the physical changes of the wetlands, as it stands at present, we shall now discuss the limnological work done in Bangladesh and adjacent regions under the same riverine systems.

Limnological Studies in Bangladesh

Adequate limnological studies in respect to biological productivity, energy budget, continual monitoring of the physical and chemical parameters at any particular place over a long period of time and the overall biological conditions from the bottom up to the surface have not been done in Bangladesh to allow a total picture to be found and

generalizations to be made. As no limnological data were maintained in the past, even four or five decades ago, no comparison with the present condition is, therefore, possible. During the past three decades or so, although the limnological studies have been initiated (Khatun 1963 and Nahar 1963), the progress has been rather slow and these have had very little impact. However, recent trend in this field is encouraging as some awareness has developed, which is reflected in the works of not only biologists but also in other disciplines. There are reasons to be optimistic, provided more (a) research and academic programmes, (b) people's dedication and awareness and (c) government's participation with generous support are all combined together to carry out the Herculean task of conserving potential resources and maintaining the productivity of the wetlands.

So far, the limnological studies made in Bangladesh were mainly concerned with the determination of the following parameters of the freshwater habitats:

> DO, % saturation of DO, BOD, COD, POD, BOC, dissolved free CO_2, pH, alkalinity, hardness, electrolytic conductivity, temperature, light penetration, thermal stratification, precipitation, turbidity, basin shape, CO_3 and bicarbonate content, nitrogenous and phosphorus compounds, nutrients, primary production through carbon or % oxygen method, incident and photosynthetically active radiation, soluble reactive P_2, water depth, bottom soil, major metals (Na, K, Mg, Ca, Mn, Fe), minor metals (Co, Ni, Cu, Zn, Cd, Pb), reactive silicate, element load, standing crop, dry biomass, diel changes PAR, O_2, weight of total dissolved solids and a few other parameters including the growth of fish, shrimp, zooplankton and benthic fauna.
>
> (Islam and Khatun 1966, Islam and Nahar 1967, Islam *et al.* 1974, Islam and Saha 1975, Islam and Mendes 1976, Islam *et al.* 1979, Islam and Khondker 1991, Ameen *et al.* 1988, Mumtazuddin *et al.* 1982, Oppenheimer *et al.* 1978, Khondker *et al.* 1990, Khondker and Parveen 1992, Whitton *et al.* 1988, Alam *et al.* 1987a, 1987b, Begum *et al.* 1989, Khaleque and Islam 1983, Islam *et al.* 1992, Khondker and Rahim 1991 and Ali 1976 in Bangladesh and Vaas 1989, Pathak 1989, and Yadava 1989, in West Bengal and Assam in India).

The parameters in several ponds, lakes or rivers, however, were studied at monthly or fortnightly intervals and in some cases only for one year or six months or so, and have never been repeated. Very few correlation studies were made between the organisms' growth and the limnological parameters. In some polluted waters, the phytoplankton (and also zooplankton) composition was studied to determine the indicator species, i.e., those species tolerant to specific types of pollutants (Islam and Khatun 1966, Islam and Nahar 1967, Islam *et al.* 1991, Khonkder *et al.* 1990). Besides phytoplankton, the limnological aspects of different duckweed species (*Lemna*, and *Spirodela*) were studied in several polluted waterbodies. *Lemna* sp. was found to be very tolerant to heavy organic pollutants and to grow well in almost anaerobic condition (Islam and Khondker 1991). *Wolffia arrhiza* is another duckweed, which also grows in polluted ponds and lakes and contains 20.60% extractible protein (Islam and Paul 1977). These duckweeds could be grown in heavily polluted waters and rich biomass could be

harvested, which could be utilized as food, feed or fodder on the one hand and as water purifier on the other.

Limnological studies in Bangladesh, however, were carried out in isolation in some polluted ponds, eutrophic/hypertrophic lakes, fish ponds, some rivers, *beels* and *haors* in relation to the following aspects:

a) Limnology, pollution and phytoplankton of ponds, lakes, beels and rivers; (Islam and Khatun 1966, Islam and Nahar 1967, Islam and Begum 1969, Islam and Saha 1975, Islam and Haroon 1975, Islam and Zaman 1975, Islam and Rahman 1979, Islam *et al.*1980, 1991 and 1992, Khondker and Parveen 1992a, 1992b, Alam *et al.* 1987a, Islam and Paul 1978, Ali *et al.* 1978, etc.)

b) Limnology, growth of benthic flora and fauna; (Islam and Paul 1977, Islam *et al.* 1979, Islam and Mendes 1976, Islam and Paul 1978, Islam and Khondker 1991, Islam *et al.* 1992, Miah *et al.* 1983 and 1985, Ali 1980, etc.).

c) Limnology, water quality and primary productivity of a hypertrophic lake; (Khondker *et al.* 1988, Khondker and Parveen 1992, Khondker and Rahim 1991, etc.)

d) Limnology of fish ponds, zooplankton and other animals; (Ameen *et al.* 1988, Mumtazuddin *et al.* 1982, Ali *et al.* 1980, 1982 and 1989, Sufi and Farooque 1983, Oppenheimer *et al.* 1978, Alam *et al.* 1987b, Mahmood 1986, Begum *et al.* 1989, Khaleque and Islam 1983, etc.)

e) Limnology, macrophytes and algae of deep water ricefields of Brahmaputra and Meghna floodplains; (Whitton *et al.* 1988a, 1988b, 1988c, Rother and Whitton 1988, Catling *et al.* 1981, etc.)

f) Limnology, pollution and domestic, agricultural and industrial pollutants in the river system. (Haider 1988, Khair 1988, Alam 1988, Malik 1988, Choudhury 1988, Sharif *et al.* 1988, Safiullah and Mofizuddin 1988, Begum and Hossain 1993, Rahman 1988, Eunus 1988 etc.)

Limnological Studies in Adjacent Areas

The wetlands of the adjacent regions of West Bengal, Assam and Bihar in India are more or less similar to that of Bangladesh and sufficient limnological work has been done on those wetlands. A brief review of that work may be relevant in this connection. Pathak (1989) made comparative studies of the limnological features in *beels* in which he described the hydrochemical features, dynamics of chemical constituents and evaluation of productivity trends, nutrient cycles, organic bottom deposits, detritus energy, energy transformation and flow of energy in *beels* ecosystem. He found that the bottom deposits of decaying weeds contribute very rich organic carbon (2.8-9.0%), N_2 (605-985 ppm) and P_2 (40-185 ppm) in all the *beels* studied. This rich nutrient status of the *beels* shows immense production potential. But these major nutrients (nitrate and

phosphate), are mostly found to be accumulated and locked up by the macrophytes for a long time and therefore phytoplankton production in the water is low. The contribution of phytoplankton in energy conversion in the *beel* was found to be only 5-21% and the key role was played by the macrophytes. Energy flow in *beels* is mostly through detritus chains rather than through grazing, and managed *beels* show better energy output in terms of fish than unmanaged *beels*. If the macrophyte cycle is broken by removal or otherwise, the circulation of nutrients is very fast with the formation of phytoplankton bloom. It shows that circulation of nutrients is much faster by phytoplankton than macrophytes.

The productivity potential of any aquatic ecosystem depends on photosynthetic efficiency of the primary producers. In *beels* primary production is contributed more by the macrophytes and less by the phytoplankton. Pathak (1989) has given the following comparative values of three ponds in Assam, W. Bengal and Bihar (Table 1):

Table 1: Photosynthetic Efficiency of Different Aquatic Systems

Location	Photosynthetic Efficiency					
	Macrophytes		Phytoplankton		Total for Primary Producers	
	Cal m^{-2} day^{-1}	% of Available light	Cal m^{-2} day^{-1}	% in available light	Cal m^{-2} day^{-1}	% in available light
Dhir Beel (Assam)	43,408	2.34	10,311	0.55	53.719	2.89
Kulia Beel (W Bengal)	57,483	3.10	2,796	0.14	60,279	3.24
Muktapur maun (Bihar)	49,129	3.30	6,482	0.44	55,611	3.74

Vaas (1989) discussed the productivity status, physicochemical and biological factors of *beels* and their exploitation and productivity in West Bengal. The carbon fixation at phytoplankton level in West Bengal *beels* ranged from 3.3 to 4.9 tonnes C ha^{-1} per year. The contribution of phytoplankton towards primary production ranges from 15-30% only, a higher value than found by Pathak (1989). The carbon fixation in respect of macrophytes ranges between 3.26 and 18.7 g C m^{-2} day^{-1}. He found that under proper management the overall productivity (primary and secondary) had increased in the *beels*.

Babu Lal (1989) also studied the energy flow in Kulia Beel ecosystem in West Bengal and found the *beel* heavily choked with luxuriant growth of the macrophytes (*Eichhornia*, *Hydrilla*, *Ceratophyllum*, *Najas*, *Azolla*, *etc.*) and very low fixation of

solar energy by the primary producers was found (2500 Cal m^{-2} day^{-1}) in the first year of the study. But, in the second and third years after the removal of the macrophytes, energy fixation increased many times (photosynthetic efficiency increased from 0.12% at the beginning to ten fold immediately after the removal of the macrophytes). This was due to sudden increase in phytoplankton bloom, when the chlorophyll concentration in the *beel* also increased.

In *beel* ecosystem the macrophytes are not readily grazed upon and hence after death these are deposited as semi or undecomposed organic detritus, which is very rich in nutrient with high potential energy to be utilized by the benthic organisms. Thus, the flow of energy in *beel* ecosystem is mainly through the detritus chain. The works of Babu Lal (1989), Mitra (1989), Pathak (1989) and Vaas (1989) show that the rich nutrition status of the bottom soil of the *beels* is reflected by the luxuriant growth of the macrophytes and, unless the beel is managed, the phytoplankton growth is rather poor. However, the condition of these *beels* in the past was not exactly like the present day as reported by the above authors. For example, Bruhl and Biswas (1926), nearly seventy years ago, while studying the algae of the Loktak Lake in Manipur State, observed that the "luxuriance of the vegetation of the lake" was formed by various macrophytes, but the water hyacinth was absent and the submerged hydrophytes were densely covered with small algae which shows good light penetration.

Bruhl and Biswas (l.c.), in a few samples collected only once, recorded 121 algal taxa, of which 96 were desmids. Large number of desmids usually indicate the good quality of the water, as these are quite sensitive to pollution and eutrophication (Brook 1971, Prescott 1939). This is obvious, because in the twenties the wetlands in general were not contaminated by any chemical fertilizers, detergents or by any modern insecticides. Even in the mid-seventies the water quality of the Hakaluki Haor was almost similar to Loktak Lake (although water hyacinth invaded the area) as reflected by the good growth of desmids and other phytoplankton (Islam and Paul 1978; Islam and Haroon 1980). However, the present day status of the *haor* is not known and, therefore, no comparison could be made.

POLLUTION STATUS OF THE WETLANDS

Natural bodies of water are not absolutely pure. Various organic compounds and inorganic elements remain in dissolved form. Silt and clay remain suspended in the water for a considerable period. Many kinds of microscopic and a good number of macroscopic flora and fauna grow in different types of aquatic habitats. The physical and chemical quality of the waters vary according to nature of the basin shape and size, depth, light penetration, precipitation, location, temperature, chemical nature of the surrounding soil and dissolved minerals, pH, etc., and on these depend the biological components of the habitat. If all the physical, chemical and biological parameters are in optimum condition and a balance between these is maintained, we may assume an ideal or 'normal' condition. If, for some reason, this balance is disturbed and anyone or several of these components are in excess, then we can say that the excess materials have polluted the environment. Under natural conditions if this happens, gradually the

homeostatic condition will be naturally restored. But, if it is due to deliberate human activity, natural recovery will be difficult and ecological disasters may occur. In countries like Bangladesh, pollution problems mostly originate from 'abuse, misuse or cocktail' 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. Together with these, local wastes are added, thus making the water saturated and at times oversaturated with organic and inorganic pollutants. The wetlands of the whole country are the dumping grounds for these sediments and pollutants and flushing out of materials to the sea is quite slow. The result is serious deterioration of the aquatic resources. So far as the pollution study of the wetlands is concerned, Bangladesh may be said to be at its exploratory or identifying stage. Most of the knowledge in this regard are based on the results obtained in other advanced countries. The data obtained by our local experts are only partial. Whether it is domestic, agricultural, agrochemical, industrial or other sources of pollution which we may refer, we can tell about the chemical nature of these pollutants but their actions/effects on the biology of the aquatic organisms have not been studied in detail. No continual monitoring devices have been set up to follow and pursue the courses of the pollutants from the sources to the wetlands systems.

Major pollution sources of the aquatic environments are:

a) domestic wastes, sewage and garbages;
b) agricultural wastes, pesticides, insecticides and fertilizers;
c) industrial effluents from different heavy industries, mills, factories, cottage industries containing various pollutants; and
d) biological origin, growth of excessive microbial organisms causing health hazards, oxygen depletion, etc.

Most of the industries and factories are situated on the banks of the rivers or very close to a river system and the effluents and wastes are mostly thrown directly into the river water without any treatment to make the effluent 'safe' from the biological standpoint. As a result, the depletion of the biotic components near the sources is observed. A preliminary survey near the tanneries in Dhaka on the river Buriganga will reveal this fact. As the rivers are connected with each other and different mills and factories are situated on their banks, the recovery time of the water from the effects of the effluent is very low, and during the non-monsoon period, conditions become worse.

Chemical Pollution

Main sources of chemical pollutants in Bangladesh and also in West Bengal and Assam in India are similar and these are as follows:

a) Agricultural: fertilizers, insecticides and pesticides; and
b) Industrial: based on renewable and non-renewable raw materials, production of organic and synthetic materials and their wastes and by-products.

The chemical nature of the above materials and their effects on the living organisms in an aquatic medium are fairly well-known but systematic studies have not been done, except for a few cases in this country.

In Bangladesh the chemical characteristics and nature of the industrial and agricultural pollutants have been discussed by the chemists (Khair 1988, Malik 1988) and a fairly good idea can be had from the publication by S.Z. Haider, (Ed.), 1988. About the pollution of the *haors*, *baors* and the *beels*, no detailed information is available and, as far as is known, no systematic work on the effects of pollutants and eutrophication on the biological productivity and biodiversity of the wetland ecosystem has been carried out in Bangladesh. However, the problems of heavy metals and pesticide contamination in *beel* ecosystems in the adjacent regions of India have been discussed by Joshi (1989).

Non-point sources of pollutants

The chemical pollution of the waters in Bangladesh has been studied at different points. In the agricultural sector, the amount of chemical fertilizers used is reported to be about a million tons and chemical pesticides is estimated at about 3,000 tons annually (Safiullah and Mafizuddin 1988). This has almost doubled the crop yield from the early sixties to the mid eighties. But the indiscriminate use of fertilizers and pesticides may, in the future, lead to disaster.

Insecticides: Three types are used now in Bangladesh:

a) organochlorine (DDT, Dieldrin, keep their potency for indefinite period);
b) (Melathion) organophosphate; and
c) (Baygone) carbamate.

Both (b) and (c) have short-lived action.

Organochlorine affects the nervous system and are extremely non-biodegradable and hazardous to environment. These are (DDT, Dieldrin) extensively used in Bangladesh. The organophosphates block nerve transmissions and are more poisonous, while the carbamates are degradable and to some extent safe (Safiullah and Mofizuddin 1988). All the insecticides are poisonous; some show acute toxicity (e.g., Parathion), while others are of chronic type with long-term slow action (organochlorine type). Most of these have side effects, i.e., besides insects these can also destroy fish and other useful organisms in the rivers and the marshes. These chemicals react with water, O_2 and other environmental components and produce still more dangerous or long-lasting harmful poisons and these could be transported from the source point to distant places through rivers. Several insecticides or their changed forms may be biomagnified in plants and animals through the food chain and ultimately cause severe harm to humans.

Fertilizers: In Bangladesh most commonly used fertilizers are nitrogenous urea and TSP. Urea is highly soluble in water, so when it is used under the condition of irrigation or during monsoon, a significant 'percentage', about 40% of it, is washed into the riverine system, *baors* and *beels* (Safiullah and Mafizuddin 1988). The biological consequences are:

a) the luxuriant growth of hydrophytes including algal bloom, followed by their death and decomposition giving rise to anoxic condition resulting in fish mortality;
b) BGA during decomposition releases poisonous cyanide compounds and give off obnoxious H_2S;
c) formation of nitrite from ammonium can cause carcinogenic condition in higher animals. Safiullah and Huq (1986 in Safiullah and Mofizuddin 1988) have found that the use of urea in Chalan Beel area is much above national average and unusually high nitrite concentration in groundwater used for drinking was observed. This shows that the people are more vulnerable in that area where indiscriminate use of urea is practiced.

Excessive use of phosphate fertilizers may also lead to surface eutrophication similar to nitrogenous fertilizers.

Others: Lead from road surface run-off and mercury from atmospheric fallout are the non-point sources of metal contamination in the *beel* ecosystems. Mercury could also come from the caustic soda preparation plant by electrolysis of brine using Hg-cell. Acid rain is another non-point source of pollution (see Hussain 1988, Rahman 1988).

Industrial

Existing industries are not properly equipped with any effective pollution control measure and as a result the waste disposal has already threatened the riverine environment in which most of these industries are located. Safiullah and Mofizuddin (1988) have discussed the nature of pollutants from some selected industries, such as, paper and pulp industry with sulphite liquor as the waste product; caustic soda industry, from which mercury may be released as a serious toxic metal pollutant; tannery industry on the river Buriganga from which chromium +6 may contaminate the water and may affect the fish and other vertebrates; fertilizer industry discharges effluents into the river without any pretreatment. This causes extensive eutrophication over a large area of surface water surrounding these plants. When the spent catalyst and copper compounds used are dumped in the ground the heavy metals eventually find their way into ground water and the riverine system and cause serious pollution (another non-point source).

Hossain (1988) has analyzed the sludge formed in the CO_2 absorption section in the Urea Fertilizer Factory at Ghorasal and found that it contains 40% arsenic on an average. There is a huge quantity of such sludge accumulated and its disposal without removing the arsenic is a burning problem. The threat of arsenic poisoning of the water system is really serious in terms of bioactivity of the entire area.

Khair (1988) and Malik (1988) have discussed the nature of the chemical pollutants from the following selected industries : urea, TSP, textile, paper and pulp, refinery, tannery, viscose rayon, electroplating, caustic chlorine, pesticides, sugar, copper, chloro-alkali, cement, aluminium, plastic, pharmaceutical, paints and varnish. Thay

have mentioned the methods of monitoring different heavy metal pollutants from different sources and some control methods.

Alam (1988) proposed a new analytical method (by using atomic absorption spectrophotometry) for the separation and determination of the level of trace elements like cadmium, zinc, iron, cobalt, lead, chromium and nickel present in the surface water systems in and around Dhaka and adjacent areas with seasonal variation, *i.e.*, in the rivers Buriganga, Sitalakhya and Balu covering the stations at Hazaribagh, Pagla, Narayanganj and Ghorasal and also in the Ramna, Dhanmondi and Gulshan lakes within Dhaka city. He found that Cd (II) concentration in rainy season is higher at Hazaribagh, where there is a tannery complex, than at other stations studied in the order of: Hazaribagh > Ghorasal > Pagla > Narayanganj. In dry season this order was Pagla > Hazaribagh > Narayanganj > Ghorasal. In both the seasons Zn (II) was higher at Hazaribagh and least at Pagla in the order Hazaribagh > Ghorasal > Narayanganj > Pagla. Iron (Fe(III)) during these seasons was found in the order Pagla > Narayanganj > Hazaribagh > Ghorasal when lead (Pb(II)) was in the order Hazaribagh > Pagla > Narayanganj > Ghorasal during rainy season and reverse during dry season. Cr (III)in rainy season : Hazaribagh > Narayanganj > Ghorasal > Pagla and in dry season Narayanganj > Hazaribagh > Pagla > Ghorasal. Co(II) was higher at Hazaribagh than at Narayanganj in dry season. There is indiscriminate dumping of wastes into these rivers by the public and the industries. Innumerable municipal drains carrying sewage and sullage find their way into these rivers, thereby creating problems of health hazard and biological productivity. Rapid growth of industrialization is taking place in Bangladesh and with that the problem of air, water and soil pollution is also increasing and will ultimately cause deterioration of aquatic ecosystems and productivity.

So far as the general physiography and geomorphology (limnological parameters) are concerned the wetlands of Bangladesh are intricately connected with each other in some way through riverine systems, especially during monsoon flood period and therefore the limnological parameters operating therein will show more or less similar pattern in respect of primary and secondary productions, ecological pyramids and interaction between biotic and abiotic components. The effects of organic and inorganic pollution and eutrophication will also be similar; the difference will only be in degrees, i.e. more quantitative than qualitative.

Biological pollutants

Besides chemical pollutants, pollution by the excessive growth of microbial organisms is posing a serious threat to the health conditions of humans and fishes and birds.One aspect of limnology is the study of water quality. Clean water is free from any excess organic, inorganic or microbial contamination. With regard to the latter component, bacteria, bluegreen and other algae play their important role, not only as decomposers and primary producers, but at times they create eutrophication, anoxic condition, fish death and even human illness, and are largely responsible for deterioration of the water quality for drinking, bathing and other domestic uses.

Raw sewage contamination in water systems is the single major factor for the recurrence of various diseases. Having innumerable water systems Bangladesh is perennially plagued with as many as 32 waterborne diseases including cholera, dysentery, diarrhoea, typhoid, shigellosis etc. The diseases of fish, waterfowl, cattle and other animals are also known but not much studied. With respect to human diseases e.g. cholera, shigellosis, *E. coli* diarrhoea and rotavirus diarrhoea dysentery etc. the relationship between eutrophication, hydrophytes and the pathogenic bacteria has been discussed by Islam and Islam (1992). It has been reported that several bacteria remain attached with some hydrophytes (Table 2) and bluegreen algae, particularly during non-epidemic period and these pathogens could spread by some free floating hydrophytes and phytoplankton. Inter-village transmission of cholera pathogen takes place by the connecting waterways. Not only the diarrhoeal disease but diseases affecting skin and eyes are caused by different algae. Thus the role of hydrophytes and phytoplankton in the spread and cause of diseases in Bangladesh is an important aspect of limnology and should be studied with due emphasis.

Table 2: **Relationship between Hydrophytes and Bacteria**

Hydrophytes	Bacteria attached
Eichhornia crassipes	*Vibiro* spp., *Plesiomonas shigelloides*, *Aeromonas hydrophyla*
Pistia stratiotes	*Aeromonas sobria*
Alternanthera philoxeroides	*Aeromonas caviae*
Phytoplankton	*Aeromonas spp. and Plesiomonas shigelloides*
Anabaena variabilis	*Vibiro cholerae* 01

Source: Islam and Islam, 1993

No systematic studies have been made on this aspect of limnology which includes sanitary engineering, and other aspects associated with the disposal of sewage and domestic wastes. The fruits of *Trapa bispinosa* (*Paniphal*), *Euryale ferox (Makhna)* and lotus and the petiole of water lily (*Shapla*) are eaten raw directly from the contaminated water by the people and they become the victims of diarrhoeal diseases. Many blue-green algal blooms or the blooms caused by *Euglena*, *Trachelomonas* or *Dinoflagellates* or diatoms may cause not only oxygen depletion of the water and thereby creating problems for fish growth but several of these secrete toxigenic substances in the water which are responsible for various ailments in the human body such as skin irritation, eye trouble or if they enter into the body may affect the nervous system. No field investigation in this regard has been made in Bangladesh.

POLLUTANTS AND POLLUTION EFFECTS ON WETLANDS

Pollutants from the industrial and agricultural sources (point sources) may be checked by adopting suitable treatments or diversion, but those of non-point sources (i.e., entry to the *beels* through land runoff or atmospheric fallout) are difficult to control through conventional methods of treatment. These substances are highly persistent and thereby contaminate the entire biogeochemical cycle of the *beels* and tanks.

Biological factors also contribute to the ultimate effect of these pollutants, which may remain in low concentrations. However, through bioaccumulation and biomagnification by fish and other aquatic organisms their toxins ultimately enter the human body through the food chain with serious harmful effects. Metals and pesticides have the greatest potential for biomagnification in the aquatic food chain. For their chemical derivatives and residues see Joshi (1989) and Safiullah and Mafizuddin (1988).

The toxicity of the pesticides has been tested on fish, prawn and fish-food organisms. It was found that the latter, i.e. plankton and benthos, are very sensitive to these chemicals as compared to fish, thus adversely affecting the latter also (Joshi 1989). Metals vary in toxicity, which depend on environmental conditions and their specification. In combination metals show higher toxicity than individual metals. Zn, Cu and Cr in combination have shown several times more toxicity to *Oreochromis mossambicus* than the individual metals (Joshi 1989).

Whatever industries we already have are enough to render the entire wetlands of Bangladesh including the river systems 'biologically dead' if the conditions now prevailing are allowed to continue further. Many of our industries are creating hazardous conditions in their locality with continual disposal of toxic and harmful materials.

Consider the industrial effluent containing acids, heavy metals, ammonia, toxic substances, etc., directly thrown untreated into the water and together with these are added the agrochemical substances (insecticides, pesticides, fertilizers etc.) and the huge quantity of domestic wastes making the situation worse. Consider the pressure of the human population for food, shelter, fuel and clothing. Sanitation problem alone has created enormous health disaster, besides the damage of the biological environment of useful organisms. Over 30,000 metric tons of human excreta are defaecated daily in the open in the country and all this raw sewage ultimately contaminates the water making it polysaprobic and also unsuitable for human use due to eutrophication.

For further information regarding the nature of industrial pollutants see Eunus (1988), Khair (1988), Hussain (1988), Rahman (1988), Mahmood (1988) and Haider (1988a).

CONSERVATION OF FRESHWATER WETLAND ECOSYSTEMS

The wetland ecosystems have two complementary phases, aquatic and terrestrial (during dry season). During the latter phase it may be used for agriculture or for grazing and

both benefit the fishery by enriching the aquatic phase during flood. The former may, however, lead to cultural eutrophication.

Freshwaters are perhaps the most vulnerable of habitats through their use by humans as:

a) sinks for many products of human activity in their catchment;
b) natural drains for the removal of waste to the sea; and
c) a valuable and essential resource for various purposes.

Aquatic ecosystems have been changed by man for various reasons. For example,

a) to control water-borne diseases;
b) to establish farmland (but without the knowledge of the consequence of pollution and eutrophication); or
c) to prevent flood damage to property built on natural floodplains through stupidity or greed (Moss 1980) i.e., against the law of nature and by violating ecological principles.

Conservation of natural ecosystems can be defined in various ways (Moss 1980). For example,

a) it is a process of maintaining, through whatever means necessary or available, the maximum diversity of organisms and ecosystems;
b) it is the total management of the rural areas for the fair and equal benefit of all groups which have a direct interest in their use;
c) it amounts to making the best of what is left after waterways and their catchments have been used for the obvious needs of the society; and
d) legislation is essential for reservation of particularly interesting areas.

In spite of these, more wetlands/waterways are being degraded and lost than created and restored. The agents of change are varied but two are of widespread significance:

a) Drainage involving river dredging, building of flood banks and clearance of macrophytes; and
b) Eutrophication causing threats of toxic pollution, overfishing, introduction of exotic species and recreation pressure.

Most methods are affected by a complex of inter-connected factors. As lakes become more fertile there is a decline in the diversity of fish community, while some tolerant species may become very productive. The reasons for the changes in the fish yields of any lake/wetland may be due to intensive selective fishing, modification of the tributary rivers, introduction of exotic species and eutrophication.

STRATEGIES FOR CONSERVATION OF WETLAND RESOURCES

The uses of water and associated biological problems have strong utilitarian and economic undercurrents. The conservation of natural aquatic communities, in contrast, seem something of a luxury. This is partly true to some extent, but the costs of

seriously disrupting natural freshwaters may outweigh the benefits of doing so (Moss 1980). For conservation of wetland resources the following approach/system may be considered:

a) An ecosystem approach is needed to ensure that the water use, land use pattern, pollution and modification of the river system do not impair the trophic structure and functions of the ecosystems.

   In *beels* and *haors* ecosystems, which have a limited water spread area, large scale abstraction of water for irrigation leads to drastic variations in the water quality (Ahmed *et at*.1990.)

   The wetland waters are used for irrigation, industry, thermal power generation, potable supplies and fish production under natural system. Of these uses, fish production will be given priority over others under the ecosystem approach and this should be followed by (i) urban and industrial waste management practices, (ii) judicious use of fertilizers in agriculture and (iii) afforestation and social forestry programmes.

   In addition, there is also a need for catchment modification for the control of soil incursion, transport of fertilizers and pesticides into the *beels*, *haors*, etc., through agricultural runoff. The best management practices (BMP) are needed to control and treat pollutants (Joshi 1989), and adopt suitable horticultural practices for making grassed waterways, retention ponds and terraces for checking soil erosion. These can reduce pollutant losses in runoff and these practices provide the best cost-effective and acceptable technology for the control of soil erosion and non-point source phosphorus losses.

   Natural ecosystems are in a continuous process of change and adjustment through natural selection on the organisms comprising them and a system of maximum homeostasis is maintained under natural physical and chemical environment. There is nothing to 'improve' such an undisturbed ecosystem and under this condition fish growth is moderate or aquatic macrophyte beds are extensive. But attempts to increase the fish growth or clear the weed beds will always result in a chain of repercussions which is very expensive to counteract.

b) Geomorphological systems should be taken into consideration. The river floodplain is essential for the efficient and natural disposal of occasional high discharges. But attempts to change its use from this purpose to farming (or otherwise) have necessitated the raising of the height of the river banks. In cost-benefit analysis, so far as the general public is concerned, the balance might be very unfavourable(Moss 1980).

   For conservation measures each ecosystem or habitat with its geomorphological, physical and chemical background must be known by a limnologist to diagnose the problems and suggest solutions.

c) It is relatively difficult to have these solutions implemented, because implementation is by and large a political and social matter. Those who are responsible for and are involved in taking decisions may be either unable or unwilling to grasp the technical issues and the long-term economic implications. This conservation and restoration of the freshwater wetlands in Bangladesh, as elsewhere, cannot be achieved without a study of politics and sociology and it should not be outside the scope of the scientist concerned with the freshwater environment.

RECOMMENDATIONS

Pollution abatement conservation measures

The natural pollutants are generally biodegradable but there is a limit to their quantity which could be disposed of efficiently by the microbes. If the artificial man-made pollutants, many of which are non-biodegradable, are added to this the habitat or any ecosystem may collapse and will not function properly. There will be permanent loss of many species of flora and fauna, and whatever tolerant species survive, their growth will be stunted and productivity reduced.
The following measures are recommended:

a) The problem of pollution and eutrophication is multidimensional. The main issue lies with the people's ignorance on the one hand and unwillingness on the other, and with the government's failure to appreciate the whole spectrum of biogeochemical phenomena and technological advancement and to implement legal action wherever and whenever it is needed.
b) Awareness alone will not do much. Individually, people may be aware of the fact but collectively they will not do anything unless there are guidelines and pressure from the government. Fighting against any kind of pollution is a continuous process, which should be followed zealously as a routine matter.
c) In the agriculture sector chemical fertilizers may be replaced by biofertilizers wherever possible. Biodegradable insecticides should replace the non-biodegradable ones. Biological control should replace chemical control as much as possible. Research in this field should be encouraged. Several plant species, such as water hyacinth and duckweeds (*Lemna, Spirodela, Wolffia*), and *Pistia* should be used for continuous growth in organically polluted waters to purify the water and these in turn should be utilized for food, feed or fodder. Species tolerant to particular chemical(s) should be identified as indicator species.
d) Indiscriminate use of any fertilizer must be stopped.
e) Proper sanitary measures must be taken not only in urban areas, but also in rural areas and inside the transport systems. Faecal contamination is a major source of health hazard and eutrophication. In a densely populated country like Bangladesh this aspect should be given priority in tune with the slogan 'prevention is better than cure'.

f) Government must ensure that the industries are capable of taking adequate measures to dispose of all kinds of wastes and that they are following the rules and regulations strictly.
g) Population explosion has direct impact on pollution explosion and the people should be motivated in the right direction to reverse the deteriorating situation. Time is running against us and we must act on a priority basis.
h) People should be made aware of the causes of eutrophication and its consequences, particularly its hazardous effect on human health. Input-output modelling with reference to phosphorus and nitrogen loading in relation to eutrophication as suggested by Vollenweider (1975, 1976) is necessary.
i) Adequate supply of water to the habitat is essential. Quality and quantity of the water must be maintained throughout the year in all kinds of wetlands.
j) Good circulation of nutrients within the wetlands should be maintained. Maximum utilization of solar energy and of the inorganic nutrients by the producers must be ensured so that subsequent trophic levels and the flow of energy are not seriously disturbed.
k) Water should remain free from eutrophication, pollution or contamination by any toxic material (synthetic, heavy metals, etc.).
l) Entire catchment area and the surrounding landscape should be protected against runoff over the land surface, for which people's awareness about Environmental Impact Assessment (EIA) is required (Rahman 1988).
m) For wetland marsh limnology, it is not just the primary producers and fish production that are important but also the other biotic components.
n) Introduction of any exotic species must not be encouraged.

o) Regular continual monitoring for overall assessment should be maintained at any cost.
p) Maintenance of the good quality of the wetland waters should be the focal point around which all developmental activities should grow.
q) Excessive growth of the macrophytes should be checked by preventing entry of excess nutrients into the wetlands.

Limnological Research Need

For the efficient biological productivity of the freshwater habitats, the following aspects should be considered as part of the limnological requirements:

a) The food-chain components must be studied for maximum yield of fish, fish food and other biota.
b) Research on waste utilization and waste recovery processes is needed. It should be practiced at all the sources and certain chemicals be recycled or converted into fertilizers or used for other purposes. Reutilization of the agricultural residues through bioconversion to industrial products is essential (Choudhury 1988).
c) Environmental monitoring through biological and microbial or genetical processes be encouraged for controlling the insect pests instead of using toxic chemicals. For further discussion on the topic see Haider (1988).

d) An institute for analyses of pollutants and continual monitoring system should be established by the industrial corporations (Malik 1988).
e) Workable effluent quality standards be formulated to protect the natural water resources from degradation (Alam 1988).
f) Efforts should be made to develop indigenous methods to maximize production through industries and modern technology on the one hand and minimize damage to the environment on the other.
g) Research should be done to establish the toxic effects of BGA or other bloom-forming algae on human health or on fish or animals and to know the chemical nature of the toxins produced by them.

CONCLUSION

There are large numbers of recommendations and suggestions given by different authors regarding conservation of wetlands and other areas within Bangladesh. See Sarker and Husain (1990, p.199). For water quality, see Hoque and Hoque (1990), Rahman and Bisset (1990), etc.

Regarding awareness of the people about the environment, environmental pollution and eutrophication, the following steps should be remembered:

(a) first step is a 'cry in the wilderness';
(b) second step is the moment to listen and to think; and
(c) third step is the 'time for action'.

As time is running out very fast, we should try to follow all these three steps simultaneously and, as said before, all the relevant authorities and the specialists of different disciplines should join hands and be involved in maintaining and conserving the environment on the one hand and while exploiting its resources to the optimum not to upset its equilibrium on the other.

With its dense population and excessive poverty, Bangladesh is unable to make any tangible progress due to low productivity through photosynthesis and ecological pyramids, excessive pollution effects and narrow politics and prejudices. It is high time that strong propaganda be mounted about the environment as a whole through all the public media available at our disposal. No development is, therefore, possible without proper knowledge and assessment of seven Ps - *population*, *poverty*, *pollution*, *productivity* (biological), *politics*, *progress* and *prejudices*.

REFERENCES

Ahmad B., M. Rahaman and A. Bottrall. 1990. Surface water abstraction for irrigation. pp120-135, In: A.A. Rahman et al. (eds). *Environmental Aspects of Surface Water Systems of Bangladesh*. University Press Ltd. Dhaka.

Akonda, A. W. 1989. Bangladesh. pp. 541-581. In: D.A. Scott (ed.). *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge, UK.

Alam, A.K.M.N., M.A. Islam, M.F.A. Mollah and M.S. Haq. 1987a. Status of zooplankton in newly constructed ponds and their relation to some meteorological and limnological factors. *Bangladesh J. Fish.* 10(1) : 83-88.

Alam, A.K.M.N., M.F.A. Mollah, M.A. Islam, M.S.Haq and M.M. Haque. 1987b. Status of phytoplankton in newly constructed ponds and their relation to some meteorological and limnological factors. *Bangladesh J. Fish.* 10(1) : 75-81.

Alam, A.M. Shafiqul 1988. Application of ion-exchange and atomic absorption spectrophotometry in industrial effluent analysis. *Proc. Symp. Mon. Env. Syst.* Bose Centre for Advanced Stud. Res. Dhaka University. pp143-151.

Ali, S. 1980. Studies on benthic macroinvertebrates with particular emphasis on Oligochaetes.*Ph.D. Thesis*, Dhaka University. pp308.

Ali, S and F.Begum. 1979. The chironomid larvae of Dhaka city. *J. Asiatic Soc. Bangladesh (Sci.).* 5 (1) : 89-92.

Ali, S., A.S.M. Haque, J.R. Oppenheimer and K.M.S. Aziz. 1978. Studies on bottom fauna of three fish ponds in Dhaka city, Bangladesh. *Bangladesh J. Zool.* 6(1) : 43-55.

Ali, S.I. 1990. Haor basin ecosystem. pp79-92. In: A.A. Rahman, S.Huq and G.R. Conway (eds.). *Environmental Aspects of Surface Water Systems of Bangladesh*. University Press Ltd., Dhaka.

Ameen, M., Z.N.T. Begum, A. Mustafa and S.Ali 1988. Seasonal and dial profile of temperature, light penetration, dissolved oxygen and free carbon dioxide of fish from south of Bangladesh. *Bangladesh J.Zool.* 3:1-8.

Babu Lal. 1989. Energy flow in beel ecosystem. pp65-75. In: *Bulletin No.63*, Central Inland Capture Fisheries Res. Inst., Barrackpore, W.Bengal, India.

Begum, Z.N. Tahmida and M.Z.Hossain 1993. Physico-chemical aspects and phytoplankton of a pond receiving textile industrial effluents. *Dhaka Univ. J. Biol. Sci.* 2(1): 93-99.

Begum, A., G.Mustafa, S.Ali and K.Ahmed. 1989. Studies on limnology in a minipond and growth of *Tilapia (=Oreochromis) nilotica*. *Bangladesh J. Zool.* 17(1): 35-45.

Benergea, D. 1988. Chemical pollutants in the environment and effects of chemical poisons on human health, behaviour and mentation. (Abstract). *Proc. Symp. Mon. Env. Syst.* Bose Centre for Adv. Stud. Res. Dhaka. University. pp233-234.

Brook, A.J. 1971. The phytoplankton of Minnesota lakes - A preliminary survey. Water Resources Res. Centre, Univ. *Minnesota Bull. No. 36* : 1-12.

Bruhl, P. and K. Biswas. 1926. Algae of the Loktak Lake. *Mem. Asiatic Soc. Bengal* 8(5):257-315 + 16 pls.

Catling, H.D., M.R. Martinez and Z. Islam. 1981. Survey of algae associated with deepwater rice in Bangladesh. *Cryptogamie, Algologie* 11 (2) : 109-121.

Choudhury, N. 1988. Reutilization of the agricultural residues through bioconversion to industrial products. *Proc. Symp. Mon. Env. Syst.* Bose Centre for Adv. Stud. Res., Dhaka Univ.: 232-233.

Eunus, M.M. 1988. Monitoring the environmental systems of chemical industries particularly in fertilizer industries. *Proc. Symp. Mon. Env. Syst.* Bose Centre Adv. Stud., Dhaka Univ.: 93-99.

Haider, S.Z. (ed.). 1988a Monitoring of environmental systems of chemical industries in Bangladesh. *Proc. Nat. Symp.*, Bose Centre for Advanced Study and Research, Dhaka Univ. pp. 245.

Haider, S.Z. 1988b. Research requirements in monitoring of environmental systems for industrial development in Bangladesh. *Proc. Symp. Mon. Env. Syst.* Bose Centre for Advanced Stud. Res., Dhaka Unv. : 191-196.

Hoque, B.A. and M.M. Hoque. 1990. Faecal pollution of surface water and diseases in Bangladesh. pp. 180-187. In: A.A. Rahman, S. Huq and G.R. Conway (eds.). Environmental Aspects of Surface Water Systems of Bangladesh. University Press Ltd.Dhaka.

Hossain, M.A 1988. Monitoring and analysis of waste sludge of urea fertilizer factory, Ghorasal. *Proc. Symp. Mon. Env. Systems*. Bose Centre for Advanced and Res., Dhaka University: 127-132.

Husain, A. 1988. Acid rain - public perception and solutions. *Proc. Symp. Mon. Env. Systems*. Bose Centre for Advanced and Res., Dhaka University : 153-156.

Islam, A.K.M. Nurul. 1969. A preliminary report on the phytoplankton and other algal flora of Chittagong Hill Tracts. *J. Asiatic Soc. Pakistan* 14(3) : 343-363 + 1-13 pls.

Islam, A.K.M. Nurul, Anatunnesa and A.K.Y. Haroon. 1980. Hydrobiological studies in and around Naogaon, Rajshahi. *Dhaka University Stud.* B, 28(2) : 31-47.

Islam, A.K.M. Nurul and Z.T.Begum. 1970. Studies on the phytoplankton of Dhaka District. *J. Asiatic Soc. Pakistan* 15(3): 227-271 + pls. 1-8.

Islam, A.K.M. Nurul and A.R. Chowdhury. 1979. Hydrobiological studies of Dhanmondi lake, Dhaka. II. Phytoplankton. *J. Asiatic Soc. Bangladesh (Sci.)* 5:47-57.

Islam, A.K.M. Nurul and A.K.Y. Haroon.1975. Limnological studies of the river Buriganga. II. Biological aspect. *Dhaka Unv. Stud. B*, 23(1):25-44.

Islam, A.K.M. Nurul, A.K.Y.Haroon and K.M. Zaman. 1974. Limnological studies of the river Buriganga.I. Physical and chemical aspects. *Dhaka Univ. Stud. B.*, 22(2):99-111.

Islam, A.K.M. Nurul and M.S.Islam. 1993. Hydrophytes, eutrophication and diseases. In: Tilzer, M.M and M.Khondker (eds.). *Hypertrophic and Polluted Freshwater Ecosystems: Ecological Bases for Water Resources Management*. Proc. Int. Symp. Limnol. (in press)

Islam, A.K.M. Nurul and M.Khatun. 1966. Preliminary studies on the phytoplankton of polluted waters. *Sci. Res.* 3:94-109.

Islam, A.K.M. Nurul and M.Khondker. 1991. Preliminary limnological investigations of some polluted waters covered by duckweeds. *Bangladesh J. Bot.* 20:73-75.

Islam, A.K.M. Nurul, M.Khondker, Ashrafi Begum and Nasima Akter. 1992. Hydrobiological studies in two habitats at Dhaka. *J. Asiatic Soc. Bangladesh (Sci.)* 18(1):47-52.

Islam, A.K.M. Nurul, M.Khondker and S.Haque. 1991. Euglenoid algae of four polluted ponds in and around Dhaka city. *Bangladesh J. Bot.* 20(1):7-15.

Islam, A.K.M. Nurul and F. Mendes. 1976. Limnological studies of a *jheel* in Sher-e-Bangla Nagar. *Dhaka Univ. Stud. B* 24(2):63-71.

Islam, A.K.M. Nurul and L. Nahar. 1967. Preliminary studies on the phytoplankton of polluted waters. II. Blue-green algae. *Sci. Res.* 4(2&3):141-149.

Islam, A.K.M. Nurul and S.N. Paul, 1977. Limnological studies on *Wolffia arrhiza* (L.) Wimm. *J. Asiatic Soc. Bangladesh (Sci.)* 3(1): 111-123.

Islam, A.K.M. Nurul and N. Paul. 1978. Hydrobiological study of the Haor Hakaluki in Sylhet. *J. Asiatic Soc. Bangladesh (Sci.)* 3(2): 83-91.

Islam A.K.M. Nurul, M.Rahman and A. Rahman Choudhury. 1979. Hydrobiological studies of Dhanmondi Lake, Dhaka. I.Macrophytes and benthic flora. *J. Asiatic Soc. Bangladesh (Sci.)* 5(1): 59-75.

Islam, A.K.M. Nurul and J.K. Saha. 1975. Limnological studies of the Ramna lake at Dhaka. *Dhaka Univ. Stud. B* 23(2):39-46.

Islam, A.K.M. Nurul and K.M. Zaman. 1975. Limnological studies of the river Buriganga. III. Biological aspect. *J. Asiatic Soc. Bangladesh (Sci.)* 1(1) : 45-65.

Joshi, H.C. 1989. Problems of heavy metals and pesticide contamination in beel ecosystems. pp.95-101. In: Central Inland Capture Fish. Res. Inst., Barrackpore, W.Bengal, India.

Khair, A. 1988. Monitoring and control of toxic chemical in chemical industries. *Proc. Symp. Mon. Env. Syst.* Bose Centre of Advanced Stud. and Res. Dhaka Univ. : 133-142.

Khaleque, M.A. and M.A. Islam. 1983. A comparative study on the effect of some physico-chemical parameters on the growth of major carps in two ponds. *Bangladesh J. Aquaculture* 2-5(1):73-81.

Khatun, M. 1963. Preliminary studies of phytoplankton of polluted waters. *M.Sc. Thesis*. Dept. of Botany, Dhaka University.

Khondker, M., A.K.M. Nurul Islam, Z.N.T. Begum and S Haque. 1990. Limnological studies of four polluted ponds in and around Dhaka city with reference to indicator species. *Bangladesh J. Bot.* 19:51-63.

Khondker, M., A.K.M. Nurul Islam and R. Islam. 1988. Studies on the primary productivity of Dhanmondi lake. *Dhaka Univ. Stud. E* 3:15-21.

Khondker, M. and L. Parveen. 1992a. Species composition, standing crop and seasonality of phytoplankton in a hypertrophic lake. *Dhaka Univ. Stud. E* 7(1):49-55.

Khondker, M and L. Parveen. 1992b. Study on the physical and chemical limnology of a shallow, hypertrophic artificial lake. *Bangladesh J. Sci. Res.* 10(1):9-16.

Khondker, M and S.Rahim. 1991. Investigation on the water quality of Dhanmondi lake. I. Physicochemical features. *Bangladesh J. Bot.* 20(2):183-191.

Mahmood, A.J. 1988. Environment of Chemical Industries of Bangladesh: its monitoring and management. *Proc. Symp. Mon. Env. Systems*. Bose Centre for Advanced Study and Res., Dhaka Univ. : 171-77.

Mahmood, N. 1986. Hydrobiology of Kaptai Reservoir. *Final Report*. FAO/UNDP contract No.DP/BGD/79/615-4/FI.pp.190.

Malik, K.M.A. 1988. The functions of an analytical laboratory for environmental monitoring in chemical industries. *Proc. Symp. Mon. Syst.* Bose Centre for Advanced Stud. Res., Dhaka Univ. : 187-190.

Mitra, K. 1989. Limnological features of *beels* - Macrovegetation dynamics. pp.54-61. In: *Bulletin No. 63*. Central Inland Capture Fisheries Res. Inst. Barrackpore, W.Bengal, India.

Moss, B. 1980. *Ecology of Freshwaters*. Blackwell Sci. Publ. Oxford, London. pp332.

Mumtazuddin, M., M.S. Rahman and G.Mostafa. 1982. Limnological studies of four selected rearing ponds at the Aquaculture Experiment Station, Mymensingh. *Bangladesh J. Fish.* 2-5(1-2):83-90.

Nahar, L. 1963. Limnological studies of some polluted ponds at Dhaka. *M.Sc. Thesis*. Dept. of Botany, University of Dhaka.

Oppenheimer, J.R., M.G. Ahmed, A. Huq, K.A. Haque, A.K.M.A. Alam, K.M.S. Aziz, A. Ali and A.S.M.M. Haque. 1978. Limnological studies of three ponds in Dhaka, Bangladesh. *Bangladesh J. Fish.* 1:2-28.

Pathak, V. 1989. Limnological features in *beels* - abiotic factors. pp43-53. In: *Bulletin No.63*. Central Inland Capture Fisheries Res. Inst., Barrackpore, W. Bengal, India.

Patrick, R. 1951. A proposed biological measure of stream conditions. *Proc. Int. Assoc. Theor. Appl. Limn.* 11 : 229-307.

Prescott, G.W. 1939. Some relationships of phytoplankton to limnology and aquatic biology. *Amer. Assoc. Adv. Sci.* 10:65-78.

Rahman, M.M 1988. Gaseous pollutants in the atmosphere and their monitoring. *Proc. Symp. Mon. Env. Systems*. Bose Centre for Advanced Study and Res., Dhaka Univ. : 157-169.

Rahman, A.A. and R. Bisset. 1990. Conceptual basis for environmental assessment of water systems. pp205-231. In: A.A. Rahman *et al.* (eds.). *Environmental Aspects of Surface water Systems of Bangladesh*. Univ. Press Ltd., Dhaka.

Rother, J.A. and B.A. Whitton. 1988. Ecology of deepwater rice-fields in Bangladesh 5. Mineral composition of the rice plant and other aquatic macrophytes. *Hydrobiologia* 169:57-67.

Safiullah, S. and M. Mofizuddin 1988. Biogeochemical parameters in river waters in the industrial belts of Bangladesh. *Proc. Symp. Mon. Env. Systems*. Bose Centre for Advanced Study and Res. Dhaka University: 69-82.

Sarker, M.S.U. and K.Z. Husain. 1990. Conservation of wetland wildlife of Bangladesh. pp188-199. In: A.A. Rahman, S. Huq and G.R. Conway (eds.). Environmental Aspects of Surface Water Systems of Bangladesh. Univ. Press Ltd., Dhaka.

Sharif, M.I., A.A. Rahman and S. Huq. 1988. Study of chromium levels and oxygen demand in the water bodies of Hazaribag area of Dhaka City. (Abstract).p232. *Proc. Nat. Symp. Mon. Env. Systems in Bangladesh*. Bose Centre for Advanced Study and Res. Dhaka University.

Sufi, G.B. and D. Farooque. 1983. Water quality of fish ponds in Dhaka city in relation to fish production. *Dhaka Univ. Stud. B* 31(1):61-66.

Vaas, K.K. 1989a. Beel fisheries resources in West Bengal. pp29-35. In: *Bulletin No.63*. Central Inland Capture Fisheries Res. Inst. Barrackpore, W.Bengal, India.

Vaas, K.K. 1989b. Productivity status of beels in India. pp57-64. In: *Bulletin No.63*. Central Inland Capture Fisheries Res. Inst. Barrackpore, W.Bengal, India.

Vollenweider, R.A. 1975. Input-output models with special reference to the phosphorus loading concept in limnology. Schw. Zeits. *Hydrologie* 37(1):53-84.

Vollenweider, R.A. 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. *Mem. Ist. Ital. Idrobiol.* 33:53-83.

Whitton, B.A., A. Aziz, P.Francis, J.A. Rother, J.W. Simon and Z.N.Tahmida, 1988a. Ecology of deepwater rice-fields in Bangladesh. I. Physical and chemical environment. *Hydrobiologia* 169:3-22.

Whitton, B.A., J.A. Rother and A.R. Paul. 1988b. Ecology of deep-water rice-fields in Bangladesh. 2. Chemistry of sites at Manikganj and Sonargaon. *Hydrobiologia* 169:23-30.

Whitton, B.A., A. Aziz, B. Kawaceka and J.A. Rother. 1988c. 3. Ecology of deep-water rice-fields in Bangladesh. 3. Associated algae and macrophytes. *Hydrobiologia* 169:31-42.

Yadava, Y.S. 1989a. Beel Fisheries resources in N-E India. pp8-14. In: *Bulletin No. 63*. Central Inland Capture Fisheries Res. Inst. Barrackpore, W. Bengal, India.

Yadava Y.S. 1989b. Physiography and hydrodynamics of beels. In: Training in Management of beel (Ox-bow lake) fisheries. pp36-42. *Bulletin No.63*. Central Inland Capture Fisheries Res. Inst., Barackpore, W. Bengal, India.

WETLANDS AND FISHERIES

A.K. Ataur Rahman

ABSTRACT: Due to anthropogenic stresses, wetlands are fast disappearing and, as a consequence, fisheries which are one of the prime uses of wetlands are suffering the most. Inland fisheries in Bangladesh cover an area of 4.3 million ha, of which 94% comprises of openwater capture fisheries which support about 260 species of freshwater fish. The paper identifies a host of man-made stresses such as largescale water abstraction for irrigation, construction of embankments for flood control, siltation and soil erosion resulting from deforestation in the catchment zones, water pollution from industrial, agricultural and municipal wastes, and over-exploitation and destructive fishing practices which have left a trail of devastating effects on fish stock. It evaluates the potential of fisheries in paddyfield wetlands and recommends its introduction in Bangladesh. It outlines an integrated management approach for inland openwater fisheries.

INTRODUCTION

One of the prime uses of wetlands is fisheries. Unfortunately, owing to anthropogenic stresses, many wetlands are fast getting lost and it is difficult to find a pristine wetland. A coordinated effort to meet the threat and optimize the use of wetlands as a natural resource system is imperative.

Wetlands support an incredibly elaborate foodweb that in turn supports rich biotic communities. There are plants, the very basis for food production in any wetland, microorganisms and invertebrate benthic forms which feed the fish and birds. Among the prime uses of wetlands fisheries constitute the most significant, providing nutrition, income and employment to millions in the developing countries.

OPENWATER FISHERIES OF BANGLADESH

Inland fisheries in Bangladesh cover an area of 4.3 million ha of which 94% comprise openwater capture fisheries and 6% closed water systems. The vast inland water resources in the form of 2.8 million ha of *haors*, 114,161 ha of *beels* and 5,480 ha of *baors* offer tremendous scope and potential for augmenting fish production by adoption of culture-based fishery enhancement techniques. Rahman(1989) has described existence of 260 species of freshwater fish in the wetlands of Bangladesh.

The contribution of inland fisheries in 1987-88 was recorded to be 599,523 mt (72.5%) of the total fish production in the country and the inland openwater fisheries accounted for 423,598 mt (51.3%) indicating that inland openwater capture fisheries form a significant part of the fisheries sector(Fig.1). Even a small increase in the yield rate of inland openwater fisheries promises to make a significant mark in the national fish production and consumption.

Based on the studies conducted by the Department of Fisheries, some disturbing trends are already discernible in the capture fisheries of Bangladesh. A host of man-induced stresses due to largescale water abstraction for irrigation, construction of embankments for flood control, siltation and soil erosion due to deforestation in the catchment, water pollution from industrial, agricultural and municipal wastes, over-exploitation and destructive fishing practices have left a trail of devastating effects on fish stocks. Apart from a steady decline in the total catch, there is an alarming downward swing in the catches of the Gangetic carps. The biologically and economically desirable species are giving way to low-value species. Table 1 portrays the catch trends over the years. While inland capture fisheries contributed 471,591 tons or 62.6% of the total catch in 1983-84, the same declined to 50.4% in 1989. This, along with rapidly growing population, has led to decline in per capita availability of fish which is a major source of animal protein for the people of Bangladesh. It is estimated that by the turn of the century fish production must increase to 1.2 million tons if the growing population of the country has to consume fish at the present level. Existing records reveal that marine fisheries have already reached a level of stagnation (Rahman, 1989).

Table 1 : **Fish production by type of fisheries**

Type of Fisheries	Fish Production		
	1983-84	1988-89	1994-95 (Target)
INLAND CAPTURE			
River and estuaries	215,549	187,556	246,000
Floodplains	200,616	186,126	237,500
Beels	51,373	47,019	67,600
Kaptai Lake	4,057	3,439	7,500
Subtotal	471,591 (62.6)	424,140 (50.4)	558,600
INLAND CULTURE			
Ponds	107,944	155,012	308,400
Baors	862	1,321	5,500
Chrimp farms	8,219	27,172	46,650
Subtotal	117,025 (15.5)	183,505 (21.8)	359,550
MARINE			
Industrial	14,500	10,353	15,600
Artisanal	150,382	222,928	255,300
Subtotal	164,882 (21.9)	233,281 (27.7)	270,900
Inland Total	588,620 (78.1)	607,645 (72.2)	918,100
Marine Total	164,882 (21.9)	233,281 (27.8)	270,900
Bangladesh Total	753,502 (100)	840,926 (100)	1,189,000

This indicates that inland fisheries have to bear the brunt of augmenting fish production in the coming years. In the present scenario, capture fisheries resources are highly stressed systems and increased fish production from them will be difficult. Development and exploitation of capture fisheries resources are beset with severe challenges as compared to culture fisheries where the flexibility of ecosystem manipulation exists with ample scope for monitoring production operations at every step. On the contrary, large openwater systems exhibit such diverse ecodynanic principles that no general guidelines could be adopted for their management. Managing these stressed resources has the added responsibility of conserving the aquatreasure they harbour, apart from increasing the overall fish yield.

FLOODPLAINS - THE OVERFLOWING WETLANDS

It is well-known that major riverine fisheries are located in the potamic stretches of the rivers and their fringing floodplains. A strong correlation has been established between fish catch and flooded area of a given river stretch (Welcomme,1975). Swamp lands, which are non-forested, occur as floodplains and are usually fed by overflow from rivers. Floodplains are defined as those low-lying areas, bordering rivers, which are seasonally inundated by the overspill from the main river channel. The distinction between swamps and pools (*beels*) is made largely on the amount of macro-vegetation they harbour which may vary throughout a season. Locations where the side arms and tributaries breach the natural levees serve as major pathways for lateral migration of fish between the river and its floodplains during the periods of rising water at the beginning of the monsoon season and receding water at the beginning of the summer season. A majority of wetland systems are basically sustained by rainfall and flooding. Wetland characters of some of them are seasonal and highly dependent on rainfall regime. The water regime gradually recedes giving way to rich alluvial soil system making it rich agriculture land. This phenomenon of part wetland and part agriculture regime fluctuates according to monsoonal variations.

Floodplains are characterized by alternation of dry and wet phases. The two flooding patterns are quite distinct, one resulting in flow direction from the floodplain to the river (from local rainfall) and the other from river to floodplain (river overspill). Thus floodplain ecodynamics are influenced by the river water incursion, intensity, timing and magnitude of rainfall and geo-chemical nature of the watershed, presenting highly contrasting pictures of their area and depth within a year. Physical and chemical changes in the ecosystems of the floodplains follow the flood cycle closely (Fig.2).

During the dry season, there is an accumulation of nutrients in the form of animal droppings and rotting vegetation. These nutrients rapidly enter into solution during the early stage of flooding and, combined with river-borne silt, lead to an upsurge of productivity resulting in rapid growth of plants and other forms of aquatic biota. This productivity phase offers ideal conditions of growth, feeding and breeding of many riverine fish which migrate to floodplains with the rising waters. The flood cycle plays a very vital role in continued survival of these species (Fig.3).

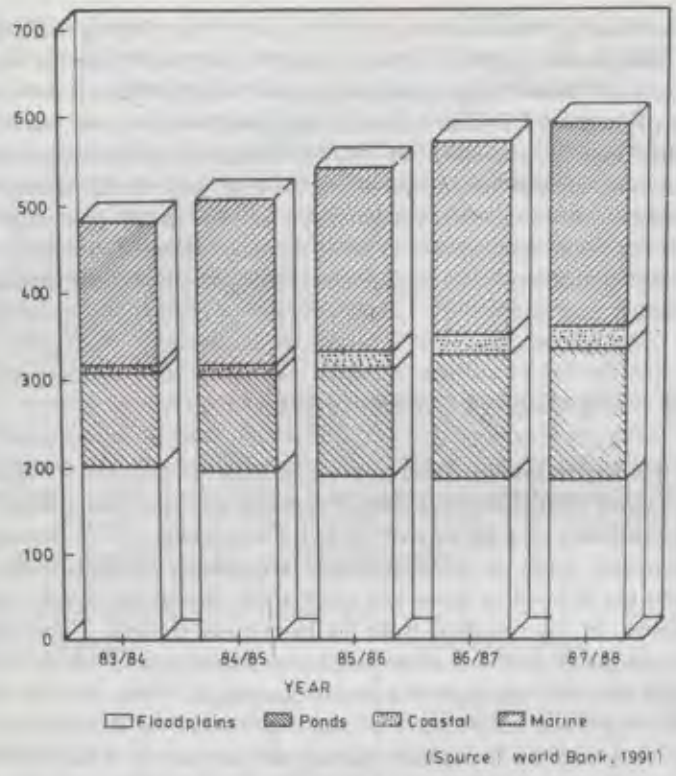


Figure 1: Production of Fish in Bangladesh

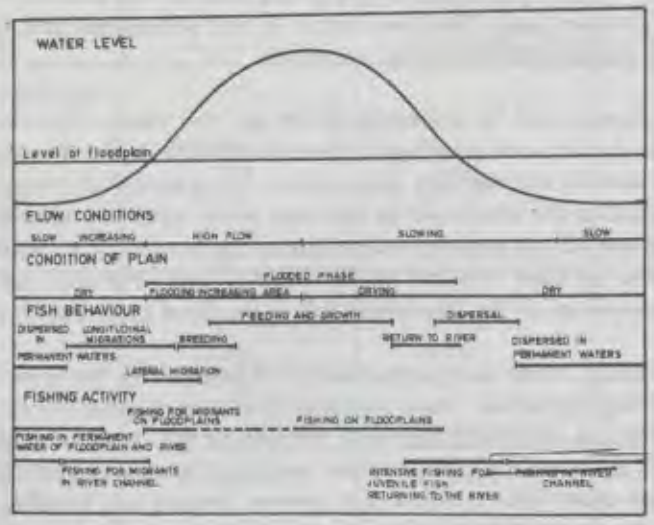


Figure 2: Major Cycles of a Floodplain Throughout the Year (Welcomme, 1975)

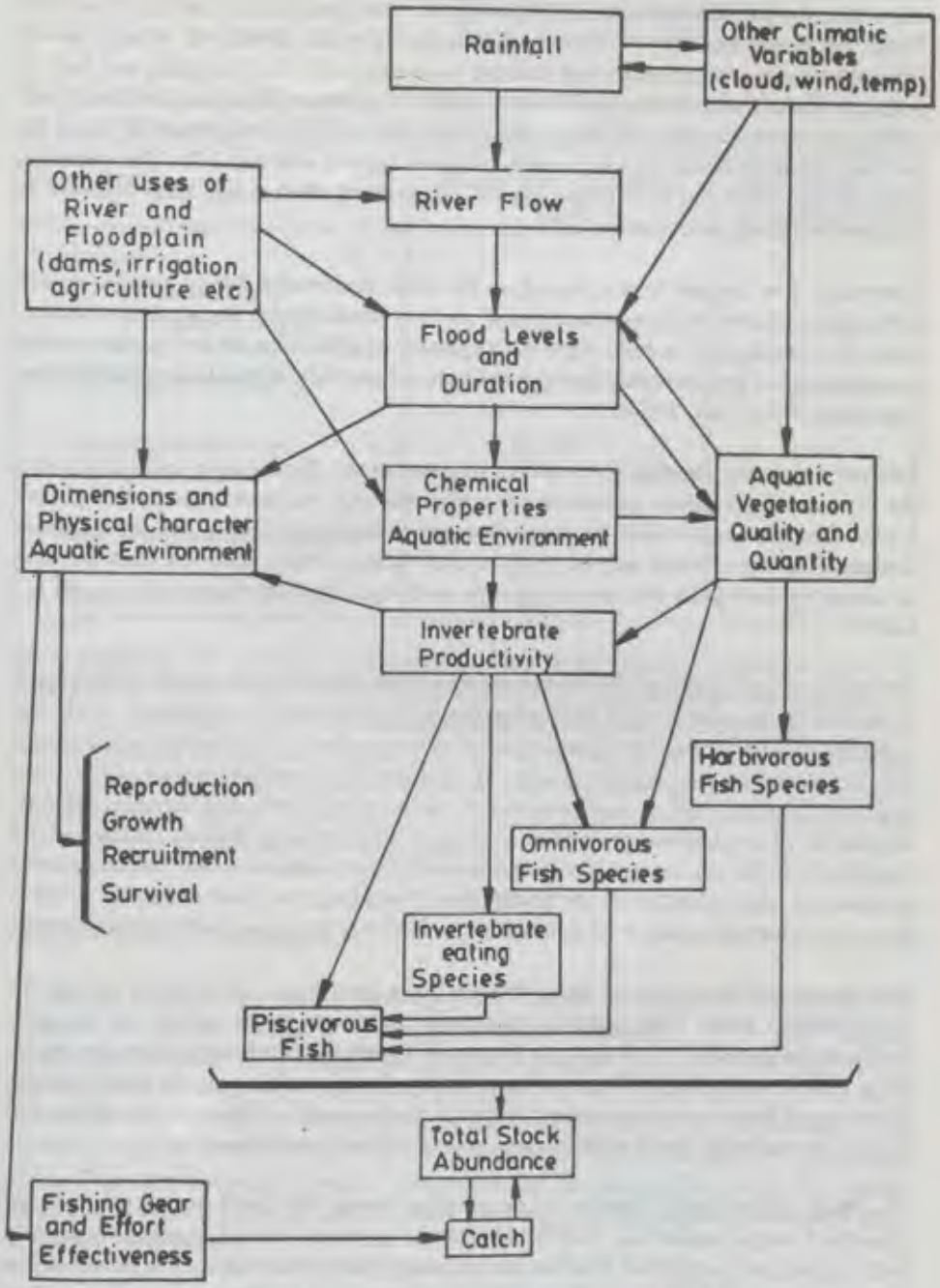


Figure 3: Some Interrelationships of Factors Affecting Fish Production in Floodplains (Welcomme, 1975)

In rivers, the characteristics of the flood regime seem to control the fish communities. Once the flood has started to rise, the depth increase should be steady, as an intermittent rise with alternate rise and fall is detrimental to fish breeding and lack of a steady rise in water level creates deoxygenated conditions to occur in the littoral zone with consequent mortality of young fish (Welcomme, 1979). Persistence of flood for too long a period results in deterioration of water quality and fish kills. The recession phase of the flood curve is rather critical. Over-rapid decline has been reported to increase stranding mortalities.

Generally, low oxygen levels prevail in the river floodplains during the dry season although variations due to wind action and photosynthesis occur. As mentioned earlier, many floodplain pools or *beels* show deoxygenated conditions in the dry season and fish mortalities have been reported due to wind-induced overturn of the deoxygenated water (Egborge, 1971; Tait, 1967).

The pH is another variable factor which is lower in the flood season and rises during the dry season. Its values depend on the soil conditions, the marshy pools being more acidic. Specific conductance has been observed to be higher during the dry season as compared to the flooded period. Holden and Green (1960) observed that the total conductivity during the wet season remains unchanged but gets diluted during the dry season.

The productivity burst with the first inundation of the summer-exposed floodlands leads to explosive increase in the phytoplankton and zooplankton populations. Although opinions vary on the season of maximum plankton productivity in floodplains, Egborge (1974) established a strong correlation of phytoplankton production with conductivity and transparency and inverse correlation with water level and current velocity. Maximum photoplankton production occurs in the pools or lagoons *(beels)* of the floodplains in the dry season. Zooplankton too follows a similar trend. The community structure of phytoplankton in the floodplains by and large indicates eutrophic series of the order Chlorophyceae > Myxophyceae > Bacillariophyceae > Conjugatophyceae.

The largest concentrations of macrobenthos have been found in the *beels* among the weed-infested areas. The benthic community has been found mainly to comprise molluscs, oligochaetes and dipteran larvae of which molluscs, especially the snails, form a dominant group. They are seen widely distributed during the flood season. Exposure of littoral areas in summer seems to cause negative impact on littoral benthos leading to mortality, poor mobility and loss of resting mechanisms

The most characteristic feature of floodplains during the rising water phase is the growth of macro-vegetation. Correlated with the increased amount of macro-vegetation is the growth of periphyton (Aufwuchs) including filamentous algae. It is believed that during periods of high flow when adequate supports are needed, periphyton replaces the phytoplankton to a certain extent. Macrophytes play a major role in governing the plankton density and primary productivity in floodplains. An increase of 37% in the standing crop of macrophytes resulted in the decrease of 64% of phytoplankton population in a span of one year (Yadav, 1990).

Table 2 portrays the improvement in productivity of plankton and the general productivity of the system consequent to the clearance of macrophytes from the *beels*.

Table 2 : **Chemical and biological features and fish production level before and after clearance of macrophytes (Yadava, 1990)**

Parameters	Macrophyte-dominated Beels	After clearance of macrophytes
1. Nutrients'		
Nitrates (mg/l)	0.18	1.10
Phosphates (mg/l)	0.04	0.19
2. Phytoplankton (units/l)	312	6,854
3. Photosynthetic carbon production ($mg/cm^2/day$)	6,138	12,265
4. Photosynthetic efficiency (%)	3.24	5.75
5. Fish production (kg/ha/yr)	337	1,112

In floodplains, the primary production occurs both through phytoplankton and macrophytes. The average rate of energy fixation by producers has been estimated to be 53,719 $cal/m^2/day$ (2.89% of incidental light) of which 43,408 $cal/m^2/day$ (2.34%) is contributed by macrophytes and only 10,311 $cal/m^2/day$ (0.55%) by phytoplankton. It is reported that in beels generally infested with macrophytes the contribution of phytoplankton as energy convertor is only 5-10%. Of the energy fixed by phytoplankton 70-80% is contributed by nannoplankton.

FLOODPLAIN FISHERIES

Bangladesh is singularly blessed with extensive floodplains. However, the productive potential of its floodlands is presently severely constrained by a poor natural recruitment. Various flood control and irrigation projects have resulted in the habitat reduction and lowering of productive capacity and disruption of natural recruitment. The major carp content of the catch from Sunamganj floodplains has declined from 66.4% in 1967 to 1.3% in 1984 (Tsai and Ali, 1988). Within two years of completion of the Chandpur Irrigation Project, fish production has declined by 35%. An annual decline of 2.4-2.9% over the last 4-5 years has been recorded in fish production from floodplains and *beels*.

In southwest Bangladesh, the cut-off meander bends of rivers have formed the *baors* or oxbow lakes covering an area of 5,488 ha. Some of them get connected with the main river channel during monsoon months and get the benefit of natural recruitment.

PRODUCTION BIOLOGY OF RIVER FLOODPLAIN FISH

Fish Migration

Daget (1960) described two types of river fish migrations: (i) longitudinal migrations within the river channel and (ii) lateral migrations to and from floodplains. Welcomme (1975) states that each type of migration requires a different type of behaviour and probably different sets of physiological stimuli. Fish migrations have been classified into four major phases (Blache, 1964; Willians, 1971):

a) Rising phase	Water confined to bank; fish may undertake longitudinal migration within channel either from the river itself or from the floodplains.
b) Rising phase	Water overspilling to floodplains; the fish spread by lateral migration over the floodplains.
c) Receding phase	Water draining from floodplains; as the flooded area diminishes there is a movement of fish to the river and other permanent waterbodies.
d) Receding phase	Reaching the river, the fish disperse into the dry season habitats.

It has been reported that the lateral migration of fish to and from the floodplains is not a random process and follows a fixed pattern. Different species arrive at characteristic time and in particular groups. Certain fishes start migration earlier than the other species. Williams (1971) observed that *tilapia* females moved earlier than males. There is a tendency for adult fish to move out of the floodplains as soon as the water level starts diminishing. The young fish have been observed to move in a pattern. Those sensitive to deoxygenated condition leave the floodplains first and the more resistant species like *Clarias* leave later. Welcomme (1975) observed two species of *Barbus* behave very differently and concluded that different species of the same genus may have different migration time.

Reproductive Cycle

The reproductive cycle is intricately linked to the intensity and timing of monsoon rains, most of the species breeding with the onset of floods. Reproductive activities continue for a number of weeks and in some species throughout the flood season. Floodplains serve as breeding grounds for the prized carps which are dependent on the seasonal floods to inundate the grounds needed for breeding. Many species breed during the rising water but this is not the only pattern. Breeding patterns are very diversified and are aimed at securing favourable conditions for the hatching, survival and growth of the larvae. Floodplain fishes, accordingly, depict conceivable variations of breeding pattern.

Feeding

Floodplain fishes portray the complete coverage of trophic range from planktophagic to piscivorous habits. The young fish mainly feed on periphyton, detritus, zooplankton and small insects. Seasonal variations in feeding intensity have been found to be correlated to flood regime. During the floods, increased food production in the form of release of nutrients, seeds, insects and molluscs prompts intense feeding activity which has been substantiated by the high condition factor of fish during this season. Reverse is true for predators which depict low feeding intensity during the flood phase when prey fish get widely dispersed and get opportunities to protect themselves in the dense growth of hydrophytes.

Growth

Within-year changes in the growth rate have been noticed in floodplain fishes owing to expansion and contraction of the aquatic body, seasonability of temperature and rainfall and flood-associated changes in food availability (Kapetsky, 1974). According to Dudley (1972), 75% of the expected first year growth of the juveniles occurs within six months after spawning. Slow growth has been observed during the dry season.

Between-year variations in growth rates of floodplain fishes have been correlated with flood intensity, severity of drawdown and temperature. Growth has been found to be positively correlated with the intensity of flooding and poor growth occurs from severe drawdowns.

Mortality

Mortality rates are higher in the dry season, especially when the water level is receding and fishes are more concentrated in the waterbody. In such a situation, they become more susceptible to attack by predators, by disease and by other environmental stresses. Between 75 to 80% mortality has been recorded during this period in floodplain lagoons with an overall decrease of 40% in biomass within a three-month period.

Between-year variations in mortality rates seem to depend on the magnitude of flooding, intense flooding resulting in better recruitment and growth. Differences in the amount of water remaining in the floodplains in the dry season, together with its duration, strongly influence survival from one year to the next (Welcomme, 1979).

Fishing

Diverse fishing methods are used in the country's floodplains. During the dry season when fishes are confined to the *beels* and in the drainage channels, there is very active fishing with a wide variety of nets and traps. The intensity of fishing varies inversely with the amount of water retained in the depressions.

FISHERIES IN RICEFIELD WETLANDS

The wetlands of ricefields are congenial to fishes both as spawning grounds as well as pastures. Many of the fishes which breed in ricefields have adhesive eggs which are laid on green plants in order to facilitate oxygenation during the day and also by rippling of water. Shallow-water spawners and nest builders also get favourable conditions in ricefields. A ricefield also acts as a pasture for those fishes which come through flood, tide or irrigation water in a natural way. Therefore, the above two groups of fishes commonly occur in ricefields.

Integrated and diversified crop-fish production systems, evolved on empirical knowledge, have a history of over two millenia in parts of South and Southeast Asia. The benefits of this system are that it continuously recycles the nutrients and energy, producing little wastes and maintaining the ecological balance. Thus integration of fish farming with agriculture crops or animal husbandry results in diversification of farm produce, increased cash income, improved quality and quantity of food and exploitation of unutilized resources available to fishermen and small farmers.

Suitable Species

Because of the lower oxygen content and higher turbidity and temperature in the shallow waters of the ricefields, mostly mud-dwellers which can survive and thrive occur there. Many species like *Trichogaster*, *Anabas*, *Channa*, *Clarias* and *Heteropneustes* have accessory breathing apparatus. Some of them breed in the ricefields while others invade the rice wetlands through flood, tide or irrigation canals. Taking advantage of this situation countries like Indonesia, Malaysia, Thailand and India started fish cultivation in these wetlands by stocking the ricefields with economically important fish species. There exists scope for establishing different systems of rice-cum-fish culture, especially in low-lying inland areas where ricefields get inundated and the water depth exceeds 75cm.

Culture Systems

The fish culture in ricefield wetlands is taken up as:

a) Synchronous culture: Fishes are grown only for a maximum period of 3-4 months during rice cultivation alone. This is prevalent in Indonesia, Philippines, Taiwan, Japan and India.
b) Sequential culture: Rice plots remaining fallow in summer are used for aquaculture. Shrimp culture in the coastal belt follows this practice.
c) Sequential and synchronous culture: In recent years, sequential culture system has been modified. Crisscross field trenching is adopted for removing silt deposition from runoff water after brackish water culture is done in summer. Topsoil is also scraped out for quick desalination through flushing by rainwater. Synchronous rice-cum-freshwater culture is then practiced in the same field. Such a system is practiced in India.

d) Interphase culture : In Indonesia, a short crop of common carp is raised by stocking them in ricefield in the gap of two rice seasons.

If rice-cum-fish culture is practiced in a systematic manner it promises to give lucrative returns, generate employment and provide better landuse. Advantages of such a farming system are the control of mosquitoes, molluscs, mice, terrestrial weeds and some harmful insect pests, saving in expenses on harrowing, and utilization of fish excreta as manure.

In spite of so many advantages, high-yielding rice cannot be grown in such a system due to waterlogged condition and limited or non-use of pesticides to avoid fish/prawn mortality.

CONSTRAINTS TO DEVELOPMENT

A number of diverse and complex problems confront the openwater fisheries development in Bangladesh. The extraction of fish riches, based on the concept of Maximum Sustainable Yield (MSY), has not been possible in the multispecies multigear fisheries of tropical countries. Fishing in the developing countries is guided by principles of economic profit rather than biological tenets. The intensity of fishing, nature of exploitation and species orientation in openwater river-floodplain fisheries of Bangladesh are governed by the following:

a) Seasonality of riverine fishing activity
b) Unstable catch composition
c) Conflicting multiple use of the resource
d) Stresses leading to nutrient loading and pollution
e) Lack of understanding of fluviatile system
f) Infirm database
g) Fragmentary conservation measures lacking enforcement machinery
h) Inadequacy of infrastructure
i) Defective marketing and distribution system and
j) Socio-economic determinants.

The above constraints can be broadly grouped under four major heads: (Jhingran, 1991):

Biological Constraints

Successful management strategies have to take into consideration the key parameters of hydrology, fish stocks and dynamics of their population together with regulatory measures for fishing. In the absence of a tested model for tropical multispecies fisheries, it is not possible to assess the status of fish stocks at any point of time or to determine the optimal measures required for the future. Infirm database on inland fisheries resources of the country has been one of the serious constraints. Statistics on catch and effort over time and space by different gear-type are essential to estimate the exploitation structure and MSY.

Presently, our capability to evaluate the biotic and ecosystem interactions in river floodplains is largely limited owing to our inability to interpret the complex spatio-temporal changes that are occurring in the fish populations of the river systems.

Environmental Constraints

Fisheries development in inland waterbodies is becoming increasingly difficult due to the environmental constraints posed by the anthropogenic stresses described earlier. Low water velocity, due to high rate of water abstraction, physiologically upsets the fluviatile communities adapted for lotic conditions giving way to communities more adapted to the pool zones through secondary community succession, thus upsetting the process of riverine community metabolism. Many physiological processes associated with feeding, breeding and migration are triggered by changes in hydrographic variables to which fishes are very sensitive. Flow regime also affects temperature, sediment and organic material transport and water quality factors.

Requirements of critical water levels for effective breeding and minimum levels of water during the dry season are not being met. Assessment in terms of threshold volume of flow and other hydrographic parameters conducive to ecological health of the river floodplains and wetlands requires serious consideration.

The main sources of effluxion are industrial, municipal and agricultural effluents. In addition to the sub-lethal chronic effects on the environment, industrial effluents cause direct fish kills, destruction of habitats for benthic and plankton communities and toxicity to organisms. The major adverse impacts of municipal effluents, often accompanied by trade wastes, are deoxygenation, high BOD load, rapid eutrophication and accumulation of heavy metals in the environment.

Legal Constraints

Fisheries legislation in the country is, by and large, governed by four sets of laws and regulations of which the protection and conservation of Fish Act, 1950, as amended in 1982, is applicable to freshwater capture fisheries. Although these comprehensive regulations, stipulating closed seasons, prohibiting irrational fishing practices and limiting the size of fish to be caught etc, should protect the fisheries, they have so far played a subordinate role in implementation due to lack of appropriate enforcement machinery. Many people are not even aware of the provisions in the regulations. The complexity of factors involved in the regulation of fisheries stems largely from the common property nature of resources, difficulties in enforcing a limited access concept, divergent auctioning and leasing policies and multiplicity of agencies that control the water resources.

Socio-Economic Constraints

Fishery exploitation of the river floodplains as a source of livelihood and subsistence has been an age-old practice for thousands of riparian fishermen. Fishing is considered as a low profession and fishermen are socially, economically and educationally

backward, lacking financial resources. They barter most of their produce for their domestic requirements. Seasonality and unstable catch composition being the characteristics of the capture fisheries, many of them are only part-time fishermen. Inadequacies of infrastructure and supporting services and lack of proper marketing and distribution channels also contribute to the high variations in the fishing activity. Trade occurs mostly at production centres and urban areas where people are relatively well-off. Institutional finance eludes the riverine fisherman as he cannot fulfil the conventional qualifications based on securities and collaterals.

MANAGEMENT STRATEGIES

Holistic Resources Management - A Basinwise Approach

The present status of the capture fisheries of Bangladesh reveals that this process has been further accelerated by the increasing demand and shrinking resources. And this is happening at a time when more and more new technologies are being developed. The paradox seems to lie in the fact that problems today are not as simple as they were earlier and the present approach to solving them on piecemeal basis in no longer valid. Resource managers, resource users, fishery scientists, sociologists and political scientists have failed to evolve a harmonious value system towards management of a common resource.

The present status of the aquatic resources well provides the basis for adoption of a holistic approach towards their management. The basinwise approach towards inland fishery management will involve watershed protection, developing industries, planting crops, adopting programmes on health and education, and people's participation. Organization of such a system will take into consideration the need for a balanced development, anticipate conflicts with other uses of the resource and resolve them in an environment-friendly manner.

Other Considerations

The marked changes that have occurred in the inland fisheries of Bangladesh have created an opportunity to review the contribution inland fisheries can make towards national economic, social and nutritional goals. The following guidelines may be taken into consideration while examining the role the fisheries can play in attaining the national objectives:

1) Fisheries are to be considered as a system or a collection of systems. An integrated approach to fisheries development and planning is essential taking the basin development in its entirety. This would comprise:
   a) A judicious water allocation policy for various sectors taking into consideration the biological threshold levels.
   b) A suitable model to predict the physical, biological and economic consequences of effluent discharges from industries and their impact on biotic wealth.

c) Fisheries management comprising conservation of aquatic fauna and flora and controlled fishing.

2) Pollution caused by industrial and municipal waste waters, land erosion and agricultural runoff poses a threat to the aquatic systems. There is a need for catchment modification to arrest the soil incursion and transport of fertilizers and pesticides into the waterbodies together with control of pollution from industrial and municipal sources.
3) Eco-toxicology includes a systematic stepwise evaluation of the environmental effects from discharge and dispersal of toxicants, their uptake by organisms and subsequent effects on individual populations and ecosystems. There is a need for fundamental research in this field with particular emphasis on the mechanisms of toxicity.
4) For conservation of fish biodiversity it is important to classify spheres of responsibilities and assign them to appropriate groups. The professional responsibility should be of the geneticists, fish breeders, ecologists and conservationists for identification and utilization of the genetic variability. The political responsibility should relate to national protection of the wetlands, prevention of genetic erosion and provision of financial assistance. People's responsibility should relate to development without destruction which has to be inculcated by awareness generated through mass media and education.
5) Entry of new fish species into a country is mostly done with the primary objective of increasing the tonnage of fish. However, with the increasing awareness for conservation of indigenous gene pool, transplantation of fish into areas where they have been previously absent, has become a subject of controversy. Utmost caution is to be exercised while introducing any exotic species. Even if the introduced species succeeds in increasing the total catch, it may do so at the cost of ruining the biotype. An objective analysis of all the risk factors should precede such decisions.
6) Development plans should take into account all aspects of the fisheries sector including harvesting, marketing and supply. The development of infrastructure, technology and human resources for better management should be given emphasis.
7) The rational management and optimal utilization of fish resources are inextricably linked with the adequacy of knowledge, ability and skill of the people associated with their exploitation management. For this enhancement of competence through training and transfer of technology is a key factor.
8) It is important to involve all concerned groups including administrators, scientists and fishermen in the process of formulating and implementing management measures. Fishermen are more likely to comply with management measures when they are in a position to see the benefits which will arise from the adopted measures.
9) Attention has to be given to making credit facilities to smallscale fishermen on terms and conditions in keeping with their weak economic and social conditions.

CONCLUDING REMARKS

The inland openwater fisheries in Bangladesh are at a critical point in their development. The degradation and loss of fisheries habitats are increasing and a national perspective is imperative for the conservation and sustainable development of the freshwater wetland resources and fisheries. Ecosystems are threatened by fast-changing biotic communities, wetland losses, environmental degradation and destructive fishing practices. Aquatic environments in developing countries like Bangladesh are especially vulnerable because the national priorities for development are often in conflict with the norms of conservation. The capture fisheries of freshwater wetlands form an important component of the fisheries resources of the country. It is strongly felt that for attainment of sustainable development drastic changes in the policy issues are essential to meet the national development objectives.

REFERENCES

Blache, J. 1964. Les poissons du bassin du Tchad et du bassin adjacent du Mayo kebbi *Mem Orstom*, 4 : 483 p. (not consulted in original).

Daget, J. 1960. Les migrations de poissons dans les eaux douces tropicals africanes *Proc IPFC*, 8(3):79-82 (not consulted in original).

Dudley, R.G. 1972. Biology of *Tilapia* of the Kafue floodplain, Zambia: Predicted effect of the Kafue Gorge Dam. *Trans : Am Fish .Soc.*, 103(2) : 281-91.

Eborge,A.B.H. 1971. The chemical hydrology of the River Oshum, Nigeria. *Freshwat. Biol.*, 4: 1 77-91.

Egborge, A.B.H. 1974. The seasonal variation and distribution of phytoplankton in the river Oshum, Negeria. *Freshwat. Biol.*, 4:1 77-91.

Holden N. J. and J. Green. 1960. The hydrology and plankton of the River Sokoto. *J. Anim E.Col*, 29: 65-84.

Jhingran, A.G. 1991. Development potential and constraints of inland fisheries management in India. Fifth IPFC Working Party of Experts and Inland Fisheries, Bogor, 24-26, June 1991 : 21 P.

Kapestsky, J.M. 1974. Growth, mortality and production of five fish species of the Kafue river floodplain, Zambia. *Ph.D. Dissertation*. University of Michigan : 194p.

Rahman, A.K.A. 1989. *Freshwater Fishes of Bangladesh*. Zool.Soc. Bangladesh, Dhaka: 364p.

Tait C.C. 1967. Hydrological data. *Fish Res.Bull.*, Zambia, 3: 26-8

Tsai, C. and L. Ali. 1988. Openwater fisheries (carp) management programme in Bangladesh. *Fisheries Information Bulletin*, 2(4).

Welcomme,R.L.1979. The fisheries ecology of African floodplains. *CIFA/T3*:50 p.

Welcomme, R.L. 1979. Fisheries management in large rivers. *FIRI/T194*: 60 p.

Williams, R. 1971. Fish ecology of the Kafue River and floodplain environment. *Fish Res. Bull., Zambia*, 5 : 305-30

World Bank. 1991. Bangladesh Fisheries Sector Review. *World Bank Report* No 8830-BD.

Yadava, Y. S. 1990. Fisheries of the floodplain lakes : a management. In: Sugunan, V.V. & Utpal Bhaumik. (eds). *Technologies for Inland Fisheries Development*. CIFRI, Barrackpore (W Bengal) India : 154-165.

AGRICULTURAL DEVELOPMENT AND SUSTAINABILITY OF WETLANDS

S. M. H. Zaman

ABSTRACT: The paper reviews the past and present agricultural practices in freshwater wetlands including cropping pattern and trends in landuse. Before the introduction of dry season irrigation in the sixties, deepwater rice or broadcast *aman* (floating rice) used to be the major crop during the summer-rainy seasons in wetland areas. It was sometimes mixed with short-duration *aus* rice which could be harvested in June allowing broadcast *aman* to grow till November. With the introduction of irrigation along with high-yielding varieties of rice the cropping pattern changed and *boro* rice got preference over broadcast *aman* and *aus* as major rice crop in the areas. This paper also discusses changes brought in agricultural practices in the wetlands after flood control and drainage schemes were implemented. The paper evaluates such changes in three selected projects along with their positive and negative effects on the sustainability of agriculture in the areas. The problems of grazing grounds and livestock in the wetland areas have also been discussed. The paper recommends steps towards sustainable agricultural development in the areas.

INTRODUCTION

Due to its geographical location in the Gangetic delta, Bangladesh has large freshwater wetlands located in the Lower Atrai Basin, Arial Beel, Gopalganj-Khulna Beel system and Sylhet Basin along with their adjacent flood-prone lowlands. Each of these basins contains many *beels* or waterbodies which serve as sanctuary for fish and birds. Due to increasing demand of the growing population all these wetlands have been subjected to considerable change that affected their long-term sustainability. The cropping and the farming system did not change much in these wetlands prior to the introduction of irrigation due to favourable ecological condition.

This paper provides some basic facts on the past and present agricultural practices in these wetlands including soil characteristics, pertinent meteorological factors, cropping pattern and trends in landuse. These have been discussed alongwith the positive and negative effects on agriculture itself and also the agroecosystem of these wetlands which can be a basis for future conservation efforts.

REVIEW OF PAST AND PRESENT AGRICULTURAL PRACTICES IN WETLANDS

The freshwater wetlands of Bangladesh consist of a large number of *beels* formed as the basins of the rivers flowing through the areas. All of the basins have a common ecology. These low-lying areas are all flood prone and get inundated during the rainy season by water from three sources - rain, river and rise of groundwater level.

All of the wetlands are subjected to sedimentation. The composition of these sediments may vary according to location. All of these have more or less claysoils rich in organic

matter. Some of these like Gopalganj-Khulna *beels* have underground peat depositions. Some soils are mucky (low-lying areas north of Shahzibazar). From July to September the basins remain flooded. These vast flooded areas are covered by crops which can tolerate waterlogging and submerged condition.

This particular ecological condition existed from prehistoric period in Bangladesh due to climate and geological actions. However, there had been great changes in the geo-morphological characteristics as evident from comparison of present channel position of major rivers with those showed in maps prepared two hundred years ago by Rennel. This has resulted in changes in the landuse pattern. These changes have been surveyed in detail and reported by FAO (1988). The following sections shall deal with the variation in crop cultivation and land management in each of the four basins identified earlier.

Lower Atrai Basin

The general soil type of the Lower Atrai Basin is noncalcareous dark grey floodplain soils. These soils generally occupy lower sites than grey floodplain soils and occur on older floodplain landscapes where the soils accumulate more organic matter in the topsoil or did so under natural swamp vegetation before the soils were brought under cultivation. Subsoil texture ranges from silt loam on the highest parts of the floodplain ridges to the silty clays in the depressions. Subsoil structure varies in texture: weak in silt loams, strong in heavier soils which dry out seasonally. The Ap horizon is neutral in reaction when submerged, but generally is medium to very strongly acidic in dry season. Permeability is generally slow and moisture holding capacity is generally high. The area is both drought and flood prone. The soil is deficient in both sulfur and zinc (FAO 1988). The area has been designated as Region 5 in FAO, 1988 Report.

The cropping pattern has not been recorded separately for the basin area. However, in *kharif* season (Mid-April to September), the broadcast *aman* or deepwater rice, lowland *aus* and T.*aman* (in the basin rims) were pre-dominant rice crops. To avoid risk and minimize economic loss the farmers used a mixed crop of *aus* and *B.aman* in the flood prone risky areas. Due to drought, there was a delay in raising seedlings of *aus* and *B.aman* which perhaps reduced pre-flood period growth and made the crops more risk-vulnerable as at least 30 days were needed by the deepwater rice seedlings to get physiological maturity to develop flood tolerance ability. In the basin rims and homesteads (usually raised mounds), summer vegetables and both seasonal/annual and perennial fruit and timber trees were grown. Wherever possible the farmers used to grow jute. Farmers also grew sugarcane and sesame where the flood used to come at a later date. Since fertilizer use was at a much lower level the yield levels were low.

In the *rabi* season, wherever the land dried up in early October to mid-October, farmers used to grow legumes, oilseeds and vegetables. Tobacco was also cultivated as cashcrop. The cultivation of linseed along with gram (*chana* or *chola*) was a common practice. Since old days two local varieties of spring wheat called *gongajoli* (pre Moslem era) and *jamali* (Moslem and later periods) were grown as a *rabi* cereal. In

some areas field pea and local wheat were grown together as pea could supply some extra nitrogen to the wheat crop. Such legume-nonlegume beneficial association was known to the farmers. The *beel* was highly infested with leeches and it is doubtful whether *boro* rice was cultivated on a largescale in the past. In fact, refugees from Assam introduced *boro* cultivation in northern districts during the post-partition period. With introduction of insecticides and lowlift pumps (LLPs) the leeches were controlled and irrigated crop culture changed both cropping and farming system in these areas.

With the introduction of highyielding Mexican wheat and modern rice varieties, Chalan Beel area needed flood regulation. But unfortunately instead of flood regulation the idea of flood control became a much wanted and fashionable technology which also received immediate patronage from the donors. The normal practice in these *beel* areas is that the *boro* seedlings are continuously transplanted in wet water lines as the water recedes until mid-March when panicle initiation is about to take place. In fact, this continuous type of *boro* seedling transplanting along the receding water line can be found in all wetlands and *beel* areas of Bangladesh. In some places special species of sedge is transplanted in the rim of the Atrai Basin. These wiry sedge stems are used to weave mattresses. With the introduction of irrigation in the rim of the basins where the land dries up adequately to grow rabi crops, cropping patterns or rotations can be observed in Table 1.

Table 1: **Present Cropping Pattern in the Rim Areas of Wetlands in Atrai Basin**

Rabi	Kharif I	Kharif II
a. Wheat	HYV Rice	Fallow
b. Wheat-Pea mixture	HYV Rice	Jute/Fallow
c. Legume	HYV Rice	Fallow or B.Aman
d. Legume + linseed mixture	HYV Rice	Fallow or B.Aman
e. Oilseeds	HYV Rice	Fallow/B.Aman
f. Oilseed + legume	HYV Rice	B.Aman/Fallow
g. Tobacco/Vegetable	HYV Rice	Aus (Late) in upper rims.

In flood prone areas, where the soil will remain wet in October and later months, *boro* and B.*aman* or *boro*-fallow are the cropping pattern. In some higher patches potato, tobacco, watermelon, cucumber, pumpkin, etc. are also cultivated. However, early heavy rain may cause considerable damage to these crops. The above pattern can be seen in poldered areas. In some areas T.*aman* has also been grown. Crop diversification is limited, because of lack of market demand and low profit margin.

Homesteads are the major areas for year-round vegetable, papaya and banana production. Timber tree production, particularly fuel trees, has reached almost a precarious level. Due to fuel shortage cowdung and crop residues are constantly used disrupting organic matter recycling. This is a major reason for Zn and S deficiency in the soil. Due to parasitic infestation and fodder shortage the cattle improvement has not progressed well. However, fishery and poultry are making some progress.

Arial Beel

Arial Beel has been shown as Region 15 in agro-ecological regions of Bangladesh (FAO, 1988). The soil of the area comprises calcareous alluvium (5%), calcareous brown floodplain (2%), calcareous dark grey floodplain (9%), and non-calcareous (70%). The top soil is slightly to very acidic. Permeability is moderate, except where there is a buried heavy clay layer in the soil. Moisture holding capacity is moderate. Most of the cropping area has non-calcareous soil.

The area is deeply flooded and either a mono culture of B.*aman* or a mixed crop of B.*aman* and local *aus* were cultivated. This mixed crop was a risk aversion technology as in most of the years *aus* crop used to get damaged by the flood. In the shallow flooded areas, however, jute and mono-culture of *aus* were in vogue. In some areas with least flood risk, sugarcane was also grown as an important cash crop. Seasonal/annual and perennial fruit crops along with fuelwood trees were grown in the homesteads. Wild rice was also nurtured carefully as fodder crop. The aquatic grasses were also nurtured and protected from the onrush of water hyacinth because during the flooded period these aquatic grasses had been used as cattle fodder from time immemorial.

During the *rabi* season where the land became dry in October, oilseed, legume and vegetables were grown. After partition and with the establishment of cold-storages in these areas, the potato cultivation began to be popular. After partition. Narayanganj and Dhaka markets had a greater demand for vegetables and therefore this area began to grow more and more vegetables. With the introduction of LLP in the 60s and shallow tubewell (STW) in the late 70s and 80s, highyielding *boro* production, particularly in the perennial wet patches, became the predominant *rabi* cereal. In the shallow flooded areas, where the soil can dry up in October, wheat/pulse/oilseed crops are followed by a HYV *boro* which is harvested just ahead of normal flood. This form has become a major cropping pattern. The other patterns are:

I	a) First *rabi* crop	wheat/potato/pulse/mustard
	b) Second *rabi* crop	HYV *boro*
	c) *Kharif*	fallow
II	a) First *rabi* crop	vegetable/onion, chilly
	b) Second *rabi* crop	HYV *boro*
	c) *kharif*	fallow
III	Early flooded areas	pulses,mustard/chilly, B.*aman*
IV	Wetlands	HYV *boro*, fallow

Gopalganj-Khulna Beels

Among the wetlands and the basin/*beel* areas of Bangladesh, Gopalganj-Khulna *beels* provide more challenging features than the others. This marshy area is considered as one of the primary centres of origin of rice. This area has been designated as Region 14 with subregion 14a and 14b in FAO, 1988. Reed swamp occupies substantial areas in the Gopalganj-Khulna peat basins.

The old rice variety *rayada* is cultivated in the low-lying marshy areas of Jessore and Faridpur. *Rayada* is the primitive form of the present day B. *aman* or deepwater or floating rice. *Rayada* is highly photosensitive but has no seed dormancy for which it can be harvested in November/December and immediately sown in the seed bed for the next crop. This long growing *rayada* was quite flood resistant and could give about a ton of unmilled paddy/acre or about 2.5 - 3 tons of paddy/ha. Much later *boro* was introduced from *haor* area and the system of mixed culture of *rayada* - *boro* became the most popular form of mixed cropping. The *boro* yield was higher and was least risk-prone. Even with short day induction in early vegetative stage *rayada* does not flower in March/April but being photo insensitive *boro* flowers in mid-March to the end of March and *boro* thus can be harvested before the onset of flood. *Rayada* continues to grow along with flood and flowers in late September or in October to be harvested after 30 days of flowering. Through human intervention various varieties of deepwater rice were selected and cultivated. With the introduction of the irrigation facilities, the irrigated *boro* rice area began to expand replacing mixed culture of *rayada* and *boro*. With completion of some flood control projects, protection to *aus* and *aman* crops have been provided.

In the higher ground where land could dry out, legumes, oil seeds, spices and vegetables were produced. However, much land remained fallow for grazing of cattle. Perennial and annual fruit crops were grown in raised homesteads. Potato, pineapple, papaya, guava and sweet potato were also grown. *Dioscoreas* and *Colocasias* were grown as roots and tubers. *Rabi* cotton was perhaps grown in higher areas with better drained soils and with least probability of an early flood. *Kusum* (safflower) was an important cash crop for both oil and dye.

Due to the remoteness of the area and absence of quick communication, production of perishable crops like vegetables, papaya, banana, melons, etc. have remained limited to local consumption need. Crop diversification has therefore remained limited to legumes, oil seeds, and winter vegetables. Largescale production of maize, millets, melons, onions, garlic, chillies, rabi cotton, linseed, sunhemp, groundnut, soybean, potato, sweet potato, etc. cannot be grown on commercial scale due to limitations of the soil and topography. These physical and pedological constraints also limit improved cattle and poultry raising. However, fish farming including sweet water shrimps can be commercialized and can be developed to a profitable level. Non-conventional aquatic foods like *singara* (*Trapa bispinosa*), *ghechu* (*Aponogeton natans* and *echinatus*) rhizome and seeds of waterlily and *makhna* (*Euryale ferox*) can be produced and popularized for the bakery industry by partly replacing wheat.

The Gopalganj-Khulna Beel soils show zinc deficiency. Zinc deficiency in the soil favors increase in the population of nematodes. The ufra disease of rice (caused by a nematode) is therefore endemic to these zinc deficient basin soils. The nematode infestation makes the rice plant very susceptible to the blast disease which usually causes greater damage to the rice crop. Therefore unless nematode is controlled there cannot be any control of blast disease of rice in these zinc deficient wetlands.

The Sylhet Basin

This is the largest basin wetland system of Bangladesh. The area is very heterogeneous topographically with deep spots and higher ridges cut across by creeks and rivers. During the rainy season the entire basin area looks like an inland sea from which the name *haor/baor* have evolved. The Sylhet basin has been designated as Region 21 in FAO, 1988. The general soil type of this area is non-calcareous grey floodplain and partly non-calcareous dark grey floodplain. The area also contains peat, grey piedmont soils and acid basin clays. By texture clayey type is the most dominant one (87%) followed by 12% of loamy soils. Western parts of the basin shows S and Zn deficiencies.

The deepwater *aman* and transplanted *aman* rice were the dominant rice groups. *Aus* was confined to the higher grounds. *Boro* originated in this basin. The name comes from BAOR - BORA, indicating a lowland crop. It is interesting that *rayada*, the primitive form of deepwater rice, was not found to be grown in Sylhet or adjoining basins. With the introduction of LLPs in these traditional *boro* areas, the area expansion began as there was plenty of water in these basins. The muddy soil remained soft, the farmers simply removed the debris and aquatic weeds and grew *boro* rice. This ploughless land preparation is a major technical specialty of this wetland. The scattered mounds or heaps of these debris provide a good media for gourd and vegetable cultivation. After *boro*, deepwater or B. *aman* was grown except in the deep *haor* where the normal depth of flood is more than three meters. The deepwater rice stem elongates and grows not vertically upward but retains a diagonal position due to the force of water current. Therefore at a depth of three meter the stem length will be about nine meter. Due to the force of current the stem anchorage is often uprooted and the entire crop may float away downstream. To prevent the "wash away" of crops the farmer usually grow *Sesbania* and *Ipomea* and some leguminous plants in broad rows which protect rice crop from washing away as well as prevent the onrush of water hyacinth from riverside. With the introduction of highyielding *boro* crop, the farmers quickly adopted this and now HYV cover about 40% of *boro* rice. It will not be wise to push HYV area beyond 60% to keep the equilibrium between the local cultivers and HYVs.

In these basin areas, poor, homeless and landless people collect *ghechu*, wild *singara* and rhizomes of waterlily. In some low lying areas around Kishoreganj and Itna, *ghechu* is also cultivated. The tuber of *ghechu* grows to the size of a thumb (about 1.5 cm in diameter). These tubers are harvested in October-November as the flood recedes and replanted after the harvest of *boro*. The tubers can be dried and then powdered to make flour from which *chapatis* or pancakes are made. The flour is milky white like that of wheat flour and has nutrient quality like that of potato. This is never affected or damaged by flood. This is the most important famine food which keeps the unaided flood affected poor people alive in the remote areas.

Random plots of *motra-pati* (*Juncellus inundatus*) are found in the upper rims of the basins. Once upon a time the famous *sheetal pati* of Sylhet was manufactured on a largescale and was popular all over the then Bengal. The *bhatshola* (*Aeschynomene*

indica) used to grow all over the floodplain. The pith was collected and used to manufacture the headgear or hat or *sholar tupi* and was used by all police and government officials to protect the head from bright hot sun. The *gach alu* (*Dioscorea*) was also a popular vegetable before the era of table potatoes. The *bulbils* as well as the underground large rhizome are in no way inferior vegetable. It does not need cold storage as any damage to the rhizome heals up automatically by its own exudation.

Crop production trend in Sylhet basin can be judged only from the crop production data of the entire district. The *boro* area declined to 25.6% in 1972-73 from 39.52% in 1947-48 showing that with the advent of irrigation other areas were growing more *boro*. The *aus* area showed only a meager decrease of 0.2% from 1947-48 to 1972-73. Tobacco area decreased by about 50% from 1947-48 to 1987-88. *Rabi* vegetable production in 20 years declined by about 50% (Table 2).

CROP VARIETIES

At one time, undivided Bengal had about 15,000 rice varieties under a single spp. *Oryza sativa*. But natural stresses and economic pressure reduced them to about 6,000. Due to heavy pressure of HYV and *pajam*, many local varieties of *boro* like *batak, jagli, joal bhanga, foni boro, begunbichi, lakhaya, rata, kaliboro*, etc. got extinct.

In the lowlying areas of Lower Atrai basin where wheat could be grown in *rabi* season, first *gongajoli* variety was culled out and replaced by *jamali* (Moslem era) which was later (40s) replaced by *pusa* varieties of wheat which subsequently got replaced by modern wheat varieties like *sonora, penjamo, mexi-pak, sonalika*, etc. Mustard crop had two major spp. Campestris (*Toria-Maghi Sarisha*) and Juncea (*Rai Sarisha*) along with other minor spp. which were less economical.

Among the pulses, *chola* (gram), *musur* (lentil), *mung, kalai, khesari, motor* (pea) were grown in the basin. Among these *khesari* which could be grown with zero-tillage and zero input in saturated soil remained popular in the basins because it is one of the best fodders and its hey could be preserved for feeding the cattle in the rainy season. In each of these legume spp. there were not many varieties and in these groups genetic erosion was the least. Due to topographical limitation indigo and muslin cotton production was absent in the past. However G. *barbadense* and *connenses* used to be grown in the homesteads in a limited way.

Tobacco production perhaps began in the 17th century along with the introduction of potato, guava, sweet potato, pineapple, tomato. It is not known how these affected the cropping system and crop diversification but gradually these crops got established and became a part and parcel of local crops. Muslin cotton (spp. not identified), indigo, *kusum* (sunflower), opium, *ganja* (Marijuana), etc. crops got either extinct or remained as marginal crops mostly due to economical reasons. Among the local seasonal fruits, the watermelon varieties of Goalanda and Patiya have almost reached the state of extinction due to heavy pressure from Japanese varieties. Perennial fruit crops like

mango, litchi (introduced from China), jackfruit, sapota, *kamranga*, pomelo, orange, lime, lemon, *ber*, guava (introduced), *jamrul*, jam, coconut, etc. did not change much and also had least genetic erosion. However, the local *ber* group is now being rapidly replaced by modern and large-sized Indian and Thai varieties. The local fibrous and sour types of mango varieties are also being replaced by better varieties like *lengra, mohonbhog, gopalbhog, khirshapat, lata Bombay*, etc. Maize and soybean could not make any headway in Bangladesh though these crops have industrial potential.

Table 2: **Statistics of Major Crops of Sylhet**

Crop		1947-48	1957-58	1967-68	1977-78	1987-88	1989-90
Aus	A	70.80	107.20	147.00	140.00	141.20	210.80
	P	47.60	97.60	168.40	174.10	177.40	227.00
B.Aman	A	441.80	474.50	502.50	118.00	139.80	106.00
	P	402.80	486.40	678.80	124.80	147.80	144.00
T.Aman	A	-	-	-	244.00	279.60	286.00
	P	-	-	-	352.10	431.00	431.00
Boro	A	120.00	154.00	209.20	253.60	222.10	277.60
	P	142.30	171.70	322.20	430.10	351.00	395.00
Pulse	A	5.20	2.92	0.84	1.05	1.36	2.40
	P	2.90	2.80	1.00	0.83	0.88	-
Oilseeds	A	6.30	3.90	6.90	6.00	7.70	7.80
	P	3.00	2.30	3.50	4.40	5.15	5.30
S.Cane	A	0.80	1.70	2.10	2.30	1.50	2.80
	P	28.20	78.20	108.50	102.30	58.30	30.00
Jute	A	11.10	14.10	9.20	2.30	1.20	1.20
	P	94.70	70.40	66.70	5.20	9.00	8.00
Tobacco	A	1.20	1.30	2.90	2.40	0.50	-
	P	1.10	0.70	2.30	1.80	0.32	-
Rabi Vege-tables	A	5.60	5.20	2.50	5.10	5.80	-
	P	36.90	28.50	18.90	5.50	44.20	-
Rabi fruits	A	2.40	2.20	-	-	-	-
	P	15.70	14.00	-	-	-	-

A Area in thousand ha
P Production in thousand ton
- Not available

Source: BAS/DA Agroeconomic Research Section, MOA 1973, BBS 1980 and BBS 1992

DRAINAGE OF WETLANDS FOR IMPROVED AND SUSTAINABLE AGRICULTURE, IRRIGATION AND FLOOD CONTROL

Drainage as a basis of land improvement was considered in the early British period (1899) when Sir R.B. Backley suggested the excavation of Madaripur-Kumar Beel Route not only to improve drainage but also to provide faster river communication. This route was excavated during 1899 to 1903. The route was officially opened on 15 June 1904 (Khan, 1977). The bed width was 150 feet, 22 miles in length, 400 feet wide with depth variation between 7 and 30 feet at stranded lowwater (SLW). In subsequent years Faridpur District Board and the local unions tried to improve the drainage at random and in an unintegrated way.

The Satla - Bagda Project (SBP)

The project is located in Southwest region covering Gopalganj, Pirojpur, Barisal and Khulna districts (Fig 1). The project area was about 29,230 ha (BWDB,1988). The land within the project is low and flat with Satla and Bagda *beels* covering the major area. The area is subject to regular tidal flood but salinity does not encroach.

Drainage was provided initially by 15 wooden boxes and 20 sluices. The area was embanked with 120 km polder of 2.74 to 3.66 meter height with a width of 4.27 meter. There are nine gravity drainage regulators and 372 inlet structures in the embankment for water courses and excavation of drainage and irrigation channels to provide gravity irrigation for an area of about 10,000 ha. It was envisaged that out of 37,246 ha of cropland B.*aman*, *aus*, and late *boro* or early *aus* (BRAUS) would cover an area of 21,255 ha or 57% and T. *aman* would cover 2,429 ha or 6.5% . This fact showed that drainage in the rainy season could not be so easily made effective. Nevertheless, early drainage of floodwater and arrangement of irrigation were helpful to expand and improve *rabi* crops. It is to be noted that the SBP could cover only 13% of the net wetland area of the Gopalganj-Khulna Beel system.

The Chalan Beel Project (CBP)

The project had almost identical objectives like that of Satla-Bagda project. The major objectives were flood protection, drainage improvement and limited irrigation.The project area was 53,036 ha of which the net benefitted area was about 38,580 ha or 73% of the gross project area (Fig 2). The net wetland in this Lower Atrai Basin is about 81,400 ha. Therefore the CBP could cover 65.19% area. This CBP project is therefore larger than the SBP of Gopalganj-Khulna *beel* system. The total embankment is about 133.63 km long with 25 sluices, 13 flood regulators, 22 irrigation inlets and 16 drain outlets. The project was initiated in 1981-82 and completed in 1987-88 (BWDB, 1987).

The cropped area under CBP was 56,037 ha with a cropping intensity of 145% and B. *aman*, *aus* and *boro* covered about 34,000 ha or 60% of total area. T. *aman* covered 7,534 ha. or 13.44% of the total area, pulse had 7,044 ha or 12.57%, wheat and oil seed, each covered about 2.4%. The envisaged cropped area was 66,099 ha, in place of 56,037 ha, i.e. an increase of about 18% of cropped area with a cropping intensity

of 171% as against 145%. *Boro* area was expanded by about 3,000 ha and wheat area was increased to 11,133 ha from 1,457 ha, i.e. the increase was about 6.64 times. B. *aman* area was also doubled. The *rabi* crop area was envisaged to be doubled with most of the area covered by wheat. In fact, the CBP planner reduced the pulse area to 6,072 ha from 7,044 ha of pre-project condition. This was not fair as pulse not only provides more and better protein but also enriches the soil with extra nitrogen. Nevertheless, there was no dispute on the utility of the project.

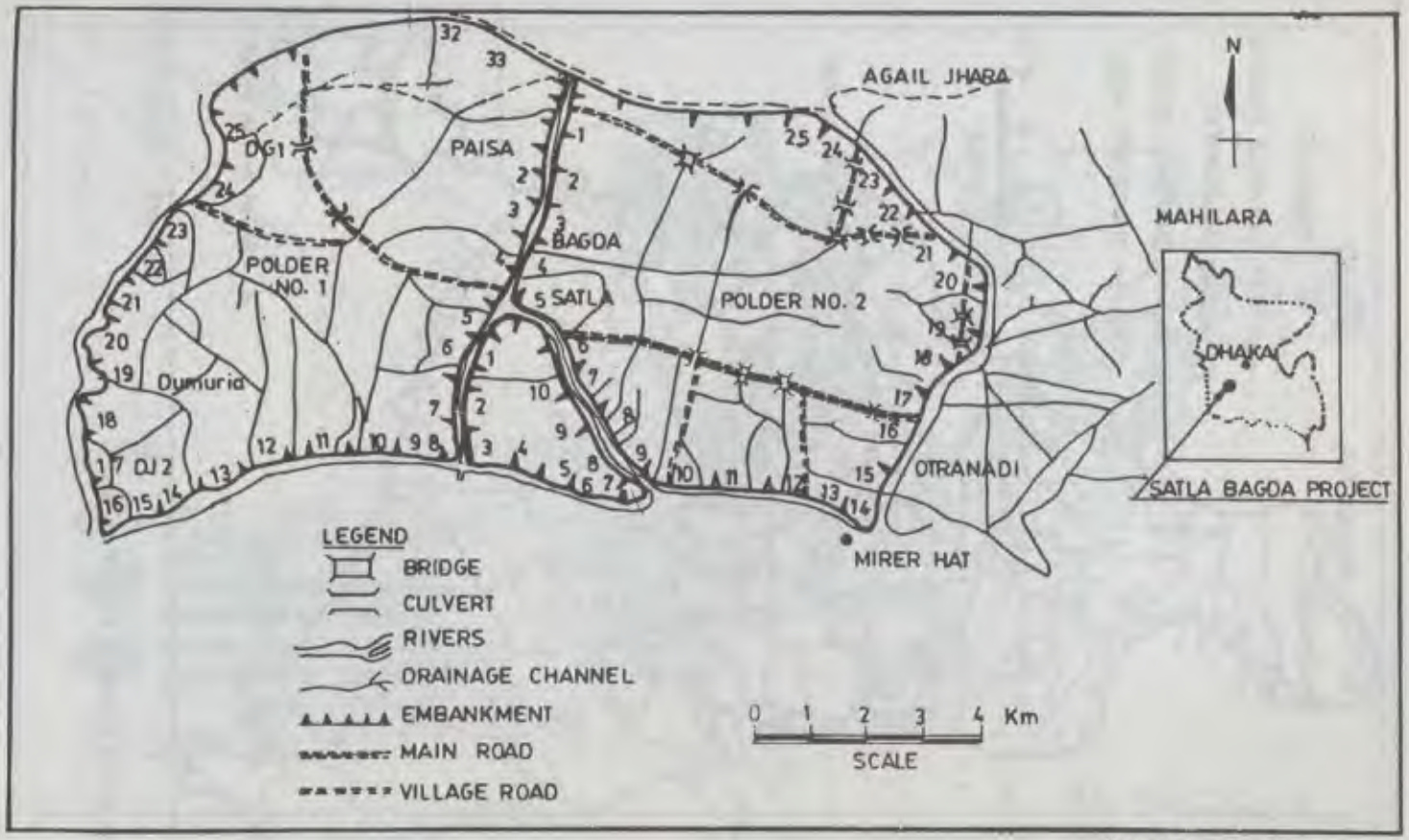
The Haor Projects

The total basin area is about 457,345 ha of which the arable area covers about 409,204 ha(89.5%). The area is very big and poses the biggest bio-technological, socio-economical as well as environmental challenges. In the Sylhet basin the total gross area under FCD projects are about 269,600 ha with a net area of about 217,600 ha (Fig 3). It has been shown that 67 to 100 percent of all schemes of BWDB and 89 percent of the projects had partly correct concept (Northeast Regional Water Management Project, 1992). The percentage of schemes with negative impacts varied from 41 to 53. The percentage of schemes with positive impacts varied from 74 to 84. It was evident that the technical aspects cannot always elevate the local traditional socio-economical conditions which most often regulate the adoption of the technology in a satisfactory way.

The planners of these projects perhaps assumed that drainage, flood control and irrigation were the three factors to boost crop production. The socio-economic conditions, land tenure system, local marketing, processing and transport system were not integrated with the project operation. As a result, the farmers could not get a fair price for their crops. The absentee land owners of Sylhet are quite different from the rest of their counterparts in Bangladesh. None of these land owners has a desire to improve the farming practices. It was also assumed that simply flood control, drainage and irrigation will keep the soil in productive form. There was no experimental results either actual or simulated on the kinetics of soil nutrients under such a changed hydrological condition.

CONSEQUENCE OF FCD PROJECTS ON ENVIRONMENT

One must note that drainage and drying of submerged soils will get quickly oxidized and change of pH along with soil moisture may create a toxicity-deficiency syndrome. The zinc deficiency and micro-nutrient availability have not been well studied by the agronomists. Irrigation is not a panacea by itself but will definitely accelerate soil degradation when used inefficiently. Mere application of water in the cropfield is not irrigation. Irrigation and drainage are two components which are to be bonded well to keep the rhizosphere in field capacity condition. Unless this is done the crops, particularly the non-rice crops which need more oxygen, will react violently.



SOURCE : BWDB (1988)

Figure 1: Satla-Bagda Project

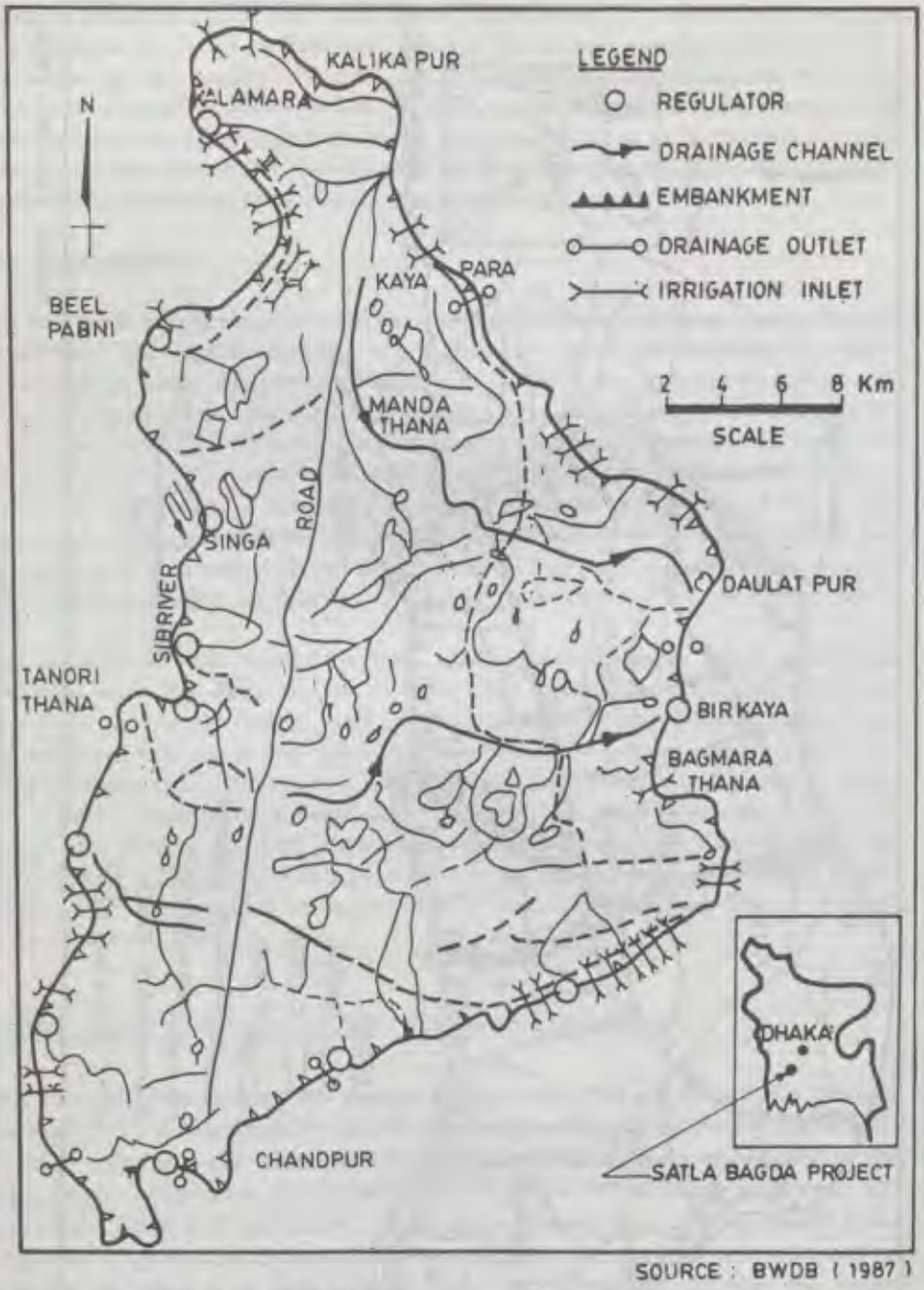
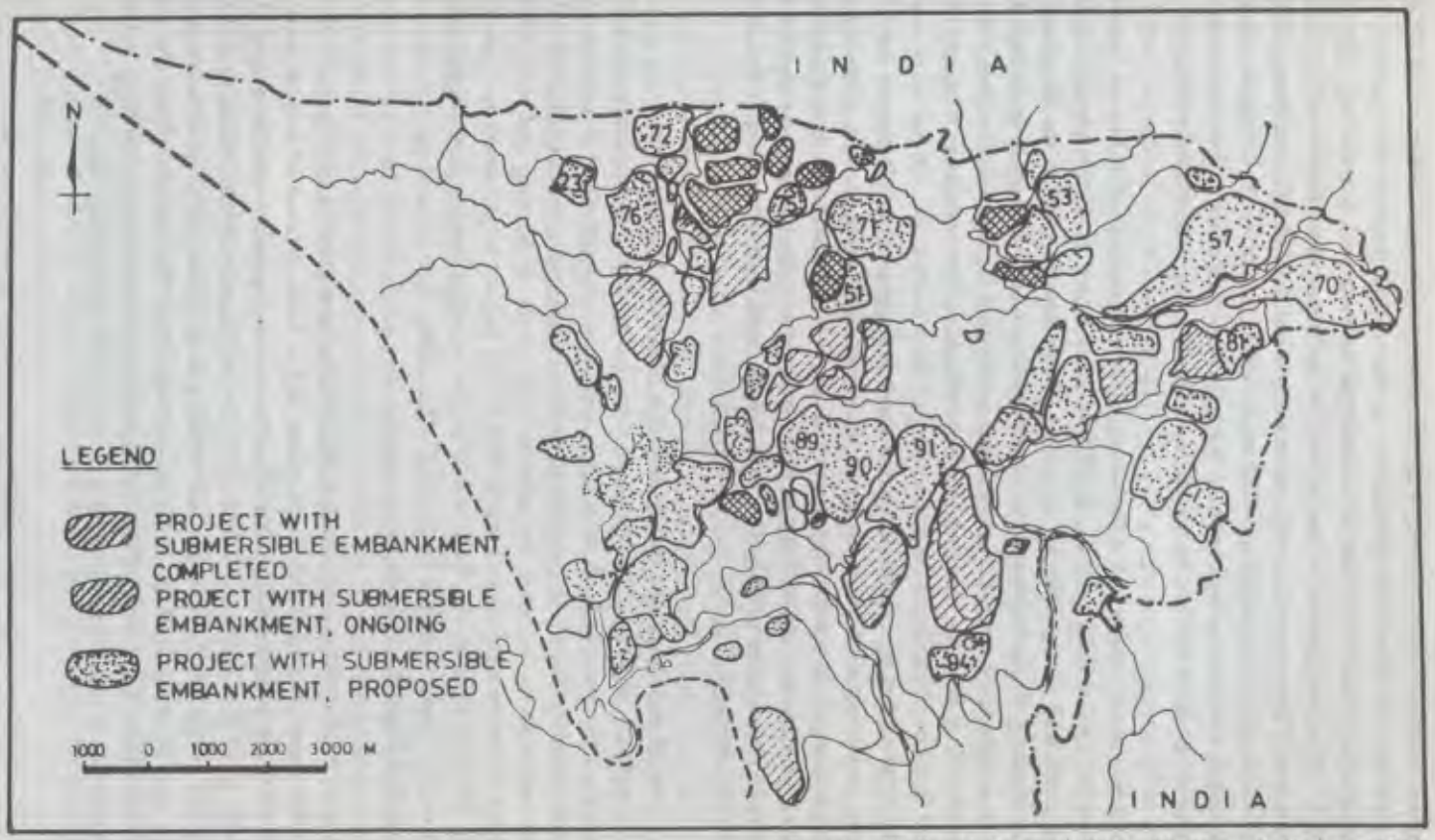


Figure 2: **Chalan Beel Project**



(Source: Northeast Regional Water Management Project 1992)

Figure 3: **FCD Projects in Sylhet Basin**

The changed edaphic condition along with the general ecological change in the FCD project area has not been well considered. In the earlier projects the question of environment and conservation was not considered as there was a knowledge gap in realization of the consequences of man-made changed eco-system. Such a state of lack of appreciation of environment is reflected in a report entitled "Bangladesh Action Plan for Flood Control: Achievements and Outlooks (FPCO, 1992). It says - "improvement in flood control and drainage will not lead to a significant loss of natural wetlands since virtually all of the lands likely to be affected have been under cultivation for centuries".

The report however failed to realize the changed edaphic, ecological and biotic factors which resulted due to FCD projects, application of chemical fertilizers, especially in an unbalanced way along with the upsetting of the equilibrium in the biosphere. Northeast Regional Water Management Project (1992) wrote - "Any major hydrological change to a natural or near natural wetland eco-system will inevitably have some negative effects, if only by reducing the "naturalness" of the system and thereby its values for baseline research on the functioning of these ecosystems. Of the six critical areas identified in this report, the most important is Tanguar Haor. It plays a crucial role in the maintenance of bio-diversity in the region, primarily because of its large size, the richness of its aquatic vegetation and its relative remoteness. It is therefore strongly recommended that the Tanguar Haor system be excluded from any proposed flood control, drainage or irrigation projects which could have any adverse effects on its ecological character."

On the technical and environmental issues associated with Hakaluki Haor, the same author comments - "Hakaluki Haor has been subjected to considerable manipulation by man and has now lost much of its natural vegetation. Nevertheless, it remains an internationally important wintering area for a variety of migratory waterfowls, and will doubtless continue to do so if the present high levels of hunting and associated disturbance can be brought under control. Any FCD/I project would result in a general lowering of water level in the *haor* would have a negative impact on the waterfowl population and should therefore be avoided". The author also pointed out the adverse effects on Hail Haor, Kawadighi Haor, etc.

According to FAO (1988), environmental hazard also took place in Gopalganj-Khulna Beels in the name of agricultural development due to land reclamation in peat areas, excavation of peat and increased abstraction of surface and ground water for irrigation. This would allow peat layers to become dry in the dry season and cause them to shrink lowering the ground level. Since the base of the peat in this region is at or below sea-level, the cost of pump-drainage might become very high. Excavation of peat for use as fuel would leave large water-filled depressions and excavation of peat from below clay-top soil that is cultivated would reduce the area of agricultural land.

GRAZING GROUND AND LIVESTOCK IN WETLANDS

In the past due to low population pressure most of the wetlands remained as a culturable wasteland and was used as grazing ground particularly in the dry season. When permanent settlement was implemented, the landlords began new settlements in these wastelands to increase their revenue income. By the beginning of the fifties the government began to implement forcefully grow-more-food projects. These wetlands where there was water the production of *boro* rice was considered to be the most economic method of extra food production. LLPs were increasingly used at subsidized rates. As a result more and more lands were brought under *boro* production. The cultivable wasteland decreased from 296,000 ha in 1969-70 to 260,856 ha in 1986-87 i.e. by about 12%. In many parts of the country like Rajshahi, Jessore, Khulna and Sylhet many cropped areas are left as current or winter fallow for grazing. *Khesari* is cultivated in Madaripur, Pabna, parts of Dhaka and Tangail for grazing of cattle for fattening. Forest land is also used for cattle grazing.

There was no organized grazing ground except that almost in every village there was one or two areas of grazing land where common grasses used to grow naturally. There is no experimental data to show whether such grazing land had any positive contribution to the growth and fecundity of the cattle population. The stall feeding was the principal practice. Poor people who had no land used to collect forage from wasteland and forest for feeding their cattle. In the wetlands, particularly during the flood, wild rice plants (*O.perennis* or *O.sativa* var *futua*, *Hygroryza asiatica* and *Vossia cuspidata)* are still used as cattle feed. Most of the community grazing grounds belonged to the landlords/*zamindars*. With the abolition of *zamindari* system these community grazing grounds went to the illegal possession of powerful village leaders. Many of the *beels* and *jalmahals* which also belonged to the *zamindars* were similarly lost.

CONCLUDING REMARKS

For development of sustainable agricultural practices in the wetlands present-day gaps in database and understanding of changes in soil due to agricultural activities need to be corrected. The following are some of the specific issues:

- soil nutrient kinetics both under poldered, drained and irrigated conditions as well as under non-poldered natural condition;
- soil nutrients (including micro-nutrients) recycling in the wetlands both within and outside the poldered areas;
- factors affecting cropping pattern and farming system both under poldered and non-poldered conditions;
- study of various cultural practices adopted by the farmers for each crop and their effect on the yield;
- study on livestock farming in wetlands with respect to breed, physiology, health, feeds and feeding, healthcare, fecundity and mortality;

- effect of drainage and irrigation on organic soils;
- influence of HYV *boro* cultivation on the genetic erosion of local cultivars, soil composition, etc;
- nature of flood and its effect on the biosphere and socio-economic aspects in the wetlands;
- need of evaluation of all FCD/FCDI projects from the viewpoint of environment and its long-term effect on soil composition and crop productivity;
- detailed study of the peat basins in connection with reclamation or mining of the peat and method of soil stabilization to prevent ponding;
- effect of biocides on the biosphere of the wetlands and *beels*; and
- present status of non-conventional foodcrops and their role as food source during post-flood period, their present and future economic role including improvement of crops on the basis of local ecological and socio-economic conditions.

ACKNOWLEDGEMENT

The author acknowledges the service rendered by Mr S.B. Saheed, Director, SRDI, and the assistance given by Dr Monirul Hoq, Ex-Director, SRDI, and by the experts of M/s Shawinigan Lavalin Inc.

REFERENCES

Agro-economic Research Section. 1973. *Bangladesh Agriculture in Statistics*. Ministry of Agriculture, Government of Bangladesh. Dhaka.

Bangladesh Bureau of Statistics(BBS). 1980. *Yearbook of Agricultural Statistics of Bangladesh*. Planning Commission, Government of Bangladesh. Dhaka.

Bangladesh Bureau of Statistics(BBS). 1991. *Statistical Yearbook of Bangladesh, 1991*. Planning Commission, Government of Bangladesh. Dhaka.

Bangladesh Water Development Board(BWDB). 1987. *Project Proforma on Chalan Beel (Polder D)*. Planning Commission, Government of Bangladesh. Dhaka.

Bangladesh Water Development Board(BWDB). 1988. *Project Proforma on Satla-Bagda Project*. Planning Commission, Government of Bangladesh. Dhaka.

Bureau of Agricultural Statistics. 1966. *Agricultural Production Levels in East Pakistan (1947-1965)*. Directorate of Agriculture. East Pakistan Government Press, Dhaka.

Flood Plan Coordination Organization(FPCO). 1992. Bangladesh Action Plan for Flood Control: Achievements and Outlook, Dhaka.

Food and Agriculture Organization(FAO). 1988. *Land Resources Appraisal of Bangladesh for Agricultural Development*. Dhaka.

Khan, Nurul Islam. 1977. *Bangladesh District Gazetteers, Faridpur*. Bangladesh Government Press. Dhaka.

Northeast Regional Water Management Project. 1992. *Regional Water Resources Development Status, Draft Thematic Study*. Flood Plan Coordination Organisation, Government of Bangladesh, Dhaka.

SOCIO-ECONOMIC CHARACTERISTICS OF FRESHWATER WETLANDS IN BANGLADESH

S. Zahir Sadeque and M. Aminul Islam

ABSTRACT: Unique socio-economic features of the wetlands of Bangladesh, known for their rich and varied bio-physical characteristics, pose challenging issues in sustainable management and conservation. This paper attempts to understand the interaction between the social and physical dynamics of these freshwater wetlands. All wetlands are flood prone and hence the agricultural practices have been adjusted to minimize the risk of flooding. Human settlements are of two types: densely populated clustered ones on high grounds which remain above water during the monsoon and elongated linear ones along natural levees. Social organizations of these areas are unique as the geo-social units are clearly demarcated in the wet months. These areas have a larger than national average of Hindu population (17%); rest are Muslims. Occupational pattern follows religious lines; where Muslims are traditional farmers and Hindus belong to fishing and services (teaching, medical and legal professions). Resolution of social disputes and leadership hierarchy transcend the occupational pattern. Management practices of *jalmahals*, which often leads to conflicts, have been discussed. The paper recommends mass functional education in the wetland areas.

INTRODUCTION

Wetlands of Bangladesh, known for their rich and varied bio-physical characteristics, also exhibit unique socio-economic features that pose challenging issues for their conservation and sustainable management. The quality of natural resource base in Bangladesh is so dependant upon and inter-linked with its freshwater wetlands, teeming with diverse aquatic species, that their survival and renewability cannot be separated from the prospects of sound resource development. Since competition for scarce resources is extremely high and access to the open and common property is declining consistently the value and importance of these wetland areas are immense. However, as is the case elsewhere, most of the resources of the wetland areas are concentrated in the hands of a few. Together with this resource owning inequality the existing harvesting techniques grossly overexploit the wetlands of Bangladesh. Wetland resources, as is the case with other fragile eco-systems, should be harnessed with approaches and concepts like maintaining 'stability' for immediate betterment of the community and 'resilience' for sustaining and renewing the resource base.

The continued loss of wetland areas threatens the very ability of the land to maintain life. It results in reduction of bio-diversity and aquatic and amphibian resources as well as in reduction of wildlife habitat leading to the displacement of wetland-based human occupation and socio-economic activities. Although roughly one third to a half of Bangladesh may be classified as wetland, traditionally wetland was equated with wasteland and there was a clear preference in the mind of the planners and administrators for conversion of wetlands into the so-called productive agricultural land. Of late, the people are increasingly becoming conscious about the fact that wetlands are the storehouse of bio-diversity, that the value of fish catch per unit of wetland area is higher than that of agricultural output and that it has other important roles such as

recharging the aquifer level of the groundwater or source of supplemental irrigation. In this context, new approaches to the management and development of wetlands are essential. But to embark upon that, understanding about the wetland bio-resources as well as socio-economic characteristics of wetland inhabitants and issues affecting their life is needed.

This paper attempts to analyse the interaction between the social and physical dynamics of the freshwater wetlands.

WETLAND ADAPTIVE RESOURCE SYSTEM

The resource system in the wetlands develops through the evolutionary process of man-environment interaction and adaptation. The physical and social dynamics of the wetland areas continually interact in forming the occupational pattern and resource management for livelihood. Therefore, the human-nature interaction results in an adaptive system, and resources therein become part of this adaptation. That is why we call the wetland resources as adaptive resources. A review of the past and present agricultural practices and other economic activities in different wetlands including cropping patterns, farming systems and present trends in landuse reveals some common social and biological characteristics.

As all wetlands are flood prone, the agricultural crop calendar in these areas is adjusted accordingly to minimize the risk of flood damage. The existing cropping systems have evolved over a long time as farmers' adaptation and response to the natural environment. This evolution and process of adaptation are usually backed by traditional and indigenous knowledge system and on rare occasions supported by modern research and extension.

Traditionally the wetland areas of the northeast were very sparsely populated. The rapid growth of population in this century has accelerated the process of settlement in these hitherto marginal and agriculturally unproductive lands. A significant area of the wetlands was covered by various types of forest including some unique and almost extinct freshwater mangrove species. Culturable waste and fallow lands surrounded the wetland area villages, as population pressure on land was not as severe as it is now. Occupational pattern and resource harvesting in wetland areas are also one of gradual change and transformation. At the early stage of settlement, fishing and cultivation of deepwater broadcast *aman* were the main activities of the wetland people. Gradually over time, this transformed into extraction of other aquatic resources and looking for other income earning opportunities, as competition for available resources stiffened. Landuse pattern in the *haor* basin depends on the land elevation. Since the basin is saucer shaped, its peripheral highland is used for homestead and adjacent to the homestead a patch of land and the sloping terraces are kept for vegetable gardening and post-harvest activity. Next hierarchy of land starts for agricultural use which is relatively higher in elevation, followed by the medium and low land. The lowest depression is the *beel* or permanent waterbodies. *Beels* are the habitat for the fish of the *haor* and the source of supplemental irrigation during dry season.

The cropping patterns in relatively high land are dominated by the crop combination of transplanted *aman* and winter crops or *aus* rice/jute-transplanted *aman* and winter crops. *Aus*/jute-fallow/winter crops are grown in the medium high to medium low land. Low-lying *beel* areas are used for *boro* and winter crops. Here broadcast *aman* is increasingly being replaced by high-yielding *boro* (winter) rice.

In the *haor* areas, *jalmahals* are the most important and dynamic resource. During the monsoon vast sea-like areas emerge between rivers submerging privately-owned and titled cropland. Within this area are large untitled deep areas which retain water throughout the year. These areas called *beel* are the most resourceful in terms of the habitat of a wide variety of indigenous fish and winter birds. These *beels* as government-owned property are usually leased out to the highest bidders on an annual or term basis. These leased waterbodies are known as *jalmahals*. Since 1979, with the enactment of national waterbody policy, fisherfolk cooperatives are preferred as lessees. However, in practice, genuine fisherfolk communities rarely receive such favours. More organized and well-connected people usually receive the stewardship, who, with the help of hired managers/musclemen, protect and harvest the resources. *Jalmahals* are sources of endemic conflict in the area pitting the lease holders against the residents, who feel that everybody has a claim on these natural open fishing grounds. Fishing occurs throughout the year, but activities certainly peaks during November to February, when the water level recedes. During rainy season (April to September), the *beels* swell and spills into adjacent areas. Residents fish in these areas which are usually outside the leased land but are often forced out by hired goons of the leaseholders, locally known as *pariahs*. These goons often confiscate their fishing gears and catches. Therefore, the leasing system, in addition to exacerbating inequality, also contributes to the use of coercive techniques by the beneficiaries and acts against the interest of the common people in harnessing the open-access common property resources.

Wetlands are one of the most productive and resourceful areas which provide food, non-food aquatic resources and retain the ecological balance for the local residents as well as for the nation. The wetland environment has united the inhabitants into a society which has a definite shape, culture and livelihood pattern. Wetlands are the source of foodcrops, fish, vegetables, pasture lands, wild fruits, wildlife, fuel, fiber and housing materials. Due to the availability of a wide variety of harvestable products, the people of the wetlands are traditionally self-reliant and have subsistence-oriented economy and livelihood.

Within the adaptive resource system of wetland areas common and open-access resources are the critical elements. Due to the presence of large tracts of land and terrestrial areas, not always clearly owned or titled, common property system prevails in the wetland (both *haor* and *char* areas), as an important property and use-right. For the poor, harvesting the common resources round the year is the major source of income, nutrition and livelihood. Poor residents of the wetland areas can only secure agricultural wage labour during the limited crop season, and are totally dependent upon the collection and gleaning of the common resources for their sustenance during the rest of the year.

HUMAN SETTLEMENT AND SOCIAL ORGANIZATION IN HAOR AREAS

In general, the settlement pattern in the *haor* complexes are of two types:

a) Villages in riverine parts of the country follow the natural levees and are usually above the flood level. Rivers are stilll one of the important sources of livelihood and means of communication and also a source of water for irrigation and domestic uses. Rivers therefore act as a linear force and influence a linear form of settlement development. Here, topographic influence is thus quite apparent in the pattern of settlement development as human habitats.

b) Other wetland features, such as *beels, haors* , *baors* and local depressions, wherein water remains almost all the year round, have confinement effect on the form and expansion of rural settlements. Here densely populated cluster settlements may be found. Settlement patterns are thus determined by the natural factors, of which landscape imposes two main forms: amorphous and elongated linear (Sultana, 1987).

Specifically, human settlements in the deeply flooded areas of the northeast region are built on *kanda*, the only high and terrace land which remains above water during the monsoon. These homesteads are overcrowded for six months of the year, since all activities are concentrated within this narrow space. Unlike the plains, there is no boundary wall or fence between homesteads, a sign of intense scarcity of high flood-free land. Community fellow feeling and accommodation amongst individuals is for obvious reasons relatively strong in the wetland settlements. This is, due to the nature of settlements, a prerequisite for survival in the habitable restricted space. During monsoon, each settlement figures as an isolated island amidst vast expanse of water. The vastness of the waterbody and strong summer wind results in powerful waves that hurl against the small islets housing the homesteads. The community homestead areas therefore are regularly threatened and eroded by monsoon floods and waves. The inhabitants together unitedly protect their raised homesteads from wave erosion by placing structures made with bamboo, soil, local long grass *(chailya)* and water hyacinth. Threat from wave erosion has increased in the areas where roads and flood protection embankments are constructed along the river and thereby leaving the settlements unprotected.

The social organization of these areas is unique in so far as their primary social units are determined by geographical boundaries of settlement areas. Therefore, the geo-social entity which is rather clearly demarcated specially in the dominant wet months of the year, forms the nucleus of the social organization in the *haor* areas. Population density of about 600 persons per square kilometer is still much less than the national average. These areas have a larger than national average Hindu (both caste and scheduled caste) population, often 17+ percent compared to national 12 percent. The rest are almost exclusively Muslims. Ethnically the areas are homogenous with exclusive Bangalee population. This distinct religious affiliation of the population, coupled with the geographic limiting factor, has resulted in a unique social organization of the areas. Historically, the wetland areas as marginal habitats were free from human

settlements. Settlements began with scheduled caste Hindus and landless Muslims spreading out to escape religious persecution and economic hardship. Later on land titling began as revenue collection process intensified and petty aristocrats were given land titles by higher authorities to act as land revenue collecting agents. Therefore, these areas characterised a sharp social division with a large group of socially marginal Hindus and Muslims as tenants and fisherfolk on the bottom layer of social stratification and on top of them were an aristocratic class of tax collectors appointed by successive state authorities (Pre-British and British).

Occupational pattern runs along the religious lines, where Muslims are traditional farmers and Hindus traditionally belonging to fishing and services (teaching, medical and legal profession). This contributes to the unique social organization of the areas. Social disputes are often mediated through *salish* and *bichar* along occupational structuring and religious lines. Hierarchy and leadership in the religion often transcend the occupational pattern and it is then that the organic entity of the village comes to the fore.

The process of new settlement and increasing population into these hitherto uninhabitated wetland areas have had significant impact on the overall bio-physical characteristics and hydrologic conditions of the wetlands. Among these, deforestation and conversion of wetland into agricultural land are important.

OCCUPATIONAL STRUCTURE OF WETLAND INHABITANTS

If the wetland areas in general are understudied, wetland socio-economy is more so. There is clear lack of hard data on wetland inhabitants largely because they are not looked upon as a distinct ecological entity and especially for the *char* areas, this is more of a problem because of the temporal and newness of the settlements. Therefore any discussion of their occupational pattern or socio-economic class position will have to be based on fragmented data supplemented by observations. The environmental study of the Bangladesh Flood Action Plan conducted an intensive appraisal type survey of the Surma-Kushiyara area of greater Sylhet district, which includes a large area of the northeastern wetlands (Surma-Kushiyara EIA Case Study, ISPAN, June 1992). From that study, some data are provided on the socio-economic profile of the northeastern wetlands.

In the recent years due to consistent decline in inland capture fisheries, agriculture has emerged as the overwhelmingly dominant sector of the economy in the areas. Estimates of occupational pattern in the Surma-Kushiyara area shows that about 85 to 90 percent of the population are involved in agriculture for livelihood (ISPAN 1992). Although there is a high percentage of absentee landlordism in the area, the dependence on agriculture is very high. This is particularly so, because of the low level of agricultural productivity and cropping intensity in the area, which compares extremely unfavorably to the national average. Another reason for this high level of agricultural dependence may be the preponderance of landless rural households who have virtually no access to other productive employments in the area.

Fishing is the second largest occupational category. However, accurate data do not exist on the number of people exclusively or primarily dependent on fishing in the area. Estimates vary between 4-9 percent of the population reported to be primarily dependent on fisheries as their major occupation. The important issue about fishing as an occupation lies in the fact that most wetland residents participate in open water capture fishery either as a secondary occupation or on occasions to supplement nutrition and income. Therefore, the extent of fishing in the occupational pattern is difficult to quantify. The problem of measuring the contribution of the fisheries sector to the income generation and occupational categories of the people is further compounded by the absence of any verifiable data set. Even with these limitations, based on our observations in the area and descriptive analyses found in other relevant reports of the area, notably the ISPAN (1992) study, it may be stated that a significant number of people, may be over 50 percent of the wetland population, are linked with fisheries to supplement their household nutrition and income, an activity which is not always linked with the market and, therefore, not quantified and thus not reflected in the national statistics. The fisheries sector exhibits another interesting feature in the occupational structure of the area. The large waterbodies i.e., *jalmahals* are leased by wealthy landlords and other influentials, as described earlier. The lessor in turn often arranges agreements with several others for the protection and harvesting of the *jalmahal* fish resources. These intermediaries together with the principal lessor form the apex in the fisheries hierarchy, often in the overall social hierarchy as well.

Riverine transportation, trading in aquatic resources and other normal petty trading and service sector absorb the rest of the wetland population. However, trading in the aquatic products is an activity that rarely finds itself in the national statistics. Once again, this is due to the subsistence nature of the use of the products and the absence of significant market transactions of these commodities. (For a detailed list of products please refer to the Resource System of Wetland section of this paper).

It is evident that the occupational structure of the northeast wetland inhabitants reflects some interesting variation from the national average, both because of their differential resource endowments and because the methods applied in the national accounting precludes several local economic activities that are not or cannot be quantified.

MAJOR ISSUES AFFECTING SUSTAINABLE MANAGEMENT OF THE WETLANDS

The freshwater wetland areas are ecological niches, rich in bioresources and are critical in the maintenance of the country's ecological balance. But, unfortunately, they are not treated as special areas and development activities are planned and implemented without their special status in mind. We believe, sustainable development of wetland areas in Bangladesh requires a recognition by all stakeholders that wetlands are special ecological zones and, therefore, all human interventions in these areas should be planned with that special status in mind. Having stated that as a general background, we discuss the following set of issues that are important for the sustainable management and development of wetland areas.

Jalmahal Management

Jalmahals are the most economically important aspect of the wetland resource system. Under the present management system these large waterbodies were until now almost exclusively managed for immediate short-term gains. But, this is a destructive and unsustainable practice. Existing management practices should be throughly examined to renew and sustainably harvest resources. New management practices should perhaps consider longer-term lease and strictly enforce the stated principle of preference of genuine fisherfolk groups in awarding the lease. Short-term encourages unsustainable harvesting to the extent that resources are no longer renewed for continued harvesting. Due to over-harvesting it also results in extinction of threatened species. Management practices should be participatory in approach involving local residents and occupational groups involved in harvesting wetland resources. Participatory approach has become a catch-all phrase these days. Therefore, caution must be taken so that it does not degenerate into a mere lip service. In developing participatory management special attention should be given to the social stratification and occupational structure of the wetland inhabitants. Conflicts will almost invariably arise out of the management of such large and seemingly boundaryless property. Therefore, mediation of disputes along the religious or occupational lines may also benefit from the existing adjudicating bodies.

Second, there is a need for recognition of the fact that wetland resources extend beyond private boundaries and property. Nowhere is the issue of common property and open-access resources more evident than in the floodplains and wetland areas of Bangladesh (Sadeque 1992). Sustainable management of wetland resources hinges on the recognition of this tenurial issue.

Restricting Agrochemical Use

Agrochemical use in the wetland areas have recently increased dramatically due to the introduction of *boro* (winter rice) cultivation. HYV *boro* requires high dose of fertilizer and often is more dependent upon pesticides than local varieties. After the harvest of *boro*, comes the rain and flood water, which washes away the agrochemicals deposited in the soil and the runoffs adversely affect the spawning and habitat of fish resources of the *haor* eco-system. Nowhere is the adverse impact of agrochemical runoff more evident than the freshwater wetlands of Bangladesh. Restrictive use of agrochemicals therefore, should be enforced within the wetland zones. Agricultural extension workers and farmers should be trained in this area and alternative methods like biological control options should be vigorously pursued. After all, the wetland aquatic resources are environmentally and economically more important than growing additional winter rice in these critical habitats. Preservation and development of habitats for pest controlling birds and other predators is another feasible and useful approach in encouraging biological control of pests.

Alternative Transportation Network

Wetland areas like the riverine areas of Bangladesh used to rely more on water transports. Siltation of river and canal beds, construction of embankments and roads and other contributing factors have resulted in the gradual decline of waterways transportation system. For the wetland areas desilting primary and secondary waterways to make them navigable throughout the year is an environmentally and socially sound option. Due to their special ecological status, structures that obstruct water flow should be discouraged as the spread and saturation of water is critically linked to the survival of wetlands.

In Bangladesh, the earth structures do not have the necessary drainage or water flow devices. Therefore, structures like roads and embankments, which impede water flow, should be avoided. Alternative means like the waterways, which are relatively benign, should be encouraged.

Spread of Education

Despite their valuable resources the wetland areas are not only economically depressed but also socially backward. Literacy rates for Zakiganj *thana* in the Surma-Kushiyara basin is well below the national average. Same is the case with most other wetland areas in the northeast. Physiographic reasons are a prime contributor to this low literacy rate. However, the physical limitations in the wetland areas have also influenced in creating a backward world view and consciousness among the wetland residents. Area development programmes with emphasis on mass functional education should be considered as a priority for wetland areas.

The above are certainly not an exhaustive list of issues for sustainable management and development of freshwater wetland areas in Bangladesh.

REFERENCES

ISPAN. 1992. *Environmental Impact Assessment : Case Study of Surma-Kushiyara Project.* Dhaka.

Sadeque, S. Zahir. 1992. Capture fisheries and other common property resources in the floodplains of Bangladesh. *Journal of Social Studies*, Vol. 55, June 1992.

Sultana, S. 1987. The form of villages in Bangladesh. *Oriental Geographer*, Vol.31, No.1&2.

SOCIO-ECONOMIC ISSUES IN MANAGEMENT OF FRESHWATER WETLANDS IN BANGLADESH

Jyotirmoy Talukder

ABSTRACT: Socio-economic and administrative issues related to management of *jalmahals*, leased out wetlands, have been dealt with to develop an understanding of the present day conflicts in landuse management. Social conflicts resulting from *jalmahal* management are also highlighted. The paper reviews the human settlement pattern and the process of resource tapping from the *haors*. The paper then proposes an approach for sustainable management of *haors* through effective involvement of local people on a "community-based management" methodology. This paper is based on two monographs - one on Kaliagota Haor and the other on Shanir Haor - produced by the Socio-Anthropological Team of Flood Action Plan 6.

INTRODUCTION

This paper reflects on certain issues related to wetlands and their resources with particular reference to *haors* of northeastern region of Bangladesh.

The villagers' concept of their *haor* is a vast area which stretches over several miles from their village. It is green during dry months and a sea-like waterbody during the monsoon months. The *haor* provides the inhabitants with rice during the winter and with fish during the monsoon. However, certain wild crops grow naturally in the *haor* and provide food especially important for the poor. Additionally, a *haor* also provides the inhabitants certain grasses and plants to be used as fuel, animal fodder, housing materials and so on. The *haor* is inundated with monsoon rains and floods from upstream. The depth of inundation varies from 1m to 10m. The villages are generally situated on the periphery of the *haor*, mostly on river levees . Sometimes a few villages are built inside the *haor* too.

HUMAN SETTLEMENT

The major settlement in the low-lying *haor* areas is understood to have been encouraged by the then *zamindars* to bring more land under cultivation. Most of the settlers came from neighbouring districts. The process of new settlement, especially in Sunamganj district, is still on-going. The villages are still quite scattered with a low population density (480 persons per square km in Sunamganj and 570 persons per sq km in Netrokona districts; 1991 Population Census).

The villages are linear-shaped, on river levees or on *kanda*-terraces of high land towards the interior of the haor.The homesteads are raised above the normal flood level and for the purpose soil is taken from the adjacent plots. The floor level of the homesteads varies from 1 m to 5 m above the ground level. The homesteads are usually close to each other. Homesteads in a cluster form a *hati* or *para*. A village may consist of one or more *hatis*.

Houses are generally made of bamboo, thatched with local grasses called *chhon* or rice straw. The houses of richer families have corrugated iron sheet roofs and bamboo or grass walls. Concrete houses are very few and belong to the richest families. The homesteads of the area are regularly threatened by monsoon floods and waves. Erosion of these homesteads take place nearly every monsoon. In many locations, roads and flood protection embankments are constructed along the river, leaving villages in more vulnerable situation outside these structures. The inhabitants try to protect their raised homesteads from wave erosion with bamboo, soil and a local long grass called *chailya*.

The residents of *haors* are mostly agriculturists, followed by traditional fishermen. There are also some other traditional groups such as traders, carpenters, blacksmiths, potters, barbers, boatmen, etc. Most of these households, including the traditional fishermen, own agricultural land. Annexure 1 contains the socio-economic profile of a typical *haor*.

The settlement process and patterns have had major impact on the overall physical characteristics and hydrologic conditions of the *haors*. The building of villages led to the destruction of most of the dense forests and vegetations of the high lands on river levees and on *kanda*. The agriculturists extended the cultivation of rice through the massive destruction of all kinds of natural vegetations - the wild grasses, bushes, trees, etc. This has further been aggravated in the name of infrastructure development like construction of roads and building of embankments. Some of these initiatives have changed the balanced characteristics of the *haor* and, in certain cases, the very physical existence of the *haors* together with their habitats, including human population, is threatened.

RESOURCE TAPPING FROM WETLANDS

Haors are considered to be one of the most resourceful wetlands of the country. They provide many valuable goods to the local residents as well as to the nation. To the local residents, *haor* is a sacred place, and the basis of their livelihood. The *haor* environment has united the villagers into a society which has a definite shape and culture. Such a social and cultural heritage is unique in many respects and is important to understand the *haor* people as well as their livelihood patterns.

Traditionally, to the local inhabitants, *haor* is the place of their ricefield and fishing ground. It is also a place which provides them vegetables, pasture lands, wild fruits, housing materials, fuel and so on. For generations, the *haor* has been providing to its residents nearly everything they needed for their subsistence.But the situation is deteriorating fast. Most of the afore-mentioned valuable resources are now being controlled and 'appropriated' by a few rich and influential residents (or non-residents) of the area.

However, the vast majority of the poor are still dependent on the *haor* resources to a large extent. In addition to working as wage labourers for agricultural activities and harvesting of *boro* crop, a relatively large quantity of public resources are collected or

gleaned by the poor for free. These include paddy gleaned after the harvest, ratoon crop (*demi dhan*) in some years, tubers (*kachu, ghechu*), water chestnuts (*singra*), rice straw (*deta*) and monsoon fodder (*pawra*, water hyacinth).

Access to fish resources is more or less open for the public in monsoon months, except for the leased fisheries. During monsoon, openwater fishing is a common practice for the *haor* residents, especially for consumption.The traditional and recently many non-traditional fishermen, who are mostly poor, earn their major income from fishing. However, in certain places, the influential lease holders of *jalmahal* harass the local residents and try to prevent them from openwater fishing.

Navigation is another important source of employment in *haor* life, especially during monsoon months. The transport system is mainly water bound and a traditional service caste called *majhi* (boatmen) provided boat service in the past. Now many non-traditional boatmen have joined the profession. However, the introduction of mechanised boats in recent years has reduced the number of country boats run by the traditional *majhis*.

Kanda (terraces on high land), also provide important resource. *Kanda* are generally considered as community land and used to be rich with natural vegetations. *Kanda* are used as pastures and are also the sources of trees, bushes and housing materials. Many poor people live on collecting/selling fuel, housing materials, etc. from such communally-owned *kanda*. Also trees and bushes play an important role in providing shelter and food for fish. Another important plant of the *haor* is *murta*, which is used for making *shital pati* (cane mat), a famous craft of the region.

Finally, a section of the poor harvest, legally or illegally, a number of animal/bird species for their own consumption, and for earning an income.

THE MANAGEMENT OF *JALMAHALS*

The haors of the region are considered to be the prime sources of freshwater fish in Bangladesh. *Jalmahals* are waterbodies serving as fishing grounds. Among *jalmahals*, *beels* are the most important in the *haor* environment. *Beels* are lakes which generally retain water round the year. However, some of the smaller *beels* may dry up towards the end of the dry season.

Beels are *khas* (government) lands and are traditionally used as a source of irrigation water for *boro*. Due to the permanent nature of most of the *beels*, they are used as *jalmahals*. A *jalmahal* can be a group of *beels*, or a single *beel* and may also include part of a river.

It is seen that majority of the larger *jalmahals* consist of more than one waterbody and form a group fishery. In many cases, such waterbodies are not attached to each other, but lie in the neighbourhood of a larger beel. The group fishery has brought the smaller waterbodies under the lease system and thus, in many cases, prevents the local

people from catching fish freely from these smaller waterbodies as they used to do in earlier days. These smaller waterbodies could also be taken on lease by local fishermen if not combined to form a large fishery. The grouping of waterbodies is mainly done to have better control over them by the leaseholders as they claim that the fish used to move (graze) to the neighbouring waterbodies during monsoon months.

The ricefields of the *haor* are also used as fishing grounds before the transplantation and after the harvest, especially in the lower fields. Sometimes the land owners dig ditches in their lower ricefields to trap fish. During monsoon months, the entire *haor* including the *kanda* becomes suitable for fishing. The casual fishermen as well as the common residents of the area consider the monsoon months suitable for openwater fishing. They not only catch fish for their own consumption but many of them earn their livelihood by selling fish.

Traditionally, fishing is considered a low-prestige job in rural society. Fishermen who had their tradition of catching and selling fish were all Hindus. Such fishermen who considered fishing as their main professibn for livelihood were socially degraded and were sub-castes among the Hindus. Such sub-caste Hindu fishermen are common among *kaibarta, barman, namasudra,* and *patni*. Traditional fishermen among the Muslims are very few. A small section of them known as *maimol* are found to catch and sell fish in the *haor* areas.

Among the traditional fishermen, the *kaibartas* and *barmans* are reported to be skilled in fishing in larger *jalmahals*. The *namasudras* and the *patnis* generally fish with small size fishing nets and with bamboo traps (*chai, guin,* etc). In *haor* environment a few *maimols* are also reported to be skilled in fishing in larger *jalmahals*.

For generations, the traditional fishermen, especially the *kaibartas* and *barmans*, and later on, the *maimols*, had the exclusive right to lease in the *jalmahals* from the relevant authorities for fishing. The *jalmahal* fishing was traditionally done at fixed intervals, normally in the winter months in every third year. For rest of the time, the leased *jalmahals* are protected by employing guards.

However, the traditional fishermen, especially the poor, used to catch fish during the monsoon months too. The fishing ground during monsoon is the open water in the *haor* which is totally flooded and *jalmahal* boundaries are submerged with *haor* and rivers allowing the fish to move freely. While catching fish in the open water, traditional fishermen used to fish in the submerged ricefields and along the peripheral zone of the *jalmahal/haor*, outside the leased *jalmahal* thus avoiding conflict with the lease holders.

The leaseholders of the *jalmahals* were generally the traditional rich fishermen. In old days, most of the larger *jalmahals* were leased in by a few very rich *kaibartas*. All of them were residents of the northeast *haor* region of the country. They were very influential and accumulated huge amounts of wealth. The *barmans* were the middle-class leaseholders and they preferred leasing in smaller waterbodies. But after the 1947 partition of the subcontinent, many traditional rich Hindu fishermen of the area

migrated to India and were replaced by the *mainols*. Now a few rich *mainols* are considered to be the most influential leaseholders of *jalmahals* in the area.

After independence of Bangladesh in 1971, the competition over fish resources have been intensified and many 'outsiders' who were not traditional fishermen, came on the scene as leaseholders of *jalmahals*. Such 'outsiders' have enough external power in terms of wealth, administrative linkage and political patronage to appropriate the fish resources and to become more powerful. Most of these leaseholders act as financiers and employ fishermen as labourers on daily, seasonal or contract basis to catch fish. Other fishermen in the *haor*, the *namasudras* and the *patnis* are generally poor and could not afford to lease in fishing grounds. They used to catch fish with smaller size fishing gears. They have no specific fishing grounds. During the monsoon months they put their bamboo traps in the bush as well as in lower ridges of *kanda* and during winter months in ricefields before transplantation.

In recent years, a new group of fishermen has emerged in the competition, especially after 1971. They are mostly the landless and the poor who could not make a living from agricultural wage. They catch fish for their own consumption as well as for the market. They are the non-traditional fishermen and their number has been increasing day by day. Perhaps they have outnumbered the traditional fishermen in the *haor* area. They generally catch fish in open water during monsoon months. They are now emerging as competitors to the lease holders, as well as to the traditional fishermen. It is observed that though the non-traditional fishermen are more in number in the *haor*, they are not socially or legally acknowledged as fishermen and their catching of fish is still considered as "stealing" fish.

In addition to the afore-mentioned fishermen groups, the common residents of the *haor* also catch fish round the year for their own consumption. It is said that the overwhelming majority of the *haor* people are habituated to catching fish. Even a wealthy landowner employs his labourers for the purpose. However, such tendency of catching fish for consumption is more among the small and marginal farmers. The ex-zamindar families, the local elites and the traditional traders generally do not catch fish, not even for their own consumption.

Fishing seasons in *haor* are mainly two - the monsoon months from mid-June to November and the dry months from December to early June. During the monsoon months, the entire *haor* is flooded leaving no boundaries with adjacent *haor* and/or rivers. The fishing grounds start from next to the homesteads covering ricefields and *kanda*.

The people get an easy access to such fishing grounds, especially during the early monsoon months (mid-June to August). During this period, the large fish is difficult to catch as water remains turbulent. However, the catch of small fish specially for own consumption is in abundance. The non-traditional fishermen and the general public find the period suitable to catch fish in the open water. The opposition from the lease holders is also less during this period.

The majority of the poor traditional fishermen also fish in the open water and they find the period more advantageous, since they need not pay any share or rent to the leaseholders. However, in all cases, the main *jalmahals* are generally avoided by them. From September, lease holders engage guards to protect their *jalmahals* from unauthorized fishing by local people.

Income from fishing generally increases during this period (September-November) when water becomes clear and calm. The fish also become less mobile and stay at particular places. This enables the fishermen to catch more fish. This period is, thus, characterized by frequent conflicts between fishermen and the leaseholders. The major conflicts between them generally take place during the late monsoon months when water starts receding and the size of the fishing grounds get reduced. It is to be noted that most of the conflicts occur when the guards of the leaseholders restrict fishing in the peripheral ricefields/*kanda* of a particular *jalmahal*.

Fishing grounds are further limited during the winter months when water remains mainly in the *jalmahal*. The access to those fishing grounds thus remain open mainly to the lease holders. However, the poor fishermen and other residents of the haor catch fish in small ditches and ricefields.

During the winter months, the traditional fishermen generally get scope to catch fish with the leaseholders either as wage labourers or on a share basis. When the final catch in the *jalmahals* is completed, these are let open for public. Such practice is generally allowed in *jalmahals* which are not dried up during the final catch.

The fishing grounds in the *haor* generally remain open for fishing to the public from late March to early June. During this period, majority of the smaller fishing grounds including the ricefields remain dry till they are filled up with early monsoon rains. The catch during this period is at a minimum. However, for a few days in this period, the movement of fish takes place with the onrush of fresh rain water either from the rivers and/or from the *beels* into the *haors*. Locally such fish movement is known as *ajaiya* (movements against water flow) and the people enjoy the catch.

The *jalmahals* are administered by the Ministry of Land and are leased through auction at district or thana level. Since 1979, fishermen's cooperative societies are given priority over non-fishermen if they bid for the lease of a *jalmahal* near their village. But in practice, many fishermen cooperatives are unable to pay the lease money and, thus lend their name to a financier who "manages" the fishery and reaps most of the profit. Many fisheries are also put up for open auction.

Once a *jalmahal* is leased/sub-leased, it requires certain activities to protect and nurse the fish. This includes employment of watchmen in the *jalmahal* for guarding against illegal catch and putting bamboo poles and branches of trees to provide shelter to fish.

Guards are generally posted from mid-August to March, until the catch is completed. However, they remain most vigilant between August and November, when the fishing party is employed to start fishing. Bamboo poles are placed in the leased *jalmahal*

during April-May. Similarly, branches of *hizol* and *koroch* trees are put in the main pockets of the *jalmahal* during August-September to provide shelter to the fish. Such practices are done by the leaseholders of large *jalmahals*.

Generally one or more fishing parties are hired, mainly from outside areas, to fish the *jalmahal*. The main reason for hiring labourers/fishing parties from outside is to have better control over them.

Sometimes a portion of the *jalmahal* is contracted out for fishing to local fishermen groups, either traditional or non-traditional. Such contract is made by the lease/sub-lease holders and the terms of contract depend mainly on the availability of fish in the *jalmahal*. However, the contract is reported to be always in favour of the leaseholders.

In 1986, the New Fishery Management Policy (NFMP) was introduced to protect the interest of the genuine fishermen. However, very few *jalmahals* have been allocated to fishermen through the NFMP, because of vested interests in maintaining auction to leaseholders. Such profit is also reaped by the money lenders. The fishermen borrow money from them to take the lease of *jalmahals*, since they have no access to bank loan.

The practice of overfishing of many *jalmahals* is widespread in the haor area. *Beels* that were harvested in the past only once in every three years are now being harvested every year. The leasing system encourages overfishing and a mentality whereby a public resource is treated as personal property to be exploited to the maximum for quick profit. In many cases, these profits from local resources are appropriated by outsiders and are not reinvested in the *haor* economy.

Moreover, powerful leaseholders extend their control over fish through force, harassment and intimidation. Even during monsoon when the entire *haor* in flooded, non-traditional and subsistence fishermen are prevented from catching fish. This is challenged in many places, but in the *haor* such problems are commonly solved by force, not always by law.

CONFLICTS IN LANDUSE MANAGEMENT

In the winter, most of the *haors* are planted with *boro*. Due to population increase the residents, especially the rich and the influential, try to bring more and more lands under cultivation. As a result, most of the community lands (the *kanda*) are diminishing at an alarming rate. This results in extensive and rapid deforestation and impoverishment of the vegetation all over the *haors*. Now in many areas, there is an acute shortage of pasture, land for growing housing materials and *chailya*, which reduces shelter for fish too.

Thus, the concept of traditional *haor* has been changing and the total ecological system is deteriorating. The flooding intensity, wave actions and the rate of erosion of the homesteads have been posing serious threats to the existence of the residents, particularly the poor.

In the name of infrastructure development and utility services many roads and embankments are constructed, with or without proper planning. This leads to various social conflicts in terms of land losses. The consequences are worst for the poor, as they generally lose their last resource.

The conflict in landuse between the farmers and the *jalmahal* leaseholders is common in the *haors*. In the months of November and December when the farmers need rapid drainage of water from their ricefields to start cultivation, the leaseholders protest and try to put bunds on the drainage canals to protect fish.

Later on, in February, when the farmers need water to irrigate their lands, the leaseholders want to decrease the water level in the *beels* to maximize the catch. Sometimes a leaseholder also wants to rent out the periphery of the *beel* for boro cultivation, which generally leads to conflicts over ownership rights with farmers owning lands on the same peripherial zone.

Regulators built across the canals are a major impediment to fish migration during the early monsoon breeding season. The result is a reduction in spawn and fish decrease. Submersible roads/embankments delay flooding, reducing hectare-month inundation. The result is a shrinking of fish habitat and an ultimate reduction in fish. Also such roads/embankments accelerate siltation of the *jalmahals*.

MANAGEMENT APPROACH FOR DEVELOPMENT PROJECTS IN HAOR AREAS

The success of any development project depends on its effective management. One of the key elements of effective management is the involvement of the local residents in the development process with special emphasis on the poor. It is the local people who know their problems best and surely they possess the basic knowledge to identify the development needs.

Many of the resources of the *haors* belong to the public. Thus, in *haor* areas, development cannot be considered without involving the people in the process including the poor who make up about a half of the population. For sustainable *haor* development, the following management approach is suggested:

1. Identification of the local residents according to various occupational groups.
2. An inventory of *haor* resources and their present utilization as per beneficiary groups.
3. Identification of community owned/khas resources in the *haor* and their present use and benefit sharing.
4. Advocate "Community Based Management" approach among the residents. Special emphasis should be given to the poor section of the community for their active participation. The approach puts emphasis on local people as the real managers of the resources of their environment.

5. A broad-based "Haor Development Committee" should be formed with proper representation from all cross-sections of the people. Also the people from different interest groups, both men and women, should be organized, motivated and trained on how to conserve and use *haor* resources and manage them.
6. For conservation of the *haor* resources and their effective use among the residents, there should not be any expansion of the ricefields on *kanda*. *Kanda* should be acknowledged as community lands and be used to restore the diverse vegetation which grew naturally in the past. Further, they should be planted with trees, bushes, grasses, etc. in a planned way and should be shared/utilized by the community.
7. The crop protection measures under FCDI should be planned and designed with active participation of the local beneficiaries. Before advocating any physical intervention in *haor* environment, the perception and opinion of the local residents should be given due importance.
8. In case of *jalmahals*, the resource should be controlled by the local fishermen, either traditional or non-traditional, and they should be the real managers of the fishery resources. The fishery habitats/mother fisheries should be protected and the practice of overfishing should be discouraged through motivation.
9. The fisheries environment should be preserved through planting of trees like, *hizal*, *koroch* and other bushes which can resist floodwater. While building regulators and constructing embankments for flood control, drainage and irrigation care should be taken so that the fish movement is not disturbed.
10. Through organized efforts steps should be taken for community afforestation and other related programmes to reduce wave actions and stop erosion of homesteads.
11. Awareness should be created among the local residents about the usefulness of rare animal/bird species living in the *haors* and not to hunt them for consumption and/or for income.

The afore-mentioned activities are certainly a challenging venture and deserves the political commitment and goodwill of the government. However, to set an example of "people's development project" through people's participation, the Ministry of Environment and Forests can try with one or two *haors* on a pilot basis and for the purpose committed local NGOs could perhaps be involved.

Annexure

Socio-Economic Profiles of Kaliagota Haor

1. Location : Located in Derai and Sulla *thanas* of Sunamgonj districts and surrounded (partly) by the old Surma and Piyan rivers, it covers 76 villages in 6 unions.

2. Area : 17,000 ha (approx).

3. Population: 89,336 (M45,746, F43,590) in 14,192 households with an average household size of 6.29 and village size of 187 households. Gender ratio is 103 male for 100 female and with 44.50% married and 4 percent widows/widowers. Divorce is not very common in the area.

4. Settlement: Process started about 300-350 years back; major settlement took place during 19th century, mainly on high lands (river levees and *kanda*) in linearly shaped villages. Muslims live in 44.74% villages while Hindus live in 36.84% villages. Others are mixed villages.

   The major settlers are agriculturists, followed by the traditional fishermen, both Hindu (*Kaiborta, Borman, Namasudra*) and Muslim (*Maimol*). Other traditional professional castes are barber, washerman, blacksmith, potters, carpenters, boatmen, traders, etc.

5. Major occupation : in % (approx)

Agriculture	25.00
Wage labour	8.70
Fishing	4.50
Trading	1.60
Service	1.20
House wife	32.50
Inactive	2.00
Student	11.50
Children (below 5 years)	10.50
Dependents (5 Yrs and above)	2.50

Distribution of major traditional professional groups in the haor are approximately as follows (in households): Carpenters(85), blacksmiths (30), goldsmiths (7), barbers (30), washermen (15), cobblers (15), traders (125 on clothes and grocery and 75-80 on rice trading) abdatman (25). There are 4 thief villages with about 100 households whose main occupation is stealing others' property.

6. Major Land use : in % (approx)

Homestead	2
Vegetable garden	5
Agricultural land (95% in boro cultivation)	70
Kanda (terraces on high land)	12
Jalmahal (Fishery)	11

There are 12 *jalmahals* of more than 8 ha in size in the *haor*, the largest one is about 150 ha having a group of 29 *beels*, and innumerable small waterbodies.

7. Land ownership pattern :

Land stratum	Household (%)	Hectarage (%)
Landless	45.86	-
0.1 - 1.0 ha	39.10	33.45
1.1 - 3.0 ha	9.78	32.00
Above 3 ha	5.26	34.55

Average farm size is 1.25 ha among the landed households. However, about 40 households own more than 20 ha agricultural land each. Also there are two ex-zaminder families in the area, each reportedly own more than 400 ha of lands. One family shares (with government) three *jalmahals* in the haor.

8. Land tenural group : in % (approx)

Owner farmer	20
Owner-cum-tenant	35
Tenant	25
Landless (did not cultivate)	20

9. Tenural System :

System	Hectarage(%) In	Out
Own land farming	70.45	85.50
Sharecropping	0.80	-
Lease (*rangjama*)	13.25	7.80
Lease (*chukti*)	12.90	0.30
Mortgage	2.60	6.40

10. Wage Labour: Average employment is only 168 days in a year of which more than 92 percent are seasonal on 6-8 months contract basis.

11. Migration : About 2,500 persons migrated outside (1991) from the haor for agricultural and other related activities in the neighbouring districts during late monsoon months and in March-early-April crisis months.

Immigrant harvesters : During April 1992, about 80-85% of the total labour harvesting *boro* came from outside districts of old Mymensingh, Faridpur, Dhaka, Pabna, Tangail and Barisal.

12. Ownership livestock and poultry

Livestock : 3-4 livestock (mainly cow/bullock) per household
Poultry : 6-8 chickens and 8-10 ducks per household

13. Indebtedness : Money lending is a common practice in the area. More than 90% households borrowed money during 1991, ranging from Tk500 to Tk10,000 per household, mainly 2-5 months before *boro* harvest. Bank loan is reported to be 55% and the rest 45% is loan from local and outside *mahajans* (1991).

WETLAND POLICIES, RULES AND REGULATIONS IN BANGLADESH

Rini Reza

ABSTRACT: This paper recognizes that wise application of sustainable development principles to wetland conservation will bring about multifarious benefits to any country that has wetlands. Present thrust of development activities in the wetland areas of Bangladesh, so far, has been mainly aimed at meeting demands emanating from the increasing demographic pressure and there is a lack of concern for managing them in an eco-friendly manner. To ensure sustainable use and management of this country's wetlands and promote development of their ecological and socio-economic functions and attributes for the long term benefits of the people, the paper proposes effective enforcement of existing rules and regulations.

INTRODUCTION

Bangladesh, along with the world community, has begun the process of accepting and incorporating sustainable development into the day-to-day life of business and government and is thereby becoming more and more aware of the implications of that concept. There are several well stated definitions of sustainable development. Two of which are:

a) Humanity has the ability to make development sustainable - to ensure that development meets the needs of the present day without having to compromise the ability of future generations to meet their own needs.
b) Development which ensures that the utilization of resources and the environment today does not damage the prospects for their use by future generations.

There now exists a wide consensus that the wise application of sustainable development principles to wetland conservation will in many ways benefit the countries having wetlands. These benefits with respect to freshwater wetlands can be listed as below:

a) promotion of soil and water conservation leading to reduced soil erosion, improved quality of groundwater and less degradation of the national agricultural base;
b) augmentation of waterfowl populations and improvement in wetland habitat quality for wildlife;
c) reduction of shoreline storm damage and watershed flood impacts; and
d) buffering of the effects of drought and longterm climate change.

With this knowledge as the parameter this paper proposes to explore the policy options available to Bangladesh along with legislation needs for implementing those policies for sustainable management and conservation of the wetlands in this country.

THEORETICAL PERSPECTIVE FOR POLICY EVALUATION AND FORMULATION

What kind of objectives can define the limits of policy implications in conservation concern for wetlands? Presumably these are the policies that aim at promoting growth, alleviating poverty and protecting the environment which are mutually supportive in the long run. In the short run, however, the objectives are not always compatible, and decision-makers often confront difficult choices in pursuing them simultaneously. It is important to consider the implications of competing claims and to determine the approaches that will help achieve the most appropriate balance in the exercise of evaluating policies or formulating them.

The issue of development or preservation of natural environments, like the wetlands, raises a number of economic concerns. Fisher and Krutilla raise this issue as being one end of the spectrum of interactions between man and the rest of the living world. The economic theory developed by the same authors about nature preservation is motivated by a discussion of current issues in relation to the disposition of wilderness lands and protection of endangered species. Three key concepts that emerge from this are uncertainty, irreversibility and option value.

Even though uncertainty is pervasive in economic life, there is more than the usual degree of uncertainty surrounding the potential future benefits from conserving ecosystems. For example, what exact benefits would be derived from preserving the habitats of wild birds is hard to predict beyond the immediate aesthetic gain. With regard to the value of in-situ resources, there is a chance that conserving ecosystems and their component populations will lead to some significant discovery, or less dramatically, it is quite possible that the value of in-situ resources will rise relative to that of extractive resources. The assumption to be emphasized here is that relevant information about the properties of indigenous species will come not from "developing" their habitats but rather from research on what, if anything, depends on preserving habitat.

Similarly, irreversibility is clearly central to thinking about endangered species or ecosystems because extinction or loss of wild lands is indeed irreversible. There is thus the question why should there be more concern about disturbing natural areas and endangered species' habitats than about issues involving the allocation of other resources of comparable value? The reason, at least partly, is that wild lands and natural populations are the results of geomorphologic and biologic processes that represent a time frame measured in eons and thus cannot be produced by man. If destroyed, or otherwise adversely affected, these cannot be replaced or restored. The distinction between reversible and irreversible decisions in economic processes has sometimes been illustrated by the differences we may notice between production and investment decisions. For example, a producer with a given plant and equipment, inventory of raw materials, and stock of finished goods faces the expected demand which is intended to meet. While the original decision might not be alterable for any given production batch, the consequences can be altered by adjusting production on subsequent runs. So, the decisions in this sense are reversible, that is, if the

consequences of a decision can be readily altered with negligible losses. But if the decision relates to the capacity of the plant, the impact of a poor decision will linger for a longer duration. Because, investment in plant and equipment, unlike investment in raw materials, cannot be liquidated in a short period of time. Consider the conversion of a wilderness ecosystem to meet the demands for the output of extractive industries. If the environmental modification results in the elimination of essential habitat for a given species -- for example, the Pallas' fish-eagle or the swamp crocodile -- restoration is not possible or at least incomplete without the fauna dependent on the original plant associations. But even if the survival of a species is not at stake, restoration is not a simple remedy for redressing the impact of an inappropriate decision that disturbed the original ecological environment. Elimination of a climax species is equivalent to the removal of the results of ecological succession that represents, in many cases, centuries of ecological processes rather than a simple cycle in the world of more typical choices. Environmental modifications that affect the abiotic base are even more difficult to contend with. If the basic geological and soil conditions are adversely affected, restoration of the original biological environment will not be possible in anything like the time span that is meaningful for human societies. For example, vast open pit mining operations and some water resource developments are among the activities that have a potential for affecting the abiotic base in a manner that is irreversible by ecological processes for all practical purposes within the frame of human time spans. There is thus a basic irreversibility that attends the modification of unique natural or biological environments.

The concept of option value is defined as the gain from being able to learn about future benefits that would be precluded by development (of an area) if one does not develop in the current period; in other words, the gain from retaining the option to preserve or develop in the future. In the literature on nature preservation, the concept of option value has played a prominent role. Beginning with an article by Weisbrod (1964), there has been a notion advanced by some but disputed by others that preservation carries with it a value (option value) above and beyond conventional consumers' surplus. One interpretation equated option value with a risk premium with the concomitant dependence on the notion of the consumers' risk aversion. A different interpretation of option value explains it as the gain from being able to learn about future benefits that would be precluded by development if one does not develop initially. Option value in this interpretation is not identical to the value of information in the development decision problem. It is instead a conditional value of information, conditional on a particular choice of first period development and is equal to or greater than the value of information.

Thus, where economic decisions have an impact on the natural environment that is both uncertain and irreversible, there is a value to retaining an option to avoid the impact. This paper draws on the three key concepts mentioned above for analytical help to evolve a policy package for sustainable management of the perennial freshwater wetlands of Bangladesh.

REVIEW OF EXISTING POLICIES, RULES AND REGULATIONS IN BANGLADESH

Policy refers to the principles and courses that govern actions directed towards given ends. Legislation is an important instrument to facilitate implementation of that policy. In reviewing any policy and legislation for the management of wetlands, certain key factors should outline the parameters, which are, uncertainty, irreversibility and the option value.

For policy considerations it must be noted that whether a wetland performs a certain function, yields specific products, or possesses certain attributes, is determined by the interaction of the biological, chemical and physical characteristics of the site. Not all characteristics are present in each wetland; so few wetlands perform all functions and not all functions are performed equally in each wetland. This links the decisions regarding wetlands with the concept of uncertainty. Also, it is apparent that any action that affects the species like the fauna, wildlife and the abiotic base negatively will have irreversible effects and since the system is an interlinked, spread-out, heterogenous one, there will be a multiplier effect of the negative impact. As yet, there is no policy package in Bangladesh that supports environmentally sustainable goals on wetland management. The only available document is the Haor Development Board Ordinance, 1977, which aimed at providing for the establishment of a Board for "development" of *haors* and for matters connected with or incidental to it.

In this Ordinance *haors* are defined as low-lying areas, and includes *beels*.

Paragraph 8 of the Ordinance states that the functions of the Board shall be:

a) to prepare projects and schemes for development of the *haors* and other similar low-lying and depressed areas;
b) to approve projects and schemes involving not more than twenty-five lakh taka each and to submit other projects and schemes costing more than twenty-five lakh taka to the Government for approval;
c) to execute approved projects and schemes; and
d) to supervise execution of projects and schemes.

The nature of development projects or schemes have not been spelt out anywhere in the Ordinance but reviewing the membership composition of the Board an assumption can be made that the primary task of the Board was to build protective dams for flood control and land reclamation and to extend agricultural activities and fisheries.

It was under this Board's authority that a number of submersible dams and roads were built in the *haor* areas. The status of the Board was not stable for a long time. Bangladesh Parliament's Act No. XIV of 1980 included an amendment of the Haor Development Board Ordinance, 1977 and by 1st October 1982 the Haor Development Board (Dissolution) Ordinance came into force and the mandate for managing the wetlands was transferred to the Divisional Development Boards.

Whatever the institutional arrangement, the concept of "development" of the wetlands *per se* as the objective was development without any reference to environmental concerns or conservation of wetlands. The policy priority being augmentation of food production, the wetlands were seen as available arable land during the dry season and as a source for proteins like fish, poultry etc. during other seasons.

Legislation only enforced the government's ability to carry out its development activities. The Wildlife Act prohibits all hunting of wildlife including waterfowl but hunting continues at a high level and there seems to be little, if any, enforcement of the regulations outside reserves protected by the Forest Department. No specific regulations for wetland conservation exist.

The wetland tenurial system has the government as the land owner. While The government leases out each identified plot for fishing and agricultural activities. But there also exist a huge number of encroachers. While leasing out the wetlands the government does not issue any instructions that would specifically support sustainable use of the wetlands.

The main thrust of wetland resource utilization was based on meeting the demands emanating from the increasing demographic and development pressure and on the traditional image of wetlands as inaccessible waterlogged marginal lands harbouring disease carrying mosquitos which should be drained and converted for useful purposes. There was no concept of managing the wetlands in an eco-friendly manner, not at least from the policy formulation perspective. The question remains how were the local people affected by these actions and what were their reactions to them? Was it any different elsewhere in the world?

REVIEW OF WETLAND POLICY, RULES AND REGULATIONS IN SOME OTHER COUNTRIES

There are still some remote regions in Russia, Mongolia and western China where wetlands remain in almost pristine condition, disturbed only by the occasional hunter, fisherman or shepherd. But such sites are becoming a great rarity throughout the more densely populated parts of Asia. The most serious threat has been drainage or reclamation for agriculture, aquaculture, industry and urban development. In the Republic of Korea, a shortage of land suitable for agriculture has prompted the government to pursue a major programme of land reclamation in estuaries and shallow bays on the south and west coasts. The economic welfare of the peoples of Asia depends to a large extent upon the sustainable utilization of wetlands. Grave mistakes have been made in the past and these are reflected in the increasing frequency of so-called natural disasters, which have inflicted enormous suffering on millions of people. In Asia, perhaps more than anywhere else on Earth, the importance of wetland conservation is becoming apparent. Destructive policies are being reversed; wetlands are being restored and ways of managing wetlands for food production are being chosen in preference to reclamation for farmland or fish pond. In several countries, notably

Russia, China, India, Indonesia, Iran and Pakistan, numerous wetland reserves have been created in recent years to ensure the survival of representative examples of the major wetland types. In China, India and Pakistan, major campaigns have been launched to focus attention of the general public on wetlands and the need for their conservation. Most nations have introduced legislations to conserve wildlife. In Mongolia official protection for waterbirds dates back to the thirteenth century. In India, the government is involved in the conservation and captive breeding of marsh crocodiles, estuarine crocodiles and gharials. But as yet there are no policies specifically for wetland management and conservation in Asia.

The African wetlands support the largest number and greatest variety of wildlife in the world. They also support the livelihood of many hundreds of thousands of indigenous peoples - permanently resident, transhumant and nomadic populations. Over the last half-century the population of Africa has increased dramatically and the wetlands are now under serious threat. It is not only the pressure of the basic needs of the local people but also because of the exploitation of the continent's natural resources by the industrialized world at minimum recompense that has made it difficult to formulate sound environmental policies in this region. But specific actions are being taken. For example, in Uganda, the Ministry of Environment Protection has a National Wetlands Conservation and Management Programme, which assesses the attributes and current uses of a wetland and the views of all interested parties including the rural community are canvassed by the organization before a final plan is made. The main points of this policy and guidelines for management are :

a) Conservation and management of wetlands
   - land tenure
   - water supply and effluent treatment
   - recovery of previously drained wetland
   - environmental impact assessments
   - biological conservation of wetland

b) Governmental and public awareness

c) Environmental law applicable to wetland

Two basic factors have been the cornerstone of this wetland management policy:
first, man's responsibility to future generations; and
second, the need for sustainable development.

It has also great degree of political commitment behind it. In fact, the multipurpose utilization of wetlands employing appropriate technologies is a great hope for the future of African wetlands.

Most wetlands in the northern half of North America are still in their natural state. From southern Canada to Mexico, though, huge areas of wetlands have been drained and considerable pressure is being placed on those that remain. The management and conservation of wetlands in North America takes several forms. Canada's federal

government manages 29 percent of all the country's wetlands. The United States Fish and Wildlife Service manages nearly 9.3 million hectares of inland wetlands and about 809,000 hectares of estuarine wetlands. A further 2 million hectares of wetlands are under state management in the United States. Non-governmental organizations are also active in wetland protection in North America. Private sector initiatives have protected at least 1 million hectares of wetlands in Canada. Other private agencies in the United States acquire land that includes important wetlands. Both Canada and the United States have designated high priority wetlands for protection.

In the United States, state and federal governments have enacted laws that regulate wetland alterations on all lands, public and private. Regulatory programmes started at the state level and are now in effect for freshwater wetlands in 14 states, primarily in the northeast and northcentral part of the United States. These regulations usually require any person who wishes to alter a wetland first to obtain a permit. The permit contains conditions that the applicant must follow to ensure that the proposed project does not impair the public health, welfare and safety functions of wetlands. In Canada, a series of national recommendations were developed in April 1990, including a call for all jurisdictions to develop mutually supporting wetland conservation policies by 1991. Subsequently in December 1990, the federal government's Green Plan proposals included a specific commitment that the federal government would adopt The Federal Policy on Wetland Conservation in 1991. This Policy was arrived at through a consultative process that was underway for over three years. It recognizes the importance of wetlands as going beyond their status as the habitat of many endangered plant and animal species. They are considered as vital elements of national and global ecosystems. The goals of the policy are to strive to achieve the following:

a) maintenance of the functions and values derived from wetlands throughout Canada;
b) no net loss of wetland functions on all federal lands and waters;
c) enhancement and rehabilitation of wetlands in areas where the continuing loss or degradation of wetlands or their functions have reached critical levels;
d) recognition of wetland functions in resource planning, management and economic decision-making with regard to all federal programmes, policies and activities; and
(e) utilization of wetlands in a manner that enhances prospects for their sustained and productive use by future generations.

Many of the wetlands in Europe and the Mediterranean have been either destroyed or degraded, and a majority of those that remain are under threat. However, it is likely that in addition to the enlargement of the extensive European network of wetland reserves, changes in national and EC policies will allow wetlands to be conserved because of the wider social and economic importance of their functions and values. Comprehensive management plans for wetland reserves to redress effects of human impacts are accepted as essential tools throughout the region. The integration of wetlands into regional and national planning has also become established with schemes

for water resources and river basin development in some countries but the European Community does not have a wetlands policy as such, although certain conservation objectives are set out by various directives. Almost all countries have laws which provide for some element of wetland protection. For instance, in Spain, the 1985 Water Law established three principles: the public character of terrestrial water; the planning of water according to the hydrological cycle; and the public administration of water in each river basin. In 1989, the Spanish Parliament passed an Act establishing the need to consider wetland conservation for river basin planning.

Thus the general trend worldwide is to consider the optional value of conserving wetlands despite the uncertainty involved in linear cost benefit analysis and at the same time try to redress the irreversibility issue through restoration efforts.

POLICY RECOMMENDATIONS FOR BANGLADESH

As various country situations are reviewed continentwise it becomes apparent that it is not too soon to undertake a wetlands programme based on a management policy and legislative package.

Before going further it should be pointed out that new laws are not always needed for effective conservation. In 1987 Greece's Supreme Administrative Court prohibited a new ship scrapping yard in the Nestos Delta site because it contravened the laws which implicitly implement the country's obligations under the Ramsar Convention. The judges added that the incompatibility of the development proposal and Ramsar status did not depend on experts' opinions, but was considered to be a matter of commonsense and experience.

In Bangladesh, options for conservation of wetland resources and their sound management need to be given the best possible review based upon the best available information and understanding of the potential value of each site.

The guidelines on the establishment of national wetlands policies as recommended by the 3rd Conference of Contracting Parties to the Ramsar Convention is taken as the basis and the following policy package is proposed for Bangladesh with the parameters of uncertainty, irreversibility and option value as the cornerstones.

(a) Policy Objectives

The objectives of the government with respect to wetland conservation and management should be such as to promote sustainable use and development of the ecological and socio-economic functions and attributes of the wetlands for the long-term benefit of the Bangladeshi people.

(b) Policy Goals

The government, in cooperation with the local government and the public through a consultative process, should strive to attain the following goals:

- Improving information by formulating an updated national wetland inventory and classification, assessing wetland values, assessing the indigenous management potential of wetland systems and undertaking wetland research activities.
- Maintenance of the functions and values derived from wetlands throughout Bangladesh.
- Recognizing wetland functions in resource planning, management and economic decision-making with regard to all national programmes, policies and activities.
- Advocating and implementing sound, sustainable management practices in sectors such as agriculture, forestry, fishery, water resource management and landuse that make a positive contribution to wetland conservation while also achieving wise use of wetland resources.
- Integrated interventions in utilization of wetlands to enhance prospects for their sustained and productive use by future generations.
- Effective use of taxation policy as incentive and inducement for conservation and sustainable utilization of wetlands.
- Identification of wetlands of significance for reserve status declaration and enhancement and rehabilitation of wetlands which through continuing loss or degradation of their functions and attributes have reached critical levels.

(c) Guiding Principles

The following principles should be adhered to by the government in pursuing the above stated objectives. These principles are in accordance with the Ramsar Convention and are critical to this policy:

- Wetland conservation and sustainable development are possible through a coordinated, cooperative approach involving all levels of government and the public, including landowners, non-government organizations, and the private sector.
- In link with the overall Environment Policy of 1992, actions should be pursued under this policy for management of the wetlands.
- The management potential of wetland ecosystems should be determined and demonstrated through experimental management. An empirical approach linked as far as possible to good scientific design and practice, because of its visibility and the more ready interpretation of findings, is more acceptable.
- Full functional assessments of different wetlands should be mandatory before any intervention in a wetland to avoid irreversible changes.
- Wetland conservation is dependent on the incorporation of environmental objectives into the economic decision making.

- Wetland conservation must be pursued in the context of an integrated systems approach to environmental conservation and sustainable development as wetlands and their functions are inextricably linked to their surroundings, particularly aquatic ecosystems.
- On-going development and enhancement of scientific knowledge and expertise in Bangladesh are fundamental to the achievement of wetland conservation.
- The national government will play a major role in advocating and achieving wetland conservation, while respecting the rights of the local and indigenous people and the individual landowners.
- Raising awareness about the values of wetland conservation through communication and education programmes.
- Government policies that contribute to wetland loss must be corrected. New conservation policies must take into account costs and benefits, both temporal and inter-temporal, of wetland conservation and the impact of current agriculture, fisheries, water, forestry, landuse and tax policies. Government policy should ensure that people see wetland conservation to be in their interest by providing necessary institutional support and developing legislation.
- Strengthening of wetland management institutions by developing human resources and through enhanced cooperation with international institutions working on wetland conservation and related issues.

STRATEGIES

The following strategies are outlined for restoration, use and management of wetlands so that they can continue to provide a broad range of functions on a sustainable basis. These strategies are proposed for immediate necessary interventions with respect to wetland management in Bangladesh.

a) Protection of critical areas is essential if any significant remnants of the once rich and diverse wetland ecosystems of the northeast region are to be preserved for posterity. Based on the guiding principle of maintenance of bio-diversity at the ecosystem, species and genetic levels, through implementation of sound management practices and rational utilization of natural wetland resources, a wetland conservation programme must be undertaken. Wherever applicable and possible restoration schemes should be initiated. Emphasis will be on development of the indigenous species as opposed to exotic ones.

b) The government should encourage research to support and promote development of expertise for sound technical and scientific basis for wetland conservation and sustainable utilization alongwith the assurance of making available to the planners, managers, regulators and other decision-makers at all levels the necessary information. For that purpose the government should encourage establishment of centres of research through which development, dissemination and exchange of information, expertise, models and tools for wetland management and conservation will occur at the national, regional and international levels.

c) To support and promote a nationally standardized approach to consistent and comparable wetland inventories, monitoring and evaluations the government should initiate formation of a socio-scientific committee. The committee will undertake, support and promote development of guidelines and standards which will indicate different target levels of quality and quantity of wetlands required to assess the threat of wetland loss or degradation of ecosystems. It will also develop techniques for integration of wetland functions into natural resource allocation decisions by indicating all the functions of wetlands and values in such techniques.

d) A national public awareness programme should be designed in collaboration with non-government organizations and the private sector. This will be targeted at all levels including the political. Also, the public will be provided with information on a regular basis through environment reporting about the condition of the wetlands alongwith the results of wetland research available in formats suitable for public use and education.

e) Involving all the stakeholders including farmer groups, landowners, field naturalists, bird observers, water agencies, non-government agencies and the local government a consensus should be built to encourage management of all wetlands of significance to promote long term protection of their functions and encourage recreational ecotourism, scientific and educational uses of wetlands so long as these uses are not detrimental to wetland functions and attributes.

f) To advance the concept of sustainable utilization of the wetlands the government through a coordinating body should encourage recognition of wetland functions in natural resource conservation and development strategies as those for forests, minerals, agriculture, water and landuse through formulation of integrated management plans. Special consideration should be given to reflect the hydrologic functions of wetlands such as groundwater recharge, waterflow regulation and water purification in the national and regional water management activities.

g) Bangladesh will continue to support and implement commitments under international conventions and agreements to which the country is a signatory.

PROPOSED LEGISLATIVE FRAMEWORK

Since there does not exist in Bangladesh a single protected wetland except the one in the coastal zone, the wetlands lack any support from the legal system of the country. The Wildlife Preservation Order of 1973 included a list of 43 proposed protected areas, twelve of which were listed as Wetland Game Reserves. But no action was taken on the

proposals. A part of Hail Haor was declared a wildlife sanctuary in 1983, but again it was not officially gazetted. There exists a Wildlife Act of 1992, which prohibits hunting of wildlife including waterfowls but the hunting activity is carried on unhindered.

To begin with, the existing rules and regulations must be strictly enforced. Then in consultation with the Ministry of Law the following areas for legislative action should be covered :

a) Specific legislation for conservation of the wetlands which have been identified as being at a critical level;
b) Declaration of wildlife sanctuary and protected areas in accordance with and, if necessary, in addition to the Wildlife Preservation Order of 1973.
c) Declaration of activities that lead to pollution of wetlands and taking part in activities which degrade the wetlands and cause loss of wetland functions and attributes as punishable offences under the Criminal Procedure Code.

CONCLUSION

People are inextricably linked to wetlands for their survival. They are the most productive ecosystems on earth. Whole civilizations developed around wetlands, yet they are disappearing at an alarming rate.

The people who live in the localities usually have detailed knowledge of the ecosystems and the species and about the ways of ensuring that they are used sustainably. Whatever the prevailing situation that knowledge is never destroyed and through the involvement of the local people that knowledge base can be used to conserve the wetlands and to reverse the scale of human impact on wetlands from irreversible to transient or temporary.

REFERENCES

Arrow, K.J. and Fisher. 1974. Environmental Preservation, Uncertainty, and Irreversibility. *Quarterly Journal of Economics*, 88.

Bangladesh Parliament Act No. XIV of 1980, Amendment of the Haor Development Board. *Bangladesh Gazette*, Extraordinary, Part V, 9th April 1980.

Bishop, Richard C. 1978. Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard. *American Journal of Agricultural Economics*.

Cicchetti, C.J. and A.M. Freeman. 1971. Option Demand and Consumer Surplus: Further Comment. *Quarterly Journal of Economics*, 85.

Dugan, P.J. (ed.). 1990. *Wetland Conservation: A Review of Current Issues and Required Action*. IUCN, Gland, Switzerland.

Finlayson, Max and Michael Moser (eds.). 1991. Wetlands. IWRB.

Government of Bangladesh. 1977. The Haor Development Board Ordinance, 1977. *Bangladesh Gazette* Extraordinary, 22nd February 1977.

Government of Canada. 1991. The Federal Policy on Wetlands Conservation. Ministry of Environment.

Hanemann, W.M. 1982. Information and the Concept of Option Value. *Department of Agriculture and Resource Economics Working Paper No. 228*. University of California.

Kneese, A.V. and J.I. Sweeney (ed.). 1985. *Handbook of Natural Resource and Energy Economics*. Vol.I.

Scott, Derek A. and S.M.A. Rashid . 1992. *Draft Final Report*, Wetland Assessment and Ornithology Main Surveys. FAP-6.

Weisbrod, B. 1964. Collective Consumption Services of Individual Consumption Goods. *Quarterly Journal of Economics 78*.

INSTITUTIONAL ASPECTS OF WETLAND MANAGEMENT IN BANGLADESH

Md. Fazlul Huq

ABSTRACT: This paper reviews the existing institutional arrangements and capabilities for wetland management in Bangladesh. Discussion on the administrative resources including institutions, policies, laws, research organizations and NGOs have been included to highlight the present status of management capabilities. Management issues have been identified and alternative strategies suggested for sustainable management. Basic steps for drawing up a management plan for wetlands in Bangladesh have been discussed in brief. An action plan/ recommendations have been suggested with proposed outlines for an integrated and improved institutionalized approach to wetland management.

INTRODUCTION

Wetland management in Bangladesh is inextricably linked to a specific cluster of socio-economic urges, that have emerged in response to age old interactions between an unique eco-system and the people who are dependent on it. The institutional arrangements and capabilities that have developed over time thus consist of the knowledge, belief systems, codes of conduct, laws, norms, ways of life, patterns of livelihood, resource use and the overall eco-system based culture. These institutions, both formal and informal, are influenced by the ecology and environment of the wetlands and in turn also influence the resource utilization trends and potentials which ultimately have substantial impacts on the wetlands as such. Some of the traditional arrangements and practices for wetland resource use and management existed there for centuries and have undergone changes in recent decades consequent upon the dynamics of natural and socio-economic forces. The formal institutions which also evolved over the past centuries have experienced qualitative and quantitative transformation as well due to socio-political and economic needs. The quality, coverage and level of all these institutional arrangements and capabilities need to be properly appraised to ensure their desired contribution and role in protection, conservation and sustainable management of the wetlands and their resource potentials.

PRESENT INSTITUTIONAL ARRANGEMENTS FOR MANAGEMENT

Ministry of Environment and Forest

The Ministry of Environment and Forest (MOEF) was created in 1989 to look after matters related to environment, ecology, biodiversity, forest, wildlife and national park etc. Though wetland was not specifically mentioned among the activities of the ministry, in recent past MOEF developed several policy documents where wetland issues have been dealt with. These are:

a) **Environment Policy (MOEF, 1992a)**: The environment policy adopted in 1992 gives due importance to wetlands and related issues. Relevant sections of the document state that :

- the rivers, canals, ponds, lakes, *haors*, *baors*, and all other waterbodies and water resources be kept free from pollution;
- environmental impact assessment (EIA) should be conducted before undertaking projects for water resources development and management;
- landuse systems compatible with various eco-systems to be encouraged;
- for protection of migratory birds wetlands may be conserved and developed;
- activities which diminish the wetlands/ natural habitats of fish be prevented and rehabilitative measures be encouraged; and
- existing projects on water resources development, flood control and irrigation be examined to determine their adverse impact on fisheries and measures for alternative fish culture be adopted upon improvement of environmental conditions.

b) **Action Plan Guidelines for Environment Policy (MOEF, 1992a)**: The action plan guidelines for the environment policy suggest specific areas of intervention for protection, management and improvement of wetlands and their resources. The following recommendations deserve mention:

- Steps to be taken to establish an agricultural system based on local ecosystems, rate of population growth and demands of the national economy. For agricultural crops and products, alternatives should be introduced.
- Waste discharge in rivers, canals and all other waterbodies from industries, municipalities and agricultural or other sources should be stringently regulated through enactment and implementation of appropriate laws.
- Treatment of domestic and industrial waste before discharging in rivers, wetlands or other waterbodies to be strictly enforced.
- Water to be identified as the most important and valuable natural resource. The organizations dealing with water resources development are to activate themselves as national resources management agencies.
- Regular surveys, research and monitoring to be conducted on changing courses and conditions of rivers, wetlands and other waterbodies.
- Priority to be given to protection of wildlife, wetlands, birds and animals. Research and development projects are to ensure protection of near-extinct species.
- The present prohibition on hunting and export of wildlife and wildlife hides to continue. Preservation of wildlife habitats and establishment of wildlife sanctuaries are to be encouraged.
- Steps to be taken to rehabilitate wetlands such as *haors*, *baors*, *beels* and declare them as protected areas for pisciculture. Wetland areas are not be encroached upon.
- Pisciculture to be encouraged in all ponds and tanks. Overextraction of fish from ponds and wetlands is to be prohibited. Similar prohibition is to be effected for shrimp fry and other fish resources.

c) **National Conservation Strategy (MOEF and IUCN, 1991)**: The Draft National Conservation Strategy document includes general overview of wetland issues pertaining to wildlife. Strategy for wetland management has been specified and issues related to wetland fisheries have also been discussed.

d) **National Environment Management Plan (MOEF, 1991b)**: The Draft National Environment Management Plan identifies the wetlands as one of the priority areas for action and suggests the following areas for mitigatory steps at the first stage:

- Hakaluki Haor of Sylhet
- Saline Polders in Khulna Area
- Matamuhuri Delta

e) **Bangladesh Country Report for UNCED (MOEF, 1992)**: Bangladesh country report for United Nations Conference on Environment and Development (UNCED) 1992 attached great importance to the loss of floodplain wetlands as one of the major environmental hazards and suggested needed action to minimize adverse effects on the wetlands and their resources.

Ministry of Land

All larger waterbodies including the rivers, *beels*, *haors* and *baors* of the country are under the administrative control of the Ministry of Land of the Government. Rivers are segmented into several compartments, each compartment being a geographical area termed as *jalmahal or jalkar* . A permanent or seasonal *beel* or *baor* is similarly termed as *jalmahal* or *jalkar*.

The Ministry of Land manages the *jalmahals* through a system of lease settlement by holding auctions to generate revenue for the Government. The ministry executes the auction and lease settlement through the Deputy Commissioners of the districts. In case of a riverine or seasonal *beel jalmahal* the term of lease is for one year only while the permanent *beels* and *baors* are leased out for a term of three years.

Forest Department

The other major openwater areas are under the administrative control of the Forest Department. All wetlands falling within the reserved forest areas are controlled by the Forest Department. The management practices of the Forest Department are also revenue oriented. No management measure is carried out to ensure sustainability of the living resources. In connection with conservation and protection of forestry resources, however, entry into certain parts of the rivers and *khals* is banned. This inadvertently also provides some protection to fish resources living in the banned segments of waters within the forest reserves.

In 1973, a wildlife circle was set up within the Forest Department to deal specifically with conservation and management of wildlife resources of the country. Though this was a positive step towards management of wildlife including those of wetlands, the wildlife circle was subsequently downgraded in June 1983, allegedly in the interest of economy. Following its general down-grading within the Department, wildlife conservation has become the theoretical responsibility of the various Divisional Forest Officers.

Department of Environment

The Department of Environment is the field level organization dealing with environment. Recently its mandate of work has been widened to include all problems of environmental management in the country. The environmentally sensitive and ecologically fragile zones which include wetlands also come within the scope of functions of the department. The department has recently prepared a project to carry a survey of the wetlands and their resource potentials.

Department of Fisheries

The Department of Fisheries (DOF) is responsible for fisheries management, development, enforcement, statistics, quality control, extension and training. Other affiliated agencies include the Fisheries Research Institute established in 1984, which operates four research stations.

Fisheries Management Policy : From 1986-87 onwards the Ministry of Fisheries and Livestock has initiated a new fisheries management policy (NFMP) with the following two objectives :

- to divert maximum benefits arising out of inland water fishing to the actual fishermen from the middlemen leaseholders who have hitherto been deriving most of the benefits from the inland water fish resources; and
- to take measures to ensure sustainability of fish productivity in the inland openwaters.

The Ministry of Land has so far handed over 150 fisheries to the Department of Fisheries to apply the management procedures envisaged in the NFMP.

Bangladesh Water Development Board (BWDB)

BWDB owns and controls access to fishing in waters that have been created in the course of implementation of water resources development projects. BWDB follows the practice of leasing out fishing rights to middlemen or other lease holders offering the highest bid. Here also, needs for steps to sustain the living resources through appropriate population management practices are neither perceived nor implemented.

Thana Administration

Ministry of Land has handed over a number of *jalkars* each measuring between 3 (1.21 ha) and 20 (8.09 ha) acres to *thana* administrations in lieu of token rents so that they could generate some income for themselves by using these fisheries. The token rent is charged by the Ministry of Land only to establish the ownership of the Ministry. Thana administrations also manage such waterbodies by leasing them out. Openwater fisheries with an area of less than 3 acres are reserved by the Ministry of Land for the communities living around the waterbodies who can fish freely therein.

The Space Research and Remote Sensing Organization (SPARRSO)

SPARRSO, established in 1980 as a focal point for all remote sensing activities in the country, has conducted a study of the total number of waterbodies in the country, both small (less than 25 ha) and large (greater than 25 ha) by using satellite imagery and aerial photographs of 1983-84. Large waterbodies, including *haors, baors*, rivers and canals over the entire country were mapped at a scale of 1:50,000 in 267 sheets. The data were used by SPARRSO to prepare a catchment water resource map of the country for the National Water Policy developed by the Master Plan Organization (MPO).

Flood Plan Coordination Organization (FPCO)

The Bangladesh Flood Action Plan (FAP) covering the five year period of 1990-95 has been commissioned as the first of the several stages in the development of a comprehensive flood control and drainage works programme to meet the long-term objectives of safeguarding lives and livelihoods, increasing crop production, enhancing development of public facilities, commerce and industry, minimizing potential flood damage, creating more flood-free land and meeting the needs of fisheries, navigation, communications and public health (World Bank, 1989). Preparation of FAP is being supervised by FPCO under the guidance of the Ministry of Irrigation, Flood Control and Water Development. Different components of the Flood Action Plan are taking steps to study relevant issues of wetland management in respective areas.

FAP 2: North West Regional Study: This study covers the northwest region of Bangladesh. Specific areas for resource conservation including wetland habitats have been identified. It has been noted that loss of these sites will not only affect the local ecology but may have long-term economic and international ramifications.

FAP 3 : North Central Regional Study: This study prepared the master plan for north-central region of the country. The report also emphasized on conservational needs.

FAP 3.1: Jamalpur Priority Project Study: The main ecological issue in this region is the way in which induced environmental change will affect the number and distribution of species, with related implications for human use and biodiversity. A programme has been included to determine the incidence of flora and fauna in the study area utilizing a check list approach. Preliminary lists of flora and fauna are available.

FAP 6: Northeast Regional Water Management Project: FAP 6 is developing a water resource management plan for the northeastern region. Within this context work has been conducted to identify wetland sites of international and national importance for wild animals and plants, especially migratory and threatened species, to identify priority areas for nature conservation, and to establish a basis of a monitoring programme designed to assess the impact of development projects on wildlife populations.

Two rapid assessment surveys of the wetlands of the haor basin have been carried out. A total of 68 sites were covered. The evaluation of sites was based primarily on the abundance and diversity of waterbirds and consideration was given to the criteria developed in relation to the Ramsar Convention. Detailed records were maintained of all birds, mammals, reptiles and amphibians observed at the wetlands. At each wetland, basic information on the condition of the wetland - water level, aquatic vegetation, terrestrial vegetation, fishing activity, hunting activity and general level of disturbance from human activity - was gathered.

It has been concluded that there has been massive loss of natural wetland habitats throughout the northeast region and that entire ecosystems have disappeared without a trace. Six systems have been identified as being of outstanding national and international importance for their nature conservation values. The present surveys have placed emphasis on the importance of wetlands in the *haor* basin for birds, mammals, reptiles and amphibians. There remains a possibility that there may be other sites of special ecological or limnological importance in the region. There is a need for a more general appraisal of the overall ecological significance of the wetlands of the *haor* basin.

FAP 17: National Fisheries Assessment: The primary objective of the FAP 17 project is to provide means of evaluating the impacts of the various FCD/I schemes on the inland capture fishery. Data and information collected under FAP 17 could be used to give accurate estimates of yield per unit area by habitat together with species composition, growth rate and other biological data.

Non-Government Organizations

There are some international and national NGOs like Asian Wetlands Bureau (AWB), International Waterfowl and Wetland Research Bureau (IWRB), IUCN, Nature Conservation Movement (NACOM) and Bangladesh Centre for Advanced Studies, who are either advocates for development of wetland management system in Bangladesh or and closely associated with wetland related activities.

AWB and IWRB emphasized the need for management of wetlands of the country at different international and national forums. IUCN has assisted the Government of Bangladesh in developing NCS and NEMAP where wetland issues have also been addressed.

NACOM has been involved with wetland inventories and development of management plans for coastal wetlands in Bangladesh. BCAS has also been associated with wetland related research activities.

Legislation for Wetland Management

Legislation is an important institution for wetland management. The existing Acts/Rules are not specific to the needs and problems of wetland conservation and management. Important sectoral laws having some bearing on wetland forests, wildlife, fisheries, management of *jalmahals* and other development activities in the wetland areas are stated below :

The Forest Act 1927 (amended in 1989): The Act prohibits certain acts like clearing, setting fire, trespassing, cattle pasturing, felling of trees, stone quarrying, cultivating land, hunting, shooting, fishing, poisoning water etc in the reserved forests. According to the provisions of this Act any public or private way or watercourse may be stopped for the public in the interest of preservation of the forest.

Rules to Regulate Hunting, Shooting and Fishing within the Controlled and Vested Forests - 1959: These rules prohibit poisoning river or other water and killing fish by explosives within the controlled and vested forests. Rules also prohibit or restrict hunting, shooting and fishing of certain species for a specific period of the year. The rules also prohibit hunting, shooting, strafing and fishing in 'A' category forests to prevent extinction of any species or to form game sanctuaries.

Bangladesh Wildlife (Preservation) (Amendment) Act 1974: This law provides for the preservation, conservation and management of wildlife in Bangladesh. The Act prohibits hunting, killing and capturing of certain categories of animals designated as protected animals and also prohibits hunting, killing and capturing of certain categories of animals designated as game animals without obtaining a permit from the relevant authority. It also prohibits trade or business of any kind of wild animals without prior permission from the authority dealing with wildlife. The Act provides for declaring an area as wildlife sanctuary or national park where hunting, shooting or killing of wildlife together with other activities affecting the wildlife population are prohibited.

A Wildlife Advisory Board was established under the provision of the Act to advise the government on wildlife related issues but it has not been functional in recent years.

East Bengal Protection and Conservation of Fish Act, 1950 as amended by the Protection and Conservation of Fish (Amendment) Ordinance, 1982; and the Rules made under this Act: This Act provides for protection and conservation of fish in the inland waters of Bangladesh. The Act prohibits various destructive methods of fishing. According to this law, the government may make rules which will apply to any water or waters, provided that no such rules shall apply to any private water except with the consent of the owner thereof and of all persons having any right of fishery therein.

The East Bengal State Acquisition and Tenancy Act, 1950 (Act XXVIII of 1950): This law has transferred ownership of wetlands/*jalmahals* from the zamindars to the government.

The Haor Development Board Ordinance (Ordinance IX of 1977)

Among other things this law required the Board :

a) to prepare projects and schemes for development of the *haors* and other similar lowlying and depressed areas;
b) to approve projects and schemes involving not more than twenty-five lakh taka each and to submit other projects and schemes costing more than twenty-five lakh taka to the government for approval;
c) to execute approved projects and schemes; and
d) to supervise execution of projects and schemes.

The ordinance did not specify what types of development projects/schemes should be taken up by the Board. But an evaluation of the activities of the Board for the very short duration of its existence shows that it mainly executed some projects related to flood control, land reclamation, extension of agriculture and fisheries. Some infrastructure projects like dams and roads were also taken up.

Wetland Research

No systematic programme of research has been conducted on the wetlands of Bangladesh. Several national bodies and many visiting scientists have carried out research in the Sundarbans, and this region has now been extremely well documented. The Fisheries Department has conducted some studies of the inland fisheries, and the Forest Department has investigated several important wetlands in the *haor* basins. The Bangladesh Space Research and Remote Sensing Organization (SPARRSO) has prepared detailed maps of the mangrove resources for the Forest Department, and is preparing maps of the inland freshwater bodies for the Fisheries Department. The Department of Zoology at the University of Dhaka has carried out a number of faunistic studies at wetland areas, particularly in the Sundarbans and the Chittagong Hill Tracts.

Informal Organizations and Capabilities

The wetlands were virtually a common property. This was particularly evident in cases of fishery and grazing. The fishery laws evolved as case laws and have been codified only in recent decades. After independence of Bangladesh, these traditional rights and practices were recognized by the state by making it mandatory that fisheries would be leased out to fishermen's cooperatives. Employment of local fishermen in the management of the fisheries leased out by the government is also significant.

However, over the years these local rights and traditions have been seriously jeopardized. The sense of belonging of the local people to the wetlands and their resources have greatly diminished. This has and still is contributing to the degradation

of wetlands. For sustainable management of the wetlands, it is essential that steps are taken to integrate the local and traditional capabilities along with the formal institutional arrangements. Improved management techniques and provision of adequate financial resources at the local and informal levels can substantially improve the situation.

Summary of Existing Institutional Arrangements and Capabilities

a) Important policy documents recognize the need for improvement of the degraded wetlands and their conservation;
b) Wetlands are both privately and publicly owned and managed;
c) Public ownership is divided among a large number of agencies under different sector organizations;
d) Even fishery is controlled by different sector organizations with divergent types of tenures and systems;
e) Management activities of the government sector organizations are related more to exploitation of wetland resources rather than their development, regeneration and sustainable use. Revenue earning is given more emphasis than conservation and sustainable management;
f) There is little coordination in sectoral activities and so various resource use trends are not compatible with the sustainability of the wetland ecosystem as a whole;
g) Lack of compatible and complementary resource use patterns by different government agencies contributes to resource degradation;
h) Unsustainable development activities by different government agencies have greatly accelerated the process of degradation of wetlands;
i) Most government institutions lack the knowledge, technology and resources to address wetland management and development issues in a sustainable manner;
j) Some autonomous bodies and NGOs are also engaged in conducting studies, improving awareness, education and research for strengthening management techniques in wetland areas;
k) Flood Action Plan studies are trying to suggest methods and measures to ensure mitigation of adverse impacts of FAP-related development activities;
l) There is no specific law to stop further degradation and ensure sustainable development and resource use in wetland areas;
m) There are sector/resource specific laws which have become outdated and are hardly implemented. They contribute very little to protection, conservation and sustainable management of wetlands and their resources; and
n) Traditional and important organizations and practices and capabilities for wetland management have seriously diminished in the past decades.

ISSUES IDENTIFIED

Wetland management issues have never received the level and quantum of importance and priority they essentially deserve. The existing institutional arrangements have failed to appreciate the uniqueness of the wetland eco-systems and resource potentials. With the creation of the Haor Development Board wetland issues got some institutional

consideration, though the emphasis in the activities/plans/ programmes were on construction of roads, embankments, culverts and other infrastructures with adverse impacts on the ecology and resources of the wetlands. However, the abolition of the Haor Development Board after a brief period again placed the issue in a low priority basket. The Divisional Development Boards with their existing resources and capabilities can make little headway in addressing the urgent issues of wetland management. Moreover, involvement of a large number of agencies such as the Deputy Commissioners, the Fisheries Department, the Department of Forest, Water Development Board etc. in handling the same resource use such as fishery with different systems and policies has created a lot of problems in sustainable management, leading to resources degradation.

Most of the wetlands in Bangladesh have degraded and lost their basic ecological characteristics and resource potentials. An analysis of the process of conversion, degradation and transformation of the wetlands leads to the identification of certain basic issues in the utilization and management of the wetlands. The important issues are:

a) Failure to recognize the uniqueness of wetland ecosystems and the need for national priority;
b) Lack of any integrated institutional arrangement for wetland management;
c) Increasing demand on wetlands for survival needs of a fast growing population and the lack of alternative resources;
d) Lack of knowledge about value of wetlands and their sustainable management and utilization;
e) Adverse impact of water development, flood control, irrigation and infrastructure development projects;
f) Lack of uniform institutional arrangements in wetlands management, i.e. presence of too many sector specific institutions;
g) Weakening of traditional arrangements and capabilities;
h) Adverse impact of externalities such as changes in the quality and quantity of waterflow;
i) Degradation through overuse and pollution;
j) Lack of proper conservation and sustainable management approaches and initiatives;
k) Lack of sustainable tenure systems;
l) Lack of adequate fund base for sustainable use, development and necessary restoration; and
m) Lack of specific and adequate legislation.

MANAGEMENT GOALS

The process of degradation of wetlands in Bangladesh is moving very fast. It is therefore imperative that specific management goals are identified for their sustainable development and management.

The following can be identified as important management goals:

a) Stopping further degradation;
b) Devise sustainable and comprehensive pattern for use of agricultural, aquatic, forestry, biodiversity and other potentials;
c) Conserve and rehabilitate where feasible to ensure maintenance of functions and utilization of values for present as well as future generations;
d) Recognize the significance of wetlands in the national, zonal and local level planning;
e) Adopt sustainable ownership, tenure and use patterns;
f) Integrate all formal and informal mechanisms including the traditional ones and forces for sustainable management at local, zonal, national and regional levels;
g) Develop technical knowledge and planning and managing capabilities; and
h) Improve awareness, education and research.

STRATEGIES

The question of formulation of appropriate strategies for sustainable management of wetlands needs proper consideration and re-examination at the national policy level. Strategy formulation must take into consideration the present status of the wetlands, the level of their degradation, the needs for conservation, the compulsions for resource use under the existing socio-economic environment, the problems and realities involved in restoration, factors leading to degradation and to what extent it is feasible with resource, technology and other constraints to rehabilitate them.

Strategy issues should recognize the uniqueness and importance of wetlands and help upgrade the level of priority and management and the following strategies are suggested for improving the institutional arrangements and capabilities for rehabilitation, sustainable use and management of wetlands in Bangladesh.

a) Treat wetlands as an unique and nationally important issue and upgrade the level of priority and management;
b) Declaration of critical wetlands as protected areas, if considered necessary in consideration of existing needs and realities;
c) Expanding coverage of wildlife sanctuaries and national parks;
d) Formulation of specific laws for conservation, protection and management of wetlands;
e) Evolve integrated management systems, mechanisms and institutional frameworks for various resource uses;
f) Create integrated management authorities or institutional set-ups through cooperation among all organizations related to wetlands;
g) Improve technical knowledge on management use and development;
h) Develop public awareness;

i) Integrate all concerned parties, interest holders, government and non-government agencies, conservationists and ecologists in the management system;
j) Support and implement commitments of all international conventions and agreements; and
k) Develop institutional funding arrangements through integrated mechanisms at national, regional and international levels.

GUIDING PRINCIPLES

The ineffectiveness and inefficiency of the institutional arrangements for wetland management are mainly due to the following reasons :

a) Sectoral organization of wetland management systems with competitive and sometimes contradictory goals practiced by different sectors;
b) Limited coverage by protected wetland system and lack of adequate management techniques;
c) Shortage of adequate number of qualified personnel;
d) Inadequate legislation; and
e) Limited resources.

It is essential to adopt appropriate guiding principles for improvement of the institutional efficiency and effectiveness for wetland management. The important guiding principles are :

a) The effectiveness of national wetland management efforts will be enhanced by the establishment and effective operation of cross-sectoral structures. The success of such efforts will depend upon the capacity of the coordinating mechanism to bring together the widest possible range of institutions concerned with wetlands and to assist them in including wetland concerns in their work, rather than by replacing their existing functions.

b) A diversity of management techniques exist for protecting wetlands of highest conservation concern. In deciding which techniques are most appropriate in specific situations, special account should be taken of externalities, in particular the impact of changes in the quality and quantity of waterflow, the dynamic character of many wetland ecosystems, and the heavy human use of the wetlands.

c) Substantial investment in training is required. Where possible, training courses should be included in the curricula of existing institutions.

d) Legislation is needed to regulate all activities which impact wetlands. Protective standards must include consideration of water pollution control for both point and non-point sources. In addition, laws must ensure adequate planning for long-term use of water and land, and must require

comprehensive impact assessment of major agricultural, residential, commercial or industrial projects before they are approved. Existing legislation should be reviewed, deficiencies identified and appropriate changes made. Where the deficiencies are particularly serious, new legislation may be required.

e) Several existing mechanisms can be used to provide funds for wetland conservation. Each institution should review the diverse options available and pursue those most appropriate for its needs, where necessary seeking international assistance in doing so.

BASIC STEPS FOR DRAWING UP A MANAGEMENT PLAN FOR WETLANDS

Data Collection and Survey: The first step for preparation of a management plan for any wetland area is fact finding survey. Unless the status of wetland is completely known, no plan can be prepared. The fact finding aims at finding out and reporting/recording total wetland resources. Further, there will be an attempt to give the significance of the area in national as well as international context. The resource potentials are to be determined from both qualitative and quantitative aspects. It will cover species diversity, abundance and the area occupied. The data collected should be in relation to physical factors.

Identification of Problems: Problems of wetland deterioration differ from region to region and from locality to locality and as such it is most essential to identify specific problems based on the resource survey referred to above.

Conservation Measures: Conservation measures need to be taken with utmost care which should include conservation of biological resources, biological diversity, landscape etc.

Protection Measures: Protection should include measures like fencing, notification of the areas where human activity should be regulated or if needed stopped; zoning of fishery areas, minimizing biotic factors etc.

Wetland Mapping: To define the boundary of a wetland area, it is essential to undertake mapping of the wetland areas and also the catchment areas which are an integral part of the wetland ecosystem.

Landscape Planning: Comprehensive plan needs to be prepared for landscape planning of the wetland ecosystem which should help both in the development of the areas on ecological basis and also beautification of the depressions. The landuse pattern, afforestation by appropriate plant species, soil conservation measures etc. need to be undertaken after detailed investigations on the basis of pilot projects.

Hydrology: To maintain an effective water regime in the wetlands which is essential for maintaining the characteristic of the wetland ecology, a plan needs to be prepared regarding water inflow, outflow, siltation rate, etc. The amount of silt coming from various sources and the rate of siltation needs to be worked out.

Removal of Encroachment: A large number of man-made barricades which have been set up in the areas need to be removed for ensuring a good flow of water which is essential for reducing nutrient load in the system.

Eutrophication Abatement: Since the wetland water is also utilized for drinking, it would be essential to stop sewage and other industrial effluents entering the lakes before being properly treated.

Aquatic Weed Control: Large areas of wetland are colonized by water hyacinth and other weeds. This is responsible for causing several problems in the depressions. Control of aquatic weeds by combination of biological and mechanical control would help in the eco-restoration of the lowlands and depressions. The weeds could be utilized for biogas and bio-fertilizer.

Wildlife Conservation: One of the serious problems of the wetlands are declining population of aquatic birds. To rehabilitate these endangered and endemic species, a portion of the wetlands needs to be declared as protected. Limited human activity should be allowed in such areas.

Fisheries Development: Fisheries development in the wetlands is essential as main occupation of the people living around is fishing. Construction of fish ponds should be totally stopped and fisheries development should be undertaken on sound ecological basis.

Environmental Awareness: This is the most important aspect. For any management plan environmental awareness is the basic tool which can make people realize their duties for protection of surrounding environment. Environmental education through audiovisuals, posters, literature, seminars and symposia etc, can be of great help in educating people about the importance of wetlands.

Organizational Set-up: Management aspects of wetlands involve study of a number of areas like pollution abatement, conservation of biological resources, landscape development, afforestation, aquaculture etc.

ACTION PLAN/RECOMMENDATIONS

It is essential to draw an action plan to address the priority issues for management of wetlands. The following steps are suggested in this respect:

a) Establish a National Wetland Committee consisting of representatives from all relevant Ministries/Divisions/Departments/Agencies/NGOs environmen-

tal groups/research organizations and other concerned groups. The Committee would give overall guidance to wetland management activities and monitor implementation of the Action Programme. The Ministry of Environment and Forest should initiate action on this process.

b) The National Wetland Committee should designate one of the relevant ministries, preferably Ministry of Land/Ministry of Environment and Forest as the lead agency to ensure integrated and coherent institutional arrangements for sustainable management.

c) Wetland conservation issues should be incorporated in the next 5-year plans. The Ministry of Planning should take necessary steps end from now on.

d) The Ministry of Environment and Forest should ensure that wetland conservation issues are adequately reflected in the final versions of the National Conservation Strategy (NCS), National Environment Management Action Plan (NEMAP) and Forestry Master Plan (FMP).

e) A national wetland inventory should be immediately prepared. The Ministry of Environment and Forest or the Ministry of Land may take the initiative. Along with this a register of experts on wetland management, conservation and research may also be prepared.

f) Immediately revive the defunct Wildlife Circle within the Forest Department and examine the possibility of creating a separate Department to look after national parks, wetlands, protected areas & wildlife. This should be done by MOEF.

g) MOEF/DOE should undertake an independent review of Flood Action Plan as a whole to determine its impact on wetlands and recommend control and mitigation measures. Specific studies should be undertaken to avoid adverse environmental impact of FAP on wetlands.

h) Conduct immediate studies to identify critical wetlands and declare them as protected areas/game reserves, if considered necessary and feasible.

i) Arrange training programmes for the staff of Forest Department, Department of Environment and other concerned agencies on wetland conservation and management.

j) A specific law should be enacted for proper management and development of wetlands.

k) Schemes should be taken up for rehabilitation of degraded wetlands as far as feasible.

l) All development schemes in the wetlands should include mitigation measures. Environmental audits should be carried out on completed projects to incorporate mitigation measures.

m) Involvement of concerned and local people should be ensured from the very prefeasibility stage of development schemes in the wetland areas. There should be a continuous interaction between the local people and the development agents. This process of involvement of the local and concerned people would reduce the adverse impacts of development schemes and necessary lessons would be learnt from past mistakes.

n) As wetland management issues are closely linked with common rivers and watershed management among the regional countries, regional and international help and perspectives should be integrated.

CONCLUSION

Wetlands are invaluable components of the environment, ecology, resource potential and biodiversity in Bangladesh. They are integral parts of the local ecosystem based cultures. To stop further degradation and ensure sustainable management of these wetlands the quality and coverage of institutional arrangements and capabilities need to be substantially improved. Present unplanned and indiscriminate exploitation of resources through different sector-based institutions without any inter and intra-sectoral linkages and lack of uniformity of goals should be replaced by an integrated institutional management approach with well-defined goals. Participation of all formal and non-formal institutions and interests at local, national, regional and international level are keys to the proposed approach to better institutional arrangement. Committed efforts should be strengthened through improvement of awareness, technical knowledge, funding mechanism and research.

REFERENCES

Ministry of Environment and Forest (MOEF) and IUCN. 1991. *Towards Sustainable Development: The National Conservation Strategy of Bangladesh*. 2nd Draft. Dhaka.

Ministry of Environment and Forest (MOEF). 1991. *Bangladesh Country Report for United Nations Conference on Environment and Development (UNCED)*. Government of the People's Republic of Bangladesh. Dhaka.

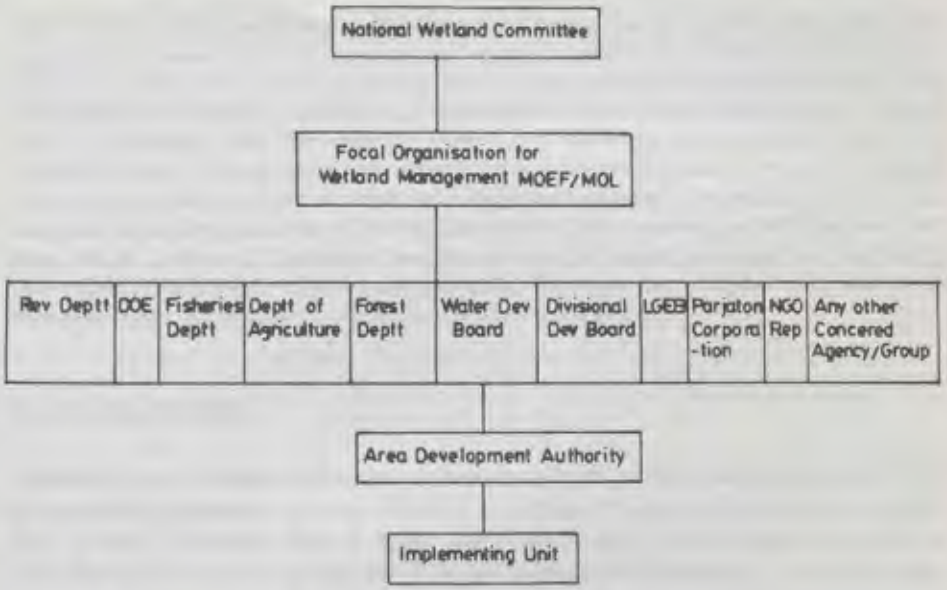
Ministry of Environment and Forest (MOEF). 1992a. *Environment Policy 1992 and Action Plan*. Government of the People's Republic of Bangladesh. Dhaka.

Ministry of Environment and Forest (MOEF). 1992b. *National Environment Management Action Plan*. 2nd. Draft. Government of People's Republic of Bangladesh. Dhaka.

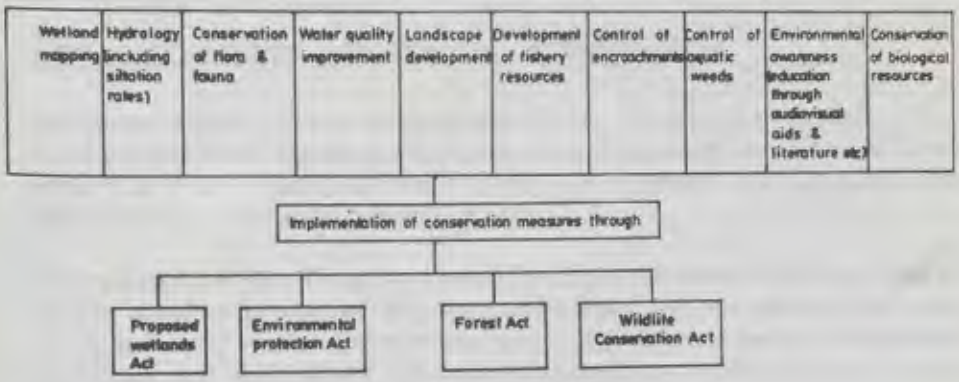
Ministry of Law and Parliamentary Affairs. 1977. The Haor Development Board Ordinance, (Ordinance IX of 1977). *Bangladesh Gazette* Extraordinary 22nd February, 1977. Dhaka.

World Bank. 1989. *Bangladesh Action Plan for Flood Control*.

PROPOSED ADMINISTRATIVE SET-UP FOR WETLAND MANAGEMENT



MANAGEMENT ASPECTS OF WETLANDS



LAWS ON WETLANDS IN BANGLADESH: A COMPLEX LEGAL REGIME

Mohiuddin Farooque

ABSTRACT: This paper briefly reviews the present legal status of wetlands in Bangladesh and highlights the serious legal limitations in any approach towards their conservation. There is a need for revision of the existing legal framework and pertinent rules and regulations. The policy and legislative or regulatory issues that are responsible for destruction or degradation of wetlands should be identified first. Wetlands for conservation should be decided on the basis of an inventory and all wetlands may not be targeted for such action. For rest of the areas sustainable development should be aimed at: legal status including ownership, possession, record of right status and institutional authority of the wetlands need to be ascertained and existing provisions may then be reviewed. Legislative measures should be undertaken under one regulatory framework which must be effective and workable. The paper also makes a brief overview of historical aspect of regulatory framework of wetland management.

INTRODUCTION

According to the Ramsar definition, perhaps two-thirds of Bangladesh can be classified as seasonal or perpetual wetland. There is a growing concern in the country to protect and preserve wetlands. But is there any wetland that can be termed as such in accordance with the law of the land ? As per physical characteristics, there are many, but in the eye of law, there is no land that has been or is being characterized as wetland. They exist as mono-sectoral resource under relevant public agencies and private occupation.

This paper briefly attempts to identify the current legal status of the so-called freshwater wetlands in Bangladesh with highlights of favourable recommendations and courses to develop a future legal regime for their protection as practicable and desirable.

LEGAL CONCEPTS AND STATUS OF WETLANDS

The phrase 'wetland' is of recent origin and concept. The term is an English word but it was not used by the legislators although the texts of legislation have been drafted and adopted in English during the last one and a half century. If the wetlands exist physically then where are they hiding in law?

An examination of the relevant laws would reveal that the wetlands of Bangladesh are already absorbed in various other legal definitions, and accordingly, have been distributed among various administrative sectors of government resource management institutions. And every sectoral institution is holding its part of the 'wetlands' like the "blind man's elephant-guessing."

According to the laws of Bangladesh, wetlands are 'lands'. The State Acquisition and Tenancy Act, 1950 (SAT) defines it as land "which is cultivated, uncultivated or covered with water at anytime of year" (section 2/16). Therefore, anything that is legitimate on a piece of land is also applicable to wetlands.

Considering the resource status and potential, a large number of wetlands are traditionally called *beel, haor* or *baor*. The common indicator in all these phrases is that they are potential 'fisheries' which are also administratively called *jalmahal* or water-estate.

In view of the above concepts and legal status, the management of the so-called wetlands are defined and incorporated in the Land Management Manual, 1991. Chapter ix of the Manual provides rules and principles regarding *jalmahals* which have been categorized as open fisheries and closed fisheries. Paragraph 187 defined closed fisheries as those known as *haor, beel, jheel* etc. Therefore, most of the wetlands are categorized as closed fisheries. There is another legal concept that may render the status of wetland as wasteland. The East Bengal Acquisition of Waste Land Act, 1950 that empowered the government to acquire wastelands defined it as "any land including marshy tracts, water courses.....which has not grown any crop for five consecutive years or more..."(Section 2). Therefore, any tract that has not grown crops is wasteland even if it produced or was the source of other resources. The government policy on these wastelands was to promote or bring them under agriculture. Hence, the Culturable Waste Land (Utilization) Ordinance was proclaimed in 1959 to encourage farmers to apply for lease of such lands for cultivation.

Finally, any marshy tract or waterbody within the government reserved forests form part of such forests. Hence, for management purposes, these tracts are within the domain of the Forest Department according to the 1927 Forest Act. Many wetlands have already been turned into agricultural fields in Bangladesh. Through irrigation and flood protection structures of the Ministry of Water Resources, Irrigation and Flood Control vast tracts of former wetlands have either been brought under irrigation or been destroyed, dried up or logged with water because of inappropriate planning and designs. Parts of wetlands suitable for navigation are under inland navigation administration. If any species of a wetland or an area of a wetland is protected under the Wild Life (Preservation) (Amendment) Act, 1974, then that would be a different legal status.
In view of the above multiple legal status and sectoral categorization of the so called wetlands in Bangladesh, it becomes clear that a number of laws need to be identified and examined to conceptualize the prevailing regulatory regime on wetland. Some of these important legislations are:

The State Acquisition and Tenancy Act, 1950
The Acquisition of Waste Land Act, 1950
The Culturable Waste Land (Utilization) Ordinance, 1959
The Forest Act 1927
The Wild Life (Preservation) (Amendment) Act, 1974
The Canals Act, 1864
The Irrigation Act, 1876

The Protection and Conservation of Fish Act, 1950
The Private Fisheries Protection Act, 1889
The Environment Pollution Control Ordinance, 1977
The Inland Shipping Ordinance, 1976
The Inland Water Transport Authority Ordinance, 1958
The Land Reform Board Act, 1989
The Agricultural Pest Ordinance, 1962
The Agricultural Pesticides Ordinance, 1971
The Land Reforms Ordinance, 1984
The Agriculture and Sanitary Improvement Act, 1920
The Embankment and Drainage Act, 1952
The Penal Code, 1860
The Tanks Improvement Act, 1939
The Non-Agricultural Tenancy Act, 1947

The above laws are either directly or causally linked with the freshwater wetlands. The cross-sectoral nature of these laws represent the complex regulatory system that cover the aspects of wetlands. There are many rules framed under the enabling or parent laws. Besides, there are executive orders and institutional legislations creating and empowering the sectoral public agencies involved in relevant activities relating to or having bearing on wetlands in Bangladesh.

MANAGEMENT AND REGULATIONS OF WETLAND

Historical Aspect

Lands and other resources in the country were mostly under private ownership perpetually granted by the British under the Permanent Settlement Regulations, 1793. These estates or *mahals* as they were called, comprised almost every kind of resources available on a specific fiscal-geographic area. Often, the *jalmahals*, especially the closed fisheries, were made part of such estates. The legal history of the marshy tracts, *haors* or *baors*, which can be termed as wetlands, hence, formed an almost integral part of the land tenure history. The lands and all resources on or attached to land were subject of settlement to private parties (Farooque, 1991). The trend was to settle almost everything possible to ensure a fixed economic return or revenue for the foreign rulers (Farooque, 1992). As a result when East Bengal (now Bangladesh) became the eastern province of independent Pakistan in 1947, 91 percent of the land were under permanent settlement of the 1793 Regulation, 3.5 percent were under temporary settlement and only 5.5 percent were under "Public Property" status or *khas mahal* (Sharafatullah et al, 1990). The wetlands which formed part of the *zamindari* (feudal) estates were within the "sub-tenancy making power of the landlords" which could be either an absolute occupancy right or usufructuary right. The tenancies created by the *zamindars* were legally valid tenures regulated by the Bengal Tenancy Act, 1885. Therefore, historically, the wetlands were not under the sole domain of public authority, rather much of it were privately owned and settled.

Abolition of Zamindari

The *zamindari* system was abolished and all rent receiving interests were acquired by the state under the State Acquisition and Tenancy(SAT) Act of 1950. The lawful settlers under the *zamindars* were made owners or tenants under the state. The term 'tenant' is used in cases of non-agricultural land governed by the Non-Agricultural Tenancy Act, 1947. However, the SAT restricted private ownership over certain categories of property as absolutely 'non-retainable' which includes "any fishery other than a tank constructed solely by process of excavation" (Section 20). Therefore, except the man-made or artificial fisheries, all natural fisheries are now public property. There is no definition of 'fishery' in the SAT or in the Protection and Conservation of Fish Act, 1950. According to a judicial decision, fishery means the business of catching fish and the rights connected therewith (Province of East Pakistan vs. Taheruddin,1978). However, this definition would not serve the purpose of finding legal status for a fishery when the contest between private and public ownership arises. In such cases, the land record or Record of Right (ROR) prepared following the cadastral survey (CS Record) under the Bengal Tenancy Act, 1885 or the subsequent revisions of that record are used by the courts to identify the nature of a parcel of land. So, if the ROR classified a tract as fishery or *jalmahal* it would stand as such for legal purposes.

The above juridical nature of fisheries under the SAT would not lead to the conclusion that all so-called wetlands in Bangladesh are public property. The wetlands that would fall under the 'fisheries categories' as per the CS Record would be vested in the state if notifications have been issued in the Official Gazette to that effect. Apart from the fisheries, many marshy tracts and *beels* are private property e.g. most parts of the huge Chanda Beel in Gopalganj are under private ownership. There are many wetlands which are categorized as wasteland and are regulated under a different legal regime. For example, the wastelands forming part of or adjacent to a natural forest can become a forest land or afforested forest under the 1927 Forest Act or the 1950 Private Forest Ordinance.

It may be worth mentioning here that many tracts of wetland in Bangladesh have been dedicated in the name of God either as Wakf (by Muslims) or Debottar (by Hindus) by former landlords prior to SAT as in the case of some fisheries or wetlands of the districts of Mymensing and Sunamganj. These properties have a very different legal status somewhere in-between public and private property. The Wakf Ordinance, 1962 governs the regime of Wakf estates managed by the Wakf Administrator.

The Land Management Manual of 1991 provides elaborate guidelines for managing 10,108 public *jalmahals* vested with the Ministry of Land. The manual enumerates the following management rules, inter alia, which are of relevance for the present discussion.

a) The fisheries measuring upto 20 acres are entrusted with the *Thana Parishad*.
b) The fisheries managed by the Ministry of Fisheries and Livestock would be available and accessible to the scientists and researchers of the Department of Fisheries for investigation and environmental information collection.

c) The fisheries not being more than three acres in size would be preserved by the Union Parishad so that people can exercise their customary right of using the waters for domestic and other purposes. To protect such fisheries from illegal encroachment the Thana Nirbahi Officer (TNO) and the Assistant Commissioner (Land) would supervise the activities. These fisheries would not be leased to anyone.
d) All other fisheries covering an area larger than 20 acres would be granted to *ijaradars* (lessees) through open auction.

Any wetland not falling under *jalmahal* category can be leased to certain classes of people in accordance with the Manual by the Deputy Commissioner (DC) if the same is public or *khas* property. Therefore, there is no restriction on leasing *khas* property to private individuals and the DCs have been settling these 'non-fishery' wetlands to people.

The parcels of wetlands under private occupancy are at the disposal of the owner who can use the same for any purpose he likes unless that affects the enjoyment of similar rights by others or the neighbours. There are certain restrictions imposed by law like the Agricultural Pesticides Ordinance, 1971 or the Irrigation Act of 1876. Private fisheries are protected by law through the Private Fisheries Protection Act, 1889. Control over irrigation and other flood control structures that may have adverse impact on wetlands suitable for fish spawning are regulated by the Protection and Conservation of Fish Act, 1950.

If any land including wetland, whether private or public, is declared as a wildlife sanctuary or park then the Wild Life (Preservation) (Amendment) Act, 1974 will govern the regime.

INSTITUTIONAL AND POLICY CONFLICTS

It is clear that wetlands under the management of various sectoral public institutions are being treated as something other than wetlands. Each sector maintains its compartmentalized priorities irrespective of adverse impact on other sectors. The mono-institutional approach has reduced the potentials of wetlands.

The question is what are the policies relevant to wetlands in Bangladesh? Since there is nothing called wetland in the law of the land but being regulated under various legal status it is essential to study those sectoral policies or guidelines like policies on fisheries, agriculture, water resources development etc. One has to identify relevant aspects of those policies that have direct or causal bearing or link with wetlands.

It is also essential to study the National Environmental Policy, 1992. There are many provisions in the policy that are relevant to wetlands. For example:

a) Keep the rivers, canals, ponds, lakes, *haors*, *baors* and all other waterbodies and water resources free from pollution.

b) Conserve and develop wetlands and protect migratory birds.
c) Prevent activities which diminish wetlands/natural habitats of fish and encourage promotional measures.

The Environment Action Plan appended with the policy further provides institutional direction for sectoral action.

It would also be quite relevant to study the proposed policy guidelines, strategy and action programme on wetlands in the draft National Conservation Strategy of Bangladesh. For example, sections 2.7.7 on wetlands, and also the relevant sectoral analysis.

It is essential to identify the policy and legislative or regulatory issues that are responsible for destruction or act as hindrances to wetland conservation or sustainable use. Unless the issues in this aspect are identified, it would be difficult to propose practicable recommendations. Specific needs or weaknesses should be identified before proposing their strengthening. In the light of emerging policy directives, the prevailing sectoral policies need reorientation, and new policies on landuse and human settlement should be adopted to ensure institutional coordination.

FINAL REMARKS

Certain measures or procedural steps can be suggested from legal perspectives for protecting the available and reversible wetlands. Introduction of a strict legal regime is a very risky effort and is likely to be rejected by the local people. Given the land shortage, it would be almost impossible to seclude land areas without compensation. In some cases, compensation or alternative economic sources would be essential prior to any conservation measure because these steps are bound to interfere with the traditional rights of the people or their wisdom. For example, there are rural communities whose livelihood is dependent, at least seasonally, on catching and selling the winter guest birds.

Suitable wetlands under private ownership would have to be acquired for effective preservation unless there are profitable scopes in law protecting private rights and interests.

In view of the above the following propositions can be considered:

1. Once an inventory of wetlands is prepared, a policy decision has to be taken to identify those to be conserved as wetlands. For Bangladesh, given the prevailing regime, all wetlands may not be preserved as such or it may not be possible at all or necessary.
2. Once the wetlands to be conserved are identified, their existing legal status including ownership, possession, Record of Right status and institutional authority should be ascertained.
3. Once the above is known, legislative measure can be undertaken to bring them under one regulatory regime. In doing so one must be least romantic to

appreciate the basic needs for human survival in Bangladesh. A statutory priority order should be adopted.

The existing legal status should be identified together with the shortcomings of prevailing legal system. The reasons for non-enforcement of laws like the Wildlife (Preservation) (Amendment) Act, 1974 should be identified. The institutional set-up is important to carry forward the policy through the regulations. An effective and workable institutional framework needs to be developed after examining the existing capabilities and mandates. The Ministry of Environment and Forests should take the responsibility and play the leading role.

It is worth mentioning that policy and legislative framework needs to be examined from its historical perspectives since each generation sets its priorities in response to the needs of a given time. It was the first priority of all foreign rulers in this subcontinent to expand agriculture for increasing revenue at the expense of forests, fisheries and wetlands. When the British left, "the grow more food" campaign once again brought agriculture to the forefront to feed the increasing number of mouths. Even today, the 1972 Constitution of Bangladesh sets the goal of radical transformation in the rural areas through the promotion of an "agricultural revolution" (Article 16). As a result, agriculture and the irrigation and drainage infrastructures are taking over the race of sustainable development of other resources. Does 'wetland' have any place in our fundamental principles of State Policy as enshrined in the Constitution? Perhaps the 'revolution' needs to be redefined and the task is wider than the preservation of wildlife.

REFERENCES

GOB. 1990. *The Constitution of the People's Republic of Bangladesh.*

GOB. 1991. *The Land Management Manual*(Bangla). Ministry of Land, Dhaka.

Sharafatullah, M and S.K.D. Gupta. 1990. *Handbook for Land Tenure and Land Records Training Course*, Assistance to the Forestry Sector, Phase II, UNDP/FAO project BGD/85/085, Dhaka.

Farooque, M. 1991. Water rights and management of water resources under conflicting demands in the Bangladesh context", In: SUWAR, KTH, Workshop on Methodology for Sustainable Water Resources Management and Development in Bangladesh, *Report No.B1, 1991*, Stockholm.

Farooque, M. 1992. *Law and Custom on Forest Land: Issues & Remedies* (A study of Sal Forest), (draft), IIESDM-Ford Foundation Project, Dhaka.

AWARENESS AND PUBLIC PARTICIPATION IN WETLAND MANAGEMENT

A. M. Sharafuddin

ABSTRACT: For sustainable wetland management, participation of local community and creation of awareness among all concerned is considered essential. This paper stresses the need for making full use of all the channels of formal and non-formal education in the country for raising public awareness on wetland management. Key actors in the conservation of wetlands are the rural poor living in and around the wetlands and hence their cooperation is of crucial importance. As such, special attention has to be given to raising awareness among the rural poor. Inclusion of conservational issues in school curricula, effective utilization of media and arrangement of social debates have been recommended. Involvement of NGOs, utilization of religious institutions in developing environmental ethics and involvement of women in community programmes have also been suggested.

INTRODUCTION

The wetlands in Bangladesh are so pervasive that the life of the whole nation is closely intertwined with their existence and quality. Hence support for wetland conservation is needed among all the concerned groups in the society, especially for the formulation, enactment and implementation of comprehensive legislation for their protection. In this respect, people's perception of the issues on the wetlands assumes great importance. In an empirical study of environmental risks associated with agricultural practices, (Islam 1990) found that the villagers usually make a distinction between two types of floods — *barsha* and *bonnya*. *Barsha* is a normal inundation of the fields during the rainy season (June-October) and is considered a benevolent agent providing sustenance and help to their agriculture. As long as the water does not overtop the homestead land and the crops in the field are not submerged, it is regarded as normal flood. On the other hand, *bonnya* is perceived as a disastrous, damaging flood. Its timing, duration and magnitude of inundation are abnormal, overtopping the homestead land and submerging the crops in the fields (Islam 1990).

Knowledge is the first precondition for a wise and effective use of the natural resources. Such detailed and comprehensive knowledge on the wetlands in Bangladesh is still lacking. Hence appropriate centres of research on wetlands should be developed and strengthened. Greater use of the existing research facilities including those in the universities should be encouraged. Such research should, as far as practicable, be directed towards relevant conservation action and policy issues rather than distant academic objectives. Another urgent need is the formulation and dissemination of proper inventory of the threatened species of mammals, fishes, birds, invertebrates and wetland plants. Comprehensive programmes should be framed for their conservation. Studies are needed on the deterioration of water quality caused by pollutants and their adverse effects on primary producers and on the fish population. Scientific information is needed on the taxonomy, biology and productivity of freshwater biota. An ecologically and socioeconomically accepted basis for managing the wetlands is needed

for proper inventory, research, monitoring, evaluation, planning and its phased implementation.

EDUCATION, TRAINING AND PUBLIC AWARENESS ON WETLAND MANAGEMENT

Education and awareness development programmes are needed to raise public awareness in all sectors of the community. These should have three common goals:

a) raising public awareness of the functions and values of wetlands;
b) raising public awareness of the diverse threats to many wetland sites and wetland species; and
c) promoting their sustainable use to prevent further destruction of wetlands (Anonymous, 1992).

In the planning of such programmes, full use should be made of all the channels of formal and nonformal education in the country. Key actors in the conservation of the wetlands are the rural poor living in and around the wetlands. Their cooperation is of crucial value in the effort. Hence special attention should be given to environmental awareness campaigns. Local community workers should be involved and appropriate messages of critical local significance should be included in the programmes.

In the curriculum of primary and secondary schools, some components of natural resources conservation have already been included but these need to be strengthened. One way to do this may be inclusion of demonstration projects, field training and voluntary services (Sharafuddin, 1991). Also, the educational materials prepared for the various groups should use language and message appropriate to the age, educational background and life experiences of the intended target groups.

The media (press, television, radio, cinema, documentary) can play an important role in disseminating information about wetland functions and values. Special debates, and special articles and discussion programmes can be arranged under their auspices. For necessary training of the media personnel, the Press Institute of Bangladesh, the Forum of Environmental Journalists and other similar professional groups may organize appropriate training programmes. Various professional societies such as Society for Conservation of Nature and Environment (SCONE), Bangladesh Wildlife and Nature Conservation Society, Wildlife Society of Bangladesh, Bangladesh Bird Preservation Society, etc. can also help in this effort.

Prevention of human interference in the protected areas requires willing participation of the people of the concerned areas. For this purpose, collaboration with local NGOs should be promoted. Social participation in general and women's participation in particular in the conservation action programmes need to be encouraged. Also, the potential role of religious institutions in developing environmental ethics and stimulating appropriate actions should be explored.

Natural disasters such as floods and droughts provide suitable opportunities for increasing public awareness of the need for wetland conservation and other preventive measures.

COMMUNITY PARTICIPATION IN WETLAND MANAGEMENT

Use and management of the environment is basically the function of the entire population of the country. Hence in the management and conservation of the wetlands the people as a whole must be involved. In ensuring such involvement we are faced with some conceptual issues as to what is actually involved in community participation. The United Nations (e.g., in *Popular Participation in Decision Making for Development*, 1975) suggested that it is more useful to conceive community participation as taking place in small communities comprising individuals 'at the lowest level of aggregation at which people organize for common effort'. According to this notion, 'participation' is considered to entail voluntary and democratic involvement of the people in (a) contributing to the development effort, (b) sharing equitably in the benefits derived therefrom and (c) decision-making in respect of setting goals, formulating policies and planning and implementing economic and social development programmes (Midgley, 1986). In the above view, community participation would require that the poorest groups of the community have an effective role in choosing social development programmes, and that they contribute together with the rest of the community in the implementation of decisions and derive equitable benefits from these programmes.

In Bangladesh, the poor are often on the verge of destitution and hence compelled to take environmental action that unwittingly cause irreparable damage to the ecology. The fact that Bangladesh has an adult literacy rate of slightly over 30 percent (this is as low as 20 percent in the rural areas) makes the situation more complex. Among the women, the literacy rate is about half of that of men. This naturally calls for the need to urgently expand the coverage of primary education and mass education throughout the country and increase the coverage of relevant environmental issues in the curriculum of primary and mass education. Bright elements in this scene are provided by the grassroot level environmental programmes such as the 'Chipko Movement' for the protection of trees in India and the various non-governmental initiatives such as the one by the Grameen Bank in Bangladesh based on self-help initiatives of the rural poor.

Community participation involves community action and often mass meetings. This is helped if the political leadership in the country takes up the environmental issue as a national cause and promotes mobilization of mass action to that effect. The canal digging programme of President Ziaur Rahman is an example of such initiatives. But to undertake such programmes on a large scale, proper environmental impact assessment studies should be undertaken before the initiation of new channels or dams so that these may not create unexpected ecological damage. As the livelihood of the people is intimately linked with the environment, any programmes likely to have largescale and long-term impact on the environment should be closely examined and debated at the expert level; and the people should also be made aware of both the likely positive and negative impacts of such intervention.

RECOMMENDATIONS

The recommendations for development of awareness and mass participation on wetlands are as follows:

Research on Wetlands: There are still large gaps in our knowledge of the wetlands in Bangladesh. Hence research on wetlands needs to be strengthened. The various universities in the country have some components on wetlands in the courses of such subjects as botany, zoology and geography at the honours and master's levels. The Bangladesh University of Engineering and Technology has an Institute of Flood Control and Drainage Research. However, there is a need to strengthen inter-disciplinary research in this area.

Educational Curricula: Some elements of the environment have now been included in the curriculum of primary and secondary schools. However, these syllabuses were prepared in the mid-seventies and a great deal of change has since taken place in our perception of environmental issues and in the knowledge relating to the environment. Hence the syllabuses of the various stages are in urgent need of updating.

Teaching Aids and Awareness Programmes: The teaching methods used in our educational institutions are still very bookish; there is very little in the way of teaching aids and supplementary reading materials. Early steps are needed to develop such materials. Various awareness development programmes can be started in the educational institutions through field visits and study groups.

Nonformal Education: Awareness development programmes are needed not only in the system of formal education but also in diverse forms of non-formal education. Since the large majority of the population of the country, including children and youths, are outside the pale of the formal educational system, such non-formal education programmes assume great importance in Bangladesh. The newly set-up Bangladesh Open University can begin special programmes on environmental education, including elements of the freshwater wetlands.

Religious Institutions: The religious institutions can play an important role in developing the environmental ethics among the people. This potential should be adequately tapped and religious institutions be involved in environmental action.

Use of Communication Media: Newspapers and the electronic media have today assumed a very important role in creating mass awareness. These should be properly used in disseminating information about the wetlands, creating awareness about the environmental issues and initiating debate on possible modes of remedial action. Although there are more than a hundred daily newspapers and several hundred weeklies in the country, very few have any special section on science, technology or environment. The newspapers can play a crucial role in educating the people. The newspapers and periodicals may be encouraged to start special sections as a public service. The programmes for radio and

television should be specially tailored to provide both accurate information and be appropriate to the special appeal and possibilities of the medium used.

Training of Personnel: Environment is a matter of relatively recent concern and can be adequately dealt with only from the standpoint of an interdisciplinary approach. Hence the persons involved in the dissemination of environmental knowledge through both formal and nonformal channels need to be provided special training appropriate to the functions they are to perform. For example, special programmes for the media personnel may be organized by the Press Institute and the National Institute of Mass Communications with the help of resource persons from other areas.

Gender and Literacy: The women form a large group in society and have a crucial role to play in the conservation of the environment. Hence special attention should be given to the needs of women — one of the prime needs, of course, being literacy. Similar special programmes may be sponsored for youth groups and children.

Local Level Participation: The conservation of the environment should be looked upon as a national movement. Especially in Bangladesh today, it has become an issue linked with the question of the very survival of the nation. Hence the various local groups should be mobilized in the planning, designing and operation of environmental programmes such as those for flood control and drainage.

National Debate on Interventions: For largescale ecological interventions, proper examination of various alternatives particularly in relation to the possible adverse environmental effect should be a precondition. Whenever possible, wide national debates should be encouraged for projects that would ultimately affect the livelihood and ways of life of many people.

Role of NGO Groups: Government can certainly take the major role in the formulation of national policy relating to the environment. But a large share of responsibility in the mobilization of the people will have to fall on the various non-governmental organizations in the country. Some are already doing very useful work but this needs to be further stepped up to make any tangible impact on the scene.

REFERENCES

Anonymous. 1992, *Action Programme for the Conservation of Wetlands in South and West Asia*. Asian Wetland Bureau (AWB), Kuala Lumpur and International Waterfowl and Wetlands Research Bureau (IWRB), Slimbridge, p. 11.

Islam, M Aminul. 1990. Environmental Perceptions and Agriculture, In: Saleemul Huq, et. al. (ed), *Environmental Aspects of Agricultural Development in Bangladesh*. University Press Ltd., Dhaka, p. 155.

Midgley, James. 1986. *Community, Social Development and the State*, Methuen, London, pp. 24-25.

Sharafuddin, A M. 1991. *Towards Sustainable Development: Environmental Awareness and Education in Bangladesh*. IUCN-WCU, National Conservation Strategy of Bangladesh, BARC, Dhaka, 1991, p. 10.

CONSIDERATIONS FOR A NATIONAL WETLAND INVENTORY

Raguibuddin Ahmed, Stanley M. Hirst,
Ron D. Livingston and Michael R. Pooley

ABSTRACT: Land and water resource development activities have caused significant reductions in Bangladesh's wetlands. Conservation of the last remaining key wetlands and their sustainable management require accurate and updated inventory information. The need for a national inventory to establish and monitor the conservation and management status of wetlands is discussed here. A national inventory would require establishment of a group with full capability for remote sensing image analysis, a geographic information system to manage the database, a number of field survey teams to collect relevant ecological and landuse data, a national committee to coordinate and review the progress and products of the inventory, and sufficient budget to maintain the activities for an initial period of at least one year. A pilot study to develop appropriate methodologies and institutions for the main inventory is recommended.

INTRODUCTION

The importance of wetlands and their value in terms of hydrology, ecology and socio-economics in Bangladesh is well recognized. However, while wetland resources have been studied in certain cases and some regional inventories conducted, a comprehensive information base for conservation and management of Bangladesh's valuable wetland resources does not appear to have been created. Reports such as the National Conservation Strategy (MOEF, 1991) have recommended more comprehensive inventory and management of the country's wetland resources. Similarly, international agencies such as the Asian Wetland Bureau have recommended the need for a national inventory of Bangladesh's wetland resources (Scott, 1989).

To prepare a wetland conservation programme, updated baseline information on wetlands at the national level is required. Such baseline data would permit more realistic appraisals of proposed development projects and changing resource use patterns which could potentially impact wetlands. They would also be used as background information for identifying nationally and internationally important wetland areas, identifying priorities for wetland management and would serve as the basis for development of guidelines for wetland management.

A needs assessment for a national wetland inventory (ISPAN, 1992a) indicated that conservation agencies, with their limited financial resources, can act efficiently in the conservation of wetland ecosystems only if they concentrate their efforts on the most important and most vulnerable systems. Such a concentration of action is possible only if it can be based on a common set of priorities, such as an agreed list of nationally or internationally important sites. In the development of an effective conservation programme, one of the first steps is the compilation of a basic inventory of these important sites which would identify priorities for future action in research, protection and management, and establish the basis for a monitoring system.

The Action Programme for the Conservation of Wetlands in South and West Asia (Asian Wetland Bureau/International Wetland Research Bureau, 1992) has listed a large number of specific priority national actions for Asian countries. For Bangladesh, a total of 17 recommendations have been made, amongst which two are germane - (a) the need for a national wetland committee or advisory group consisting of representatives from the relevant government agencies, research institutions and NGOs, and (b) the need to undertake and publish a national wetland inventory to expand and update the section in the Directory of Asian Wetlands.

PREVIOUS WETLAND INVENTORIES

Only two national-level inventories of waterbodies and wetlands in Bangladesh have been undertaken to date. The Directory of Asian Wetlands (Scott, 1989) has a specific section dedicated to Bangladesh in which twelve wetland areas were identified and documented. These sites were selected on the basis of common knowledge that they were of special importance for wildlife. It is likely that other areas of significant value may have been overlooked. Information on general status and ecological importance, legal protection and land tenure situation at each site was collected during a one-day site visit, while for very large sites up to 3 days were spent collecting data. Most information was compiled and collected from secondary sources, indicating the very limited baseline information available on wetland areas. The format used for data collection was based on the RAMSAR data sheets. This same approach has been applied to all twentyfour Asian countries included in the Directory.

Also at a national level, the Space Research and Remote Sensing Organization (SPARRSO) conducted a study of the total number of waterbodies in the country, both small (upto 25 ha) and large (greater than 25 ha) by using satellite imagery and aerial photographs of 1983-84 (SPARRSO, 1984). Large waterbodies, including *haors, baors*, rivers and canals over the entire country were mapped at a scale of 1:50,000 in 267 sheets. The data were used by SPARRSO to prepare a catchment water resource map of the country for use in the National Water Policy developed by the Master Plan Organization. This inventory indicated the practicality of undertaking national level inventories of waterbodies based on remotely sensed imagery, but the information is of limited use in conserving and managing wetlands since it lacks an accompanying wetland ecological and landuse database.

A small number of regional wetland and waterbody surveys have been made in recent years providing useful experience in applying inventories at a wider national level. SPARRSO carried out a pond survey for the Department of Fisheries in 1984 covering forty selected thanas, and produced a pond map for each thana at a scale of 1:50,000. In the northeast region, two rapid assessment surveys covering 68 sites have been carried out in the *haor* basins (Northeast Regional Water Management Project, 1992). Basic information was gathered on the condition of each wetland i.e. water level, aquatic vegetation, terrestrial vegetation, fishing activity, hunting activity and general level of disturbance from human activity. The evaluation of sites was based primarily on the abundance and diversity of waterbirds, with consideration given to the criteria developed in relation to the Ramsar Convention.

Three main groups of wetlands were distinguished:

a) large sites comprising either a single large *beel* or a group of *beels* of outstanding importance for wildlife and retaining some natural qualities of considerable ecological significance in a regional context;

b) mainly large *beels* or groups of *beels* supporting significant number of wintering waterfowls and in some cases also small populations of breeding birds; and

c) small, isolated *beels* in densely settled areas or highly modified wetlands given over almost entirely to the cultivation of rice and of little importance for wildlife and of limited ecological significance.

WETLAND CLASSIFICATION

An essential feature of any national level inventory of wetlands is a classification of wetlands according to criteria which permit identification of priorities for conservation and management. Classifications should reflect the hydrological and ecological functions of wetlands. Two recently developed classification systems for Malaysia and the Philippines(Table 1) illustrate this approach. Any classification used in a Bangladesh inventory should encompass standard definitions of wetland types such as *beels*, *haors* and *baors*, but might also usefully be based on the landtype concept (Master Plan Organization, 1984) or some adaptation of it (Table 2).

The wetland classification system applied in the Philippines (Davies et al., 1990) is based on a concept which would be of practical value and utility in Bangladesh, i.e. using criteria which reflect both ecological and viability values. Viability criteria aim to answer the questions:

a) how long is the site likely to retain its conservation value, and
b) how feasible is the management of the site?

The intent of the approach is to make use of scarce resources to focus on those sites of high ecological value which are likely to be successful in terms of subsequent management. The methodology has been used to identity wetlands for inclusion in a protected areas system, using a set of preliminary ecological criteria before field survey and a set of detailed ecological criteria after survey (Table 3).

Table 1. **Wetland Classification Schemes in Malaysia and the Philippines**

Malaysia[1]	Philippines[2]
1. Sea bays and straits (under 6m at low tide)	1. Swamps
2. Estuaries, deltas	i. Swamp Forest
3. Small offshore islands, islet forests	a. Peat swamp
4. Rocky sea coasts, sea cliffs	b. Other swamp forest
5. Sea beaches (sand, pebbles)	ii. Non-forested swamps
6. Intertidal mudflats, sandflats	a. Overflow wetland
7. Mangroves	b. Other swamps
8. Coastal brackish and saline lagoons	2. Mangroves and brackish and water swamps and marshes
9. Salt pans (artificial)	3. Coral
	4. Seagrass and seaweed
10. Aquaculture ponds	5. Lakes
-Brackish	i. Lakes and tarns
-Freshwater	ii. Ponds
11. Rivers, slow-flowing streams (lower perennial)	iii. Reservoirs
	6. Estuaries
12. Rivers, fast-flowing streams (upper perennial)	7. Rivers
	i. Rivers, streams, torrents
13. Oxbow lakes and riverine marshes	ii. River pools
14. Freshwater lakes and associated marshes (lacustrine)	8. Rice fields
	i. Tidal
15. Freshwater ponds (under 8 ha), marshes, swamps (palustrine)	ii. Non-tidal
	a. Rain-fed
16. Salt lakes, saline marshes (inland drainage systems)	b. Irrigated
	9. Aquaculture
17. Water storage reservoirs, dams	10. Salt ponds
18. Seasonally flooded grassland	
19. Rice paddies	
20. Flooded arable land, irrigated land	
21. Freshwater swamp forests, temporarily flooded forests	
22. Peat bog	
23. Peat swamp forest	
24. Nipa swamp	

[1] Malaysian Conservation Foundation, 1987
[2] Davies et al. 1990

Table 2. Possible Wetland Classification[1] System Based on Application of Land Type Definitions[2]

Seasonality	Classification	Definition
Perennial wetland	W_0	Area under water throughtout year including dry season
Seasonal wetland	W_1	Area flooded to depth of 1.8m to 3m during peak flooding
Seasonal wetland	W_2	Area flooded to depth of 0.9m to 1.8m during peak flooding
Seasonal wetland	W_3	Area flooded upto depth of 0.9m during peak flooding

[1] ISPAN, 1992b
[2] Master Plan Organization, 1984

Table 3. Ecological and Viability Criteria Applied to Wetland Classification[1]

Preliminary Ecological Criteria

1. Habitat diversity
2. Unique/rare habitats
3. Species diversity
4. Occurrence of rare/endemic/ endangered species

Detailed Ecological Criteria

1. Habitat diversity
2. Habitat distribution
3. Floral species richness
4. Rare wetland plant species
5. Wetland bird species richness
6. Wetland bird species abundance
7. Presence of rare/endemic/endangered bird species
8. Fish species richness
9. Fish endemism
10. Special consideration (top predators)

Viability Criteria

1. Size
2. Shape
3. Site condition
4. Catchment condition
5. Land tenure status
6. Peace and order situation
7. Plans for site
8. Population in site
9. Population in adjacent areas

[1] Davies et al, 1990 and Davies & Giesen, 1992

APPLICATION OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO WETLAND INVENTORIES

Use of remote sensing (including aerial photography) for wetland inventories at national level dates back to 1954 when the U. S. Fish and Wildlife Service (USFWS) conducted an inventory of wetlands across the United States to assess the amount and types of waterfowl habitat (Lillesand and Keifer, 1987). In 1975 the USFWS initiated a National Wetland Inventory programme to prepare multipurpose wetland maps of the United States at scales of 1:10,000 and 1:24,000 for a variety of potential users including wildlife managers, hydrologists, landscape planners, economists, engineers, and other public and private users.

Because of the large areas to be covered, a national wetland inventory of Bangladesh would have to make use of remotely sensed imagery as the basis for mapping, sampling and inventory. Recent satellite imagery covering the whole country is available. LANDSAT multispectral scanner (MSS) and thematic mapper(TM) imagery is available in digital format and hard copy at various scales, typically 1:250,000 for MSS and 1:100,000 for TM. SPOT imagery is available in digital format as well as in coloured and panchromatic images at 1:50,000 scale. Spatial resolution and spectral band width are the two characteristics of satellite data which set the limitations as to their use in mapping land and water cover. Spatial resolution is the area of land over which the spectral reflectance is averaged. Identification and mapping of spatial features require a group of 20-25 pixels of similar reflectance signatures. For 20m resolution SPOT imagery this would represent about 1 ha and for 30m resolution Landsat TM images it is about 2 ha. This level of resolution over large areas effectively requires digital processing and the resultant mapping would be limited in what it could display. However, basic wetland types and size categories would be identifiable. The main purpose of a digitally processed map covering a large area would be to serve as a complete inventory source and a guide to the field sampling procedures. All information obtained, however, would be in Geographical Information System (GIS) format and would lend itself to further processing by overlaying of other features such as salinity and soil mapping.

The task of making a national inventory at this level for Bangladesh would require the acquisition and digital processing of some 75 SPOT or 14 TM scenes. A major consideration would relate to the timing of the inventory and the classification adopted. Dry season surveys would emphasize permanent waterbodies which are of key importance as wildlife and fish refuge habitats, while surveys at other times would have to contend with the extensive monsoon flooding which would extend beyond the dry season limits. MSS and TM imagery taken during the monsoon period is usually hampered by extensive cloud cover; this problem is likely to be overcome in future through the use of radar imagery taken by the European Radar Satellite (ERS-1).

Efficient use of imagery and GIS for mapping and inventory purposes would require good integration between the image processing activities and the field sampling and data collection. A recommended procedure would be to utilize a GIS to obtain full useful information content from a number of image sources, e.g. SPOT complemented by

LANDSAT and aerial photography (in specific cases) for compiling an overall inventory and classification of all wetlands of defined size. From this a sample would be drawn on a stratified random basis of all major wetland types. The sample wetlands would be located in the field and a full appraisal made of their ecological and conservation status. The resultant data would be fed back to the GIS for compilation, analysis and overlaying with other relevant data, and extrapolation to areas not directly sampled in the field. To develop an effective integration of image processing, GIS mapping and field inventory, it would be essential to have an initial pilot survey of a limited area to test and confirm methodologies before proceeding on a national scale.

SCOPE OF A NATIONAL WETLAND INVENTORY

A national inventory should encompass all types of wetlands, from coastal mudflats and mangroves to inland swamps, *haors* and *beels*, and should consider all wetland values, including hydrological, biophysical, ecological, social, cultural, faunal and floral. The national inventory would identify priorities for future survey, research, management and protection, and would provide a sound basis for monitoring. The national inventory should emphasize dry season wetlands which are permanent or perennial. A three phased approach to the inventory is suggested.

Phase I would be a pilot study wherein a relatively small area (say about 25 km x 25 km) would be selected and subjected to an inventory as described under Phase II to test and refine image analysis and field sampling and inventory procedures. The sample area should be small enough for complete inventory coverage within a few weeks, but large enough to encompass a representative selection of different wetland categories to thoroughly check image, mapping and field sampling methodologies. Digital satellite imagery and recent aerial photographic coverage should be readily available. A complete inventory and mapping for all seasonal and permanent wetlands using image processing and GIS methods, including classification of all wetlands on the basis of state criteria such as size, shape, location and any other discernible features, should be carried out. The database should include available overlays of topography, soil types and other relevant data to aid in the classification process. From the preliminary image analysis, a statistically based sample of all wetland types should be selected for field checking. A rapid field sampling protocol based on present knowledge of Bangladesh wetlands and on the approaches and methods used in other countries, should be designed, and field surveys carried out. The results should be reported, preferably in a national forum, and used towards the designing of a full-scale national inventory programme.

Phase 2 of the inventory would be the main phase, using the methods and approaches evolved in the pilot phase. All existing data - hydrological, physical, ecological and socio-economic on the location, status and resource values of Bangladesh's wetlands should be collected and analyzed. A GIS, complete with all necessary hardware, software and trained personnel, should be established within a suitable institution. A classification system for a national wetland inventory should be developed, and a set of imagery suitable for national inventory purposes, including most recent SPOT and

LANDSAT digital imagery, procured and supported by selected aerial photographs for important wetland areas.

The main inventory phase would identify and map all major wetland systems on the basis of topographic, vegetation and soil maps, aerial photography and satellite imagery. Following this, a number of interdisciplinary teams would conduct a rapid field assessment of representative samples of all wetlands to be included in the national inventory. The surveys should include Global Positioning System (GPS) technology to facilitate the accurate incorporation of field data into the GIS database. Photographs taken on site could be located by geographic reference points and catalogued at the inventory organization library. Site ecological surveys would include vegetation and soil surveys, censuses of resident and migratory birds dependent on wetlands (distribution, status, habitat requirements, and abundance with special emphasis on rare and endangered species), associated surveys of mammals, reptiles, and amphibians associated with wetlands, surveys of fish fauna (distribution, status, habitat requirements and abundance with special emphasis on rare and endangered species), as well as limnological surveys of selected wetlands (including an assessment of seasonal fluctuations and productivity). Socio-economic surveys of villages in the area of identified wetlands, to assess local use and dependance on wetland products, should be included in the inventory, as also determination of current landuse activities, land tenure, ownership and resource management practices in the selected wetland areas. Finally, the hydrological regime affecting selected wetland sites should be defined.

The GIS-based wetland database and catalogue would be suitable for statistical analysis of information on a regional, national and wetland classification basis. The database should be linked to the narrative accounts to enable selective retrieval of entire information sheets or just the relevant sections of the text on the basis of any selected parameters (e.g. wetland type, land tenure, legal status, threat, etc.).

National level mapping should be conducted at 1:250,000 (17 map sheets). Areas of particular interest where more detailed baseline data collection is to be done (in phase-3) should be mapped at 1:25,000.

The products of the national inventory would be manifold. Primarily, it would indicate the national status of all wetlands and wetland types and provide immediate pointers to urgent conservation and management considerations including seasonal hydrological and sediment dynamics, migration and reproduction dynamics of fish stocks, the role of wetlands for migratory birds and the socio-economic value of wetlands.

Phase 3 would be a comprehensive, scientifically based field investigation programme to obtain baseline hydrological and physical, ecological, and socio-economic data at selected wetland areas determined to be of regional, national or international importance, and would serve as representative sites for long-term monitoring.

REFERENCES

Asian Wetland Bureau/International Wetland Research Bureau. 1992. Action programme for the conservation of wetlands in south and west Asia. AWB, Kuala Lumpur and IWRB,Slimbrige, U.K.

Davies, J., P.M. Magsalay, R. R. Rigor, A.A. Mapalo and H. Gonzales. 1990. *A Directory of Philippine Wetlands. Vol I & II AWBPFI/HF. Cebu, Philippines.*

Davies, J., and W. Giesen. 1992. *Towards a Methodology for Identifying Tropical Freshwater Wetlands for Protection.* Draft.

ISPAN. 1992a. A needs assessment for a national wetland inventory in Bangladesh. Bangladesh Flood Action Plan, Dhaka.

ISPAN. 1992b. *Environmental Impact Assessment Case Study: Surma- Kushiyara Project.* Bangladesh Flood Action Plan, Dhaka.

Lillesand, T., and Keifer R. 1987. *Remote Sensing and Image Interpretation.* John Wiley & Sons, New York.

Malaysian Conservation Foundation. 1987. *Malaysian Wetland Directory.* Department of Wildlife and National Parks, Peninsular Malaysia, Kuala Lumpur.

Master Plan Organization. 1984. National Water Plan Project. *Second Interim Report.* Ministry of Irrigation, Water Development and Flood Control, Dhaka.

Ministry of Environment and Forest. 1991. *National Environment Management Plan.* An Action Plan for Bangladesh. Draft. Dhaka.

Northeast Regional Water Management Project. 1992. *Wetland Assessment and Orninthology Main Surveys. Draft Final Report.* Flood Plan Coordination Organization, Government of Bangladesh. Dhaka.

Ramsar Convention Bureau. 1971. *Convention on Wetlands of International Importance Especially as Waterfowl Habitat.*

Scott, D.A. (ed.). 1989. *A Directory of Asian Wetlands.* IUCN, Gland, Switzerland and Cambridge, UK. 1181 pp.

SPARRSO. 1984. Standing Water Bodies in Bangladesh. Report to the Master Plan Organization, Dhaka.

POTENTIAL INITIATIVES FOR WETLAND MANAGEMENT IN THE NORTHEASTERN REGION OF BANGLADESH

S.L. Bennett, Anisuzzaman Khan
and S.M.A. Rashid

ABSTRACT: This paper summarizes the initiatives that have been formulated for inclusion in the regional water management plan covering the northeastern region of Bangladesh which is presently under preparation. Development of a regional water management plan requires understanding of all water related aspects of regional development including hydrology, sedimentation, agriculture, fisheries and wetland ecosystem. This requires an interdisciplinary approach. The recommended initiatives include community-based management of rotating bird sanctuaries, community-based resource management for wetland sites, afforestation of economically important swamps, monitoring of wetland sites of ecological importance, farming of high-valued wild species, restoration of endangered plant species, water quality management, and strengthening institutional support. These initiatives are in addition to potential initiatives in agriculture and fisheries.

INTRODUCTION

This paper presents a subset of potential initiatives that are being considered in preparation of a Regional Water Management Plan for the northeast region of Bangladesh. Within the framework of this plan, individual water management projects are to be selected, implemented and operated for the benefit of agriculture, fisheries and related sectors with due attention to the growing landlessness of the rural people (Northeast Regional Water Management Project, 1991).

The Northeast Regional Water Management Plan (NERP) is taking the approach that rational planning for regional water management must be based on an understanding of all water-related aspects of regional development: hydrology, sedimentation, agriculture, fisheries and wetland ecosystem (Northeast Regional Water Management Project, 1992a; Scott and Rashid, 1992). When completed, NERP will present an integrated interdisciplinary view of the region and suggest directions for overall future development, with an emphasis on water resource development. The plan components will include structural and non-structural flood control, drainage, irrigation (FCDI) initiatives, and also initiatives that address the management of water resource-linked systems such as fisheries, wetlands, etc. The proposed initiatives towards wetland management are presented in this paper. Not discussed here are potential initiatives in fisheries, agriculture and water resources.

STRATEGIES WITH RESPECT TO WETLAND RESOURCES

Within the overall planning context, two broad strategies specifically addressing wetland resources management have been identified:

a) Identify, develop and support the best use of all sites in the region. Best use means development and management strategies that benefit both wetland habitats and animal/plant populations and address the needs of the human population.
b) Identify, develop and support development alternatives that maintain options for future generations. Biodiversity conservation is one example of maintaining options for the future.

In developing the regional plan, the following issues have been given special attention (Northeast Regional Water Management Project, 1992b & 1993a):

a) Special or key sites, where biophysical conditions critically influence conditions over much larger areas. These sites include those used by internationally migrating waterfowls in large numbers and by fish broodstock to evade traditional fishing techniques). Sites of special importance for physical processes also exist; for example, unstable river bifurcations that control flow splitting and large *haors* (river backswamps) that store flood peaks and release water in leaner periods. Finally, urban areas are 'special sites' from an economic and environmental quality perspective.
b) Dominant agroecological settings. Intensive field studies, including ethnobiology, are being undertaken in a submersible embanked *haor*, unembanked *haor*, a full flood control project, all the deeply flooded areas and in the less deeply flooded Kangsha River basin.
c) Regionwide processes, patterns and trends.

Specialist studies have been undertaken in the areas of water resources, hydrology/hydrogeology, sedimentology, social anthropology (including ethnobiology), agriculture, fisheries, ornithology, wildlife biology, botany and economics.

SELECTED POTENTIAL INITIATIVES RELATED TO WETLAND MANAGEMENT

Development of Community-based Management of Rotating Bird Sanctuaries

Threat: While physically suitable wetland habitat for migratory waterfowl still exists, and internationally significant number of waterfowls visit the region, disturbance levels are high everywhere. Birds must expend precious energy moving constantly in search of undisturbed areas, and the overall carrying capacity of the habitat is reduced.

Initiative: Special sanctuary areas at each of the internationally-important wetland sites identified under NERP should be established to create disturbance-free zones

for nesting and roosting birds. Such sanctuaries would rotate from *beel* to *beel*, depending on which *beels* are not being fished in any given season/year. In most cases, these sanctuaries would only need to be maintained for a part of the year, e.g. during the breeding season or during the period when wintering waterfowls are present.

Under this project, the *beel* by *beel* fishing schedule would be ascertained at each wetland site. Then field workers would contact the interested parties (*jalmahal* leaseholders, fisheries guards employed by them, Department of Fisheries officials, and local residents) for awareness-building activities.

At sites where the programme is accepted by the interested parties and proves successful, arrangements should be made to hand over responsibility to local people, with continuity, on-going support and conflict mediation through the Conservation Education Centre.

Development of Community-based Resource Management for Wetland Sites

Threat: NERP has identified internationally important sites such as Tanguar Haor, Pashua Beel (Gurmar Haor), Balai Haor, Hakaluki Haor, Kawadighi Haor and Hail Haor (Figure 1). These include a number of *haor* systems and a threatened reedland (Figure 2). High levels of human exploitation, continuing encroachment and ongoing FCDI development threaten to degrade these sites resulting in a loss of wetland products and services, including biodiversity.

Initiative: Wetland resources at these sites need to be stabilized and if, possible, enhanced through a variety of means such as:

a) additional field studies including social anthropology to understand resource base, exploitation and management practices;
b) community-based management strategy at each site; implementation strategy (which should include non-formal education etc); and
c) local communication to generate conservation project proposals for submission to international NGOs, donors for funding.

For reedland, the starting point should be a study of remaining reedland, then development of a strategy to maintain a suitable representative site.

Afforestation and Management of Economically Important Swamp Forest Trees

Threat: Significant areas of the northeast used to be swamp forest. Remaining remnant areas, some with trees many decades old, are rapidly being converted from sustainable community-based management (coppicing) to short-term cash lease, leading to destruction. These trees provide a variety of critically important functions such as erosion control and nesting sites for birds and other animals.

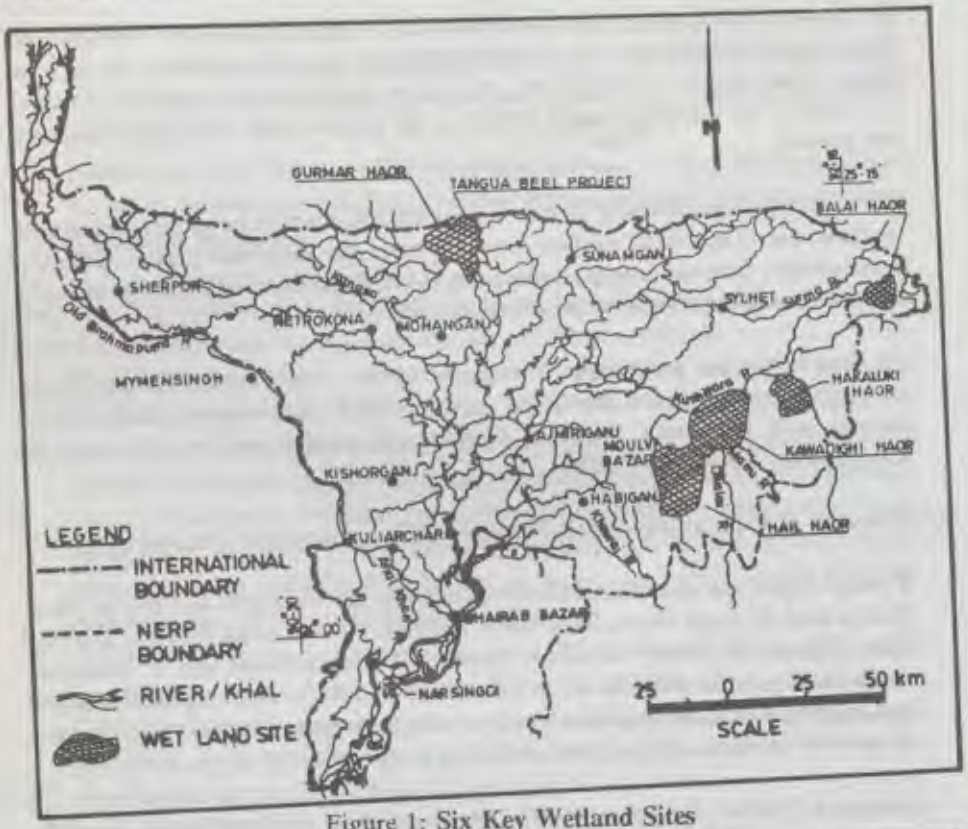


Figure 1: Six Key Wetland Sites

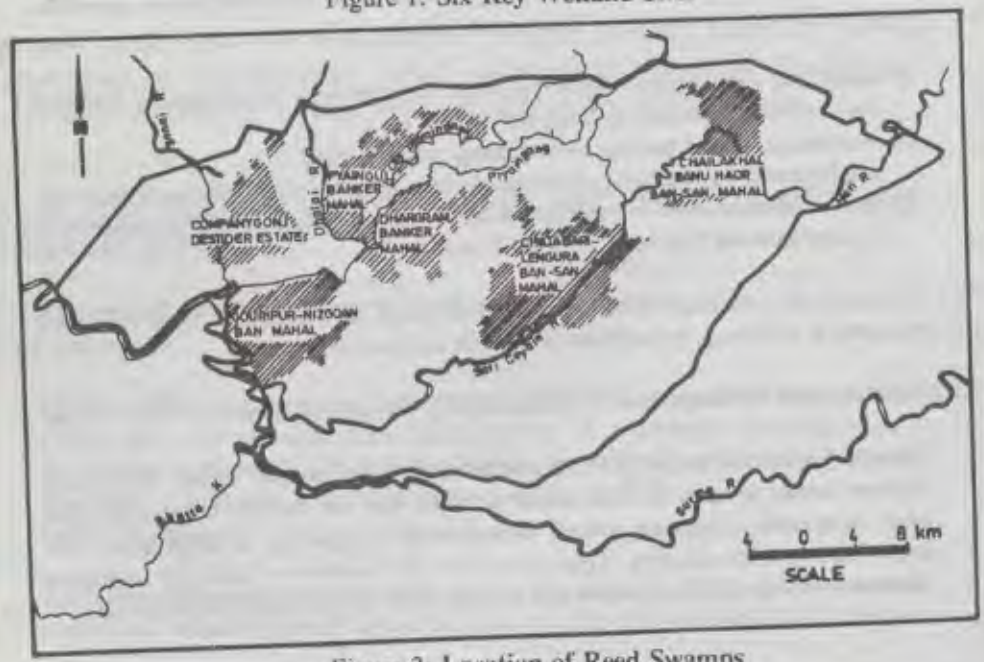


Figure 2: Location of Reed Swamps

Initiative: Development of methodologies for afforestation and management of economically important swamp forest trees. Project steps would include:

a) Locate and study management etc. at existing stands of *Barringtonia (Hizal), Pongamia (Koroch).*
b) Stabilizing existing sites from encroachment etc; extend management and other methodologies to new sites.
c) Species studies (natural regeneration, plantation, etc).

Ongoing Environmental Monitoring at Wetland Sites of International Importance

Threat: Trends such as increasing use of agrochemicals, increasing irrigation abstractions reducing base flows, industrialization, urbanization, and wetland conversion threatened gradually to degrade environmental quality, including water quality. Environmental quality, as measured by a variety of parameters, is critical to agriculture, fisheries, domestic use, etc.

Initiative: Undertake an integrated interdisciplinary environmental monitoring programme (e.g. to include water quality monitoring, micro- and macro- flora and fauna, water levels and flow rates etc.), at internationally-important wetlands and at other carefully selected key sites in the region such as selected rivers as they enter Bangladesh, discharges of selected industries, selected drainage channels for areas farmed with HYVs, selected key fisheries habitats (mother fisheries, beels where fish overwinter, spawning sites), etc.

Farming of High-valued Wild Species and Restoration of Endangered Species through Breeding

Threat: Various species are under threat due to strong domestic and international demand for meat, skins and other products.
Opportunity: Strong demand for a product suggests that employment and income could be generated in meeting the demand.
Initiative: Establish species suitability criteria (e.g. ease of breeding/raising, strong domestic/international market demand, reasonable initial investment and good cash flow for producers, etc.). Project steps would include:
a) identify suitable indigenous species;
b) for each species, set up pilot breeders; and
c) for successful species, extend.

Conservation of Threatened Plant Species

Threat: Exploitation and habitat loss from encroachment and FCDI development threaten some wild plant species.

Initiative: Steps should be taken to conserve threatened species of wild plants and disappearing local varieties of cultivated plants, for which the northeast region is

an important reservoir. The existing institutions and programmes - National Herbarium, Botanical Garden, Bangladesh Rice Research Institute - concerned with these matters are being supported by regular government funding as well as special projects (e.g. ODA to assist National Herbarium to relocate and expand its facilities). But additional funds should be made available for studies and *in situ* and *ex situ* conservation targeted to the botanical resources of the northeast region.

Water Quality Management

Threat: Fast rates of urbanization and, to some extent, industrialization will cause locally severe water pollution but in urban and industrialized areas where people are most exposed to the water will possibly degrade water quality more generally.

Initiative: This could have two aspects:

a) Wetland wastewater recycling for secondary towns. As the secondary towns of the northeast grow, there will be an increasing need to safeguard human health and environmental quality through improved wastewater handling. The possibility that wetland areas can be used for wastewater recycling - as has been done for many years in Calcutta, in combination with fish farming should be given serious thought.

b) Assistance to industries for effluent treatment. Existing industries that discharge effluents into the air and water (Chhatak Pulp Mill, Fenchuganj Fertilizer Factory, etc.), both public and private, and any industries brought into the region should be assisted in establishing reasonable targets for effluents, and in developing and implementing methods for adequate treatment. Such efforts should take a pragmatic approach: if an assessment of the costs of treatment vs the economic and social costs of the pollution (in fisheries, public health, etc.) is favorable but public or private action is unlikely (e.g. at a government industry that consistently loses money but will likely not be closed down for some time), then donors should consider providing grant assistance for effluent treatment.

Information Education Centre

Threat: Lack of a local institutional focal point and long-term institutional input will hamper efforts to safeguard wetland values.
Initiative: A facility to provide a regional focus for conservation efforts, would include *inter alia:*

a) reference library, research facilities and accommodation for visiting scientists;
b) non-formal education programme, including nature walks, video and slide shows;
c) local conservation initiatives including biological control; and
d) local participatory activities.

The aim would be to achieve self-funding or funding on a matching-grant basis within five years.

This approach has several advantages: it allows for relationship built up during NERP and other activities to be maintained; addresses possible inter-generational attitude shifts; and backstops community-based management efforts, including those undertaken as part of other initiatives such as those listed above.

GOB Institutional Strengthening: Wetland Field Workshops

Threat: GOB policies and programmes impacting wetlands will result in less than optimal contributions from wetlands to the national wealth in Bangladesh, and to the welfare of local communities, because officials are unaware of wetland values or unable to reflect these in their work.

Initiative: To be more effective in the various wetland-related sectors, GOB officials need greater awareness and understanding of how wetland ecosystems function - including the role of people in these systems. To address these needs NERP is developing a Wetland Field Workshop as a pilot training activity. This workshop would bring GOB officials from a variety of disciplines/sectors together for field visits to wetland sites; discussions with key rural informants such as master fishermen, managers of community forests, etc.; and appropriate classroom discussions, lectures, and projects. This pilot training activity could be continued within NERP, or could be taken from the Regional Plan project portfolio by another donor.

CONCLUDING REMARKS

Each initiative presented here addresses an identified threat to the wetland resources of the northeast, or an opportunity for achieving greater production of valued goods and services from these resources. The initiatives presented here are in a very preliminary stage. They could most appropriately be described as "ideas for initiatives". A considerable amount of work will be required to formulate them fully. In finalizing the initiatives, the following questions need to be answered:

a) What other wetland threats/opportunities exist? Are the identified threats/opportunities conceptualized correctly?
b) How can the initiatives be improved to address threats/opportunities more effectively?
c) What other approaches or initiatives could be investigated?

REFERENCES

Northeast Regional Water Management Project. 1991. *Work Plan for the Northeast Regional Water Management Plan (Draft).* Flood Plan Coordination Organization, Government Bangladesh, Dhaka.

Northeast Regional Water Management Project. 1992a. *Environmental Planning, Assessment and Management.* Flood Plan Coordination Organization, Government of Bangladesh, Dhaka. pp38.

Northeast Regional Water Management Project. 1992b. *Regional Plan Considerations.* Flood Plan Coordination Organization, Government Bangladesh, Dhaka. pp 54 + vix.

Northeast Regional Water Management Project. 1993a. *Interim Report.* Flood Plan Coordination Organization, Government Bangladesh, Dhaka. pp 111 + xxii.

Northeast Regional Water Management Project. 1993b. *Wetland Specialist Studies* (Draft Final). Flood Plan Coordination Organization, Government Bangladesh, Dhaka. pp210.

Scott, D.A. and S.M.A. Rashid. 1992. *Wetland Assessment and Ornithology Main Surveys* AWB/NACOM. Dhaka. pp 55+lxii.

WETLAND MANAGEMENT AND INTERNATIONAL PERSPECTIVE

Patrick J. Dugan

ABSTRACT: All over the world, degradation of wetlands has taken place as they are drained, dredged and filled as dams have been built and water diverted, and as wetlands are converted into agricultural land. This paper makes a brief review of the areas of major wetland loss all over the globe. In recognition of the importance of wetlands and the environmental, social and economic consequences of wetland loss, a growing number of countries have initiated national programmes to address wetland conservation needs. National programmes are being developed in many countries. This paper reviews the approaches taken by Canada, Uganda and Vietnam. An overview of international conventions and efforts is then made wherein the provisions of Ramsar Convention, World Heritage Convention, Bonn Convention and Biological Diversity Convention are discussed. Then it summarizes international experiences, initiatives and lessons learnt based on which the wetland management approach for Bangladesh may be built. The salient points of these are recognition of their economic value and preparation of a national programme based on a national policy wherein intersectoral concerns and consultation with rural communities will be ensured.

INTRODUCTION

Most of the world's great civilizations were centered upon rivers and their extensive floodplains, while for centuries the growing concentration of people along the coasts of five continents have drawn upon tidal wetlands for their food supply. In view of this history of close human interaction with wetlands, it is ironic that for much of this century, concern for wetlands has centered upon their role in supporting large populations of waterbirds and other wildlife. Even as late as the early 1980s this remained the principal focus for international investment in wetlands conservation.

Over the course of the past decade however, many nations have begun to recognize that as wetlands have been lost and degraded, it is not only wildlife that have suffered but also the millions of people worldwide who derive a wide range of benefits from wetlands. These wetland benefits stem from the functions performed by wetlands, such as flood control and storm protection, and the products they yield such as wildlife, fisheries and forest resources. In addition there are ecosystem scale attributes such as biological diversity and cultural uniqueness/heritage that have value either because they induce certain uses, or because they are valued themselves. It is the combination of these functions, products and ecosystem attributes that make wetlands important to society.

Today these benefits are being lost as wetlands are drained, dredged and filled, dams are built and water supplies diverted, and coastal wetlands are converted to aquaculture (Box 1). This happens because people have viewed eliminating wetlands as a small price to pay for the benefits expected from wetland conversion. Today such policies are increasingly condemned as short-sighted and socially and economically indefensible.

WETLAND LOSS : SOME EXAMPLES

Wetlands everywhere have been lost or altered because of the disruption of natural processes by agricultural intensification, urbanization, pollution, dam construction, regional water transfers, and other forms of intervention in the ecological and hydrological system.

In Europe, canalization of the Rhine in the 19th century reduced its length by over 100 km. This increased stream velocities by up to 30%, caused a fall in the watertable of between 3 and 4 meters over an area up to 3 km from the river and resulted in the river lowering its bed by 3 to 4 meters at Duisburg. Besides the expensive work necessary at the port of Duisburg, it has been estimated that in South-Baden the desiccation caused agricultural damage of US$ 139 million, damage to forestry of US$ 24 million and US$ 8 million to fisheries (Braakhekke and Marchand, 1987).

In west Africa, 114 major dam projects are underway or planned (Ketel, van et al., 1987). Many of these have already harmed wetlands and more damage is likely. Productive floodplains downstream, often across national boundaries, have been deprived of their annual river flood. This has forced farmers into marginal lands and caused nomads to graze their cattle on smaller areas of floodplain pasture, leading in turn to overgrazing, rising livestock mortality, and emigration of many herding communities into surrounding arid rangelands where the degradation continues (Dugan, 1989).

The Aral Sea, once the world's fourth largest lake, now ranks only sixth. Since 1960 the Amu Darya and Syr rivers which flow into the lake have had so much of their water diverted for agriculture that there is not enough remaining to counteract evaporation. As a result water levels have fallen and salinity increased. At present rates of inflow the Aral will continue to shrink and by the year 2000 will be reduced to two-thirds of its present size (Ellis, 1990).

In Ecuador, development of mariculture has led to clearance of mangroves over a large area. As a result, natural reproduction of shrimp has been greatly reduced and insufficient larvae are available to stock the shrimp ponds. In 1985 some 40% of the ponds were left empty. Although designed to strengthen the rural economy much of the benefit from aquaculture has gone to a few city people, while the rural poor have lost a valuable natural shrimp fishery.

In the Philippines, the National Pollution Control Commission estimates that copper mining has badly polluted 14 rivers in Luzon, the Visayas, Palawan, and Marinduques. Where these rivers enter the sea, fishing yields have declined by 50% (Aditjondro, 1989).

In the lower Mississippi River Valley of the United States, coastal marshes are disappearing rapidly due to a combination of natural and human causes. Over the past several decades land has been lost at rates as high as 100 km2 per year and it is estimated that by the year 2040 nearly 400,000 more hectares of wetlands will be lost. Upriver dams have reduced flow of sediments to the coast by half, and lower river levees prevent overbank flooding and the distribution of freshwater and sediments to the remaining marsh (Gagliano et al., 1981. Turner et al., 1982). At the time the dams and levees were constructed there was no requirement to assess fully the impacts of these actions on wetlands that were outside the boundaries of the dam or levee projects.

1979, 42 of the major rivers in Peninsular Malaysia were declared dead as a result of pollution, primarily from oil palm and rubber effluents, sewage and industrial wastes. These rivers no longer supported fish, shellfish, or crustaceans, and were unfit for drinking or washing (Sababat Alam Malaysia - cited in Jayal, 1984).

Source: Dugan (1990)

Dams and other river basin schemes have come under special criticism for having destroyed wetlands while falling far short of their predicted benefits (Goldsmith and Hildyard, 1984), and bringing hardship to those populations dependent upon the floodplain and other wetlands downstream.

The issue of floodplain development highlights the general principle that wetlands will be destroyed where people see other uses of the water as more productive. Yet this assumption is now being questioned. When efficiency is measured in terms of profit per unit of water, data from African floodplains suggest that there is little difference between traditional extensive methods of agriculture and intensive rice cultivation. And when the costs of the capital investment are taken into account, rice cultivation can lose money. Evidence suggests that natural processes in the inner delta of the Niger are worth around $1 per 100 m^3 and that they produce a much wider range of foodstuffs than a monoculture of rice (Drijver & Marchand, 1986). More detailed study of these issues is certainly required, but intensive irrigated agriculture is no longer viewed as the only option for floodplain use.

At the same time, irrigated agriculture is meeting serious problems in most parts of the world. FAO estimates that waterlogging, salinization, and alkalization of soils affect 40 million ha, 20% of the world's irrigation schemes (Alexandratos, 1988). As a result, millions of hectares of irrigated land are being abandoned each year (WCED, 1987). In other instances irrigation has been achieved at the cost of disrupting normal water supply and compromising the long-term viability of the investment. In Peninsular Malaysia, 90% of freshwater swamps have been drained for rice cultivation. However, without the freshwater normally supplied by the swamps rice production has been far below expectations.

In the past, loss of these wetland benefits has generally gone unremarked because the relatively strong national and household economics of industrialized nations can afford to pay for the consequences. Flood control and water purification, once provided free by wetlands, are today replaced by dams, dykes and other measures financed by increased taxes. And high prices are paid for fish and other wetland products now becoming scarce. But finally the cost of wetland loss to the industrialized world has reached such proportions that major efforts are being made to conserve the remaining wetlands as functional ecological and economic units. For example, in the United States where loss of privately owned wetlands has resulted in major public costs, federal aid for drainage activities has now been removed, and crop subsidies are no longer available for land-owners who drain wetlands.

In the developing world, the rural economy and human well-being are even more closely dependent upon the wetland resource. Only rarely are national or household economics strong enough to replace goods or services once provided free by wetlands. The consequences of wetland loss are therefore fundamentally more severe in developing countries. There, loss of wetland resources leads not only to increased taxes, but to flood damage, contaminated water, suffering and death.

Similarly, in societies that rely on wetlands for fish protein, pasture, agricultural products or timber, any reduction in productivity is felt acutely. At best an increased proportion of the household budget has to be spent on subsistence and less on housing or education, while in many cases it means a lower quality diet, or a decline in total food intake. In the more extreme cases, as in many African floodplain systems, it can lead to rising mortality and emigration.

NATIONAL AND INTERNATIONAL RESPONSES

In recognition of the importance of wetlands and the environmental, social and economic consequences of wetland loss, a growing number of countries have initiated national programmes to address wetland conservation needs. In support of this work a number of international organizations have increased substantially their investment in wetland conservation and management. International Water fowl and Wetland Research Bureau (IWRB), World Wildlife Fund (WWF) and IUCN were the major international pioneers in this work with Asian Wetlands Bureau (AWB) playing an important role in Asia. Today the multilateral banks are paying increasing attention to wetlands and the Global Environmental Facility (GEF) has supported a range of wetland projects.

The development of national programmes is of special interest because these reflect the development of a broad-based concern for wetlands in many countries, while also providing useful comparative material for other nations as they seek to pursue wetland conservation work. Canada, Uganda and Vietnam provide useful examples of approaches taken.

Canada

Over the course of the 1980s concern grew across Canada at the loss of critical natural habitats, and increasing resources were given to the rehabilitation of those habitats that had suffered from neglect. Much of this interest and effort was centered around wetlands which are one of the most important features of the Canadian landscape, and which have suffered most from agricultural and urban expansion.

While many initiatives to conserve wetlands have been taken at national and provincial level, the most significant in many ways was the announcement of the Federal Policy on Wetland Conservation on 9 March 1992. One of the first of its kind by a national government, the central focus of the policy is the Federal Government's objective "to promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions now and in the future". In support of this objective the Policy outlines seven strategies to provide for the wise use and management of wetlands so that they can continue to provide a broad range of functions on a sustainable basis consistent with the Wise Use Concept developed by the Ramsar Convention. The seven strategies are focused on:

- developing public awareness;
- managing wetlands on federal lands and waters and in other federal programmes;
- promoting wetland conservation in Federal Protected Areas;

- enhancing cooperation with Federal, Provincial, Territorial and Non-governmental - partners;
- conserving wetlands of significance to Canadians;
- ensuring a sound scientific basis for policy; and
- promoting international actions.

While the adoption of a national wetlands policy is in itself a major achievement the process of dialogue through which this was achieved is of special significance. Thus, over a period of several years the policy in its various drafts was discussed at federal and provincial levels of government, with urban and rural interest groups, and with a wide range of NGOs, including those representing Canada's native peoples. In April 1990 a national policy conference was held. Called the "Sustaining Wetlands Forum", the purpose of this conference was to stimulate discussion on opportunities to sustain wetlands by providing the broadest possible environmental and economic benefits to Canada. The forum focused upon the integration of soil, water and wetland conservation initiatives and how these coordinated approaches might generate benefits for all sectors (Newcombe, 1992). Building upon the recommendations of the forum, a Canadian Wetlands Conservation Task Force (CWCTF) was established to continue and develop the initiative, and strengthen the intersectoral focus, which have been started by the forum.

Uganda

When President Yuweri Museveni came to power in Uganda in 1986, he brought with him first-hand experience of the social consequences of wetland drainage in the southwest of the country. Wetlands conservation was therefore one of the priorities of the newly created Ministry of Environment Protection (MEP). Over the course of the past six years a comprehensive series of wetland conservation actions have been built up, culminating in the development of a national wetlands policy. This programme has included a survey of the distribution and status of the country's wetlands, their use by local people and an analysis of the benefits that they generate. To oversee this work and coordinate the development of the National Wetlands Policy, a Wetlands Unit was established within MEP, and an Interministerial Wetlands Committee was established under the chairmanship of the MEP. The composition of this Committee is of special importance and includes participation from all major line ministries concerned with wetlands, and from scientific institutions and NGOs.

Government in Uganda is highly decentralized, with all decisions on landuse being taken locally by District Development Committee (DDC). For this reason the DDCs have played a central role in the development of the National Wetland Policy and will continue to do so in its implementation. For example the draft policy was discussed with all DDCs to ensure that it reflects their concerns and will be implemented by them. At the same time a major investment has been made in building broader awareness of the multiple values of wetlands and of the dangers of single-purpose use. Training has also been provided for staff from MEP as well as the line ministries.

Vietnam

As the first signatory to the Ramsar Convention in South-East Asia, Vietnam has provided important leadership in wetlands conservation in the region. With the Mekong delta dominating the south of the country, and the red river delta the north, this attention to wetlands is hardly surprising. Yet with these two areas supporting 42% of the country's population on only 16% of the land, the pressures upon the natural ecosystems is great and a carefully designed approach to their long-term management is essential.

As the first step towards achieving this, the State Committee for Science held a first national wetlands workshop in Hanoi in May 1992. By bringing together technical staff and administrators from all line ministries and technical institutions concerned with wetlands, this workshop has been able to identify national priorities and build consensus for the action that is required to address these. And while this is but the first step in what will be a long and complex process, the success of this initiative bodes well for this approach in Bangladesh.

THE ROLE OF INTERNATIONAL CONVENTIONS

As concern for wetland conservation has grown, so the number of international instruments that can support this work has also grown. Of these, four are of special interest.

Ramsar Convention

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat was adopted in the town of Ramsar, Iran, in 1971. As of October 1992 there were 70 Contracting Parties with several others anticipated prior to the next Conference of Contracting Parties which will be held in Kushiro, Japan, in June 1993.

The broad objectives of the Convention are to stem the loss of wetlands and to ensure their conservation in view of their importance for ecological processes as well as for their rich flora and fauna. To meet these objectives, the Convention provides for general obligations relating to the conservation of wetlands throughout the territory of the Contracting Parties and for special obligations pertaining to those wetlands which have been designated in a "List of Wetlands of Importance" (Navid, 1991). In joining the Convention, countries are required to designate "suitable wetlands within its territory" for inclusion in this "List", including at least one at the time it signs, ratifies or accedes to the Convention. Bangladesh designated 59,600 ha of the Sundarbans when it joined the Convention in May 1992. In addition to these listed sites, parties also agree to promote the conservation of wetlands in their territory through the establishment of protected areas. This applies to wetlands whether or not they are included on the "List".

In the early days of the Convention the principal focus was placed upon the listing of sites, and their protection under the Convention. However, while this remains important, increasing attention is being given to other provisions. First amongst these is the Convention's general requirement that parties should "formulate and implement their planning so as to promote ... as far as possible the wise use of wetlands in their territory". The third meeting of the conference of the Contracting Parties in Regina, Canada (27 May - 5 June, 1997), adopted the following definition of wise use of wetlands:

"The wise use of wetlands is their sustainable utilization for the benefit of humankind in away compatible with the maintenance of the natural properties of the ecosystem".

Sustainable utilization is defined as "human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations".

Natural properties of the ecosystem are defined as "those physical, biological or chemical components, such as soil, water, plants, animals and nutrients, and the interactions between them".

The development of national wetland programmes and policies in Canada, Uganda and Vietnam provides the basis for applying this wise use requirement of the Convention across the national landscape of these contracting parties. This work is now being used by the Convention Bureau to demonstrate to other nations the ways in which the Convention can make a major contribution to addressing major issues of landuse and economic development policy.

Finally, as understanding of the importance of wetland conservation has grown, so the need for international collaboration has been recognized to play a central role in finding lasting solutions. The specific provisions of the Convention that encourage international collaboration have therefore received increasing attention in recent years. Successive conferences of the parties have therefore encouraged cooperation between contracting parties on the management of shared wetlands and species, and urged that development assistance policies be pursued in support of wetland conservation. This focus on international cooperation is likely to grow further as more developing nations join the Convention. Already many development assistance agencies are supporting wetland management as part of their work, in part because of the contribution that this can make to meeting their obligations under the Convention.

World Heritage Convention

The World Heritage Convention serves to conserve objects of "outstanding universal value" that are part of the natural and cultural heritage of the world. Its value in maintaining natural ecosystems is therefore very specific and limited. In addition, in contrast to the Ramsar Convention, sites cannot be designated unilaterally by the contracting parties but are selected by the World Heritage Committee from proposals

made by the parties in whose territories the sites are situated (Biber-Klemm, 1991). However, the inclusion of sites on the World Heritage list can serve as a powerful argument in securing international support for their conservation and management needs, and many wetlands have already benefitted from this prestige.

Bonn Convention

Recommendation 32 of the United Nations Conference on the Human Environment, held in Stockholm in 1972, asked governments to undertake actions to protect by international legislation migratory species that cross international boundaries. Work towards such legislation was undertaken by the Federal Republic of Germany in close consultation with the IUCN Environmental Law Centre, and was concluded in 1979 with the signing of the Convention for the Conservation of Migratory Species of Wild Animals or the "Bonn Convention" (Boere, 1991).

The Convention is a basic nature conservation convention aiming to conserve migratory wild animals, including birds, regardless of the origin and nature of the threats they are facing. This broad approach means that the Bonn Convention can in principle address all kinds of conservation issues in an integrated way, such as pollution, habitat protection, exploitation (including hunting), landuse management, recreation and a diversity of other factors. Conservation measures may vary between countries because the nature of the threats can differ considerably. Illegal hunting may be a threat in one country whereas pollution or land management may be the major problems for the same population in another country.

Biological Diversity Convention

The Convention on Biological Diversity was signed by over 150 governments during the course of the Earth Summit in Rio de Janeiro in June 1992. It provides a framework which will enable each government to decide for itself how best to conserve its own biodiversity, though the Convention itself provides few if any specific means of implementation. In the Convention, governments affirm that they have sovereign rights over their own biological resource, but are responsible for conserving biodiversity and for using their biological resources in a sustainable manner. While recognizing the importance of information and research, they do not accept scientific uncertainty as an excuse for postponing measures to reduce threats to biodiversity. Governments agree that it is vital to address the causes of biodiversity loss and that *in situ* maintenance of ecosystems and habitats is the foundation for conserving biodiversity. Further, the Convention recognizes the traditional dependence of many indigenous and local communities on biological resources, and the desirability of enabling local communities to share equitably in the benefits arising from the use of indigenous knowledge. In a sense, the Convention marks a major change in the way governments address the management of their biological resources, making the issue much more comprehensive and making the conservation of biodiversity an important international issue (J.A. McNeely, personal communication).

The Convention commits governments to promoting increased inter-governmental cooperation, as well as with the NGO sector and with private corporations. Finally, the Convention recognizes that more money is needed to conserve biodiversity, and that increased investment will bring considerable environmental, economic and social benefits at local, national and global levels.

Only six months old, the structures for implementing the Convention are only now being put into place. However it is clear that this Convention will add another powerful tool to assist developing nations to pursue their conservation actions.

CONCLUSIONS

Bangladesh has demonstrated its concern for wetlands. This is manifested in the National Environment Policy, the convening of workshop on wetlands and in the signing of the Ramsar Convention. As Bangladesh builds upon this concern and these initiatives, it is important that lessons that can be drawn from international experience be incorporated. While there are many, five are of particular importance.

a) **Economic values** : While the importance of wetlands for the maintenance of biological diversity has long provided the driving force for wetlands conservation, it has only been with the realization of the economic benefits that wetlands bring that governments have begun to make major investments in wetland conservation. At the same time the costs of wetland loss and the widespread failure of largescale engineering approaches to wetland management, have led to the search for alternatives that work within the constraints of the ecosystem. In the context of the severe economic constraints faced by the Government and people of Bangladesh, calls for a significant investment in the conservation and management of natural wetland ecosystems will, as in so many other countries, need to draw upon clear economic and social arguments, if it is to receive attention from the government and from the international community.

b) **National Programmes** : As the wider values of wetlands have become more fully realized, so the need for broad-based approaches to wetland management has been realized. In recognition of this need, over fifteen countries are now pursuing National Wetlands Programmes, many as components of National Conservation Strategies or other national environmental programmes and processes. Thus, while the answer to each country's wetland problems will only be found by recognizing the specific needs and realities of each, the value of this particular approach is now widely recognized.

c) **National Policy** : National programmes are likely to be more effective if they are designed in support of a National Wetlands Policy, which provides a clear national commitment to the conservation and sustainable use of wetlands. Thus, while here again every policy needs to be adapted to the specific needs

of each country, the important role that these policies are beginning to play in diverse economic and social contexts argues strongly for examining the feasibility of their development in every country where a major investment in wetlands conservation is being planned.

d) **Cross-sectoral action** : National programmes can be successful only if they draw upon the concerns and expertise of the widest possible range of disciplines, and the departments and institutions within which these are found. Fisheries, forestry, water resources, agriculture, and national parks and wildlife are but five of the many sectors which have an important role to play in wetland management. Mechanisms through which they can work together need to be developed if national wetlands programmes are to achieve their goals.

e) **Consultation** : The rural communities that use wetlands intensively must be involved closely in making decisions on wetland conservation and use. Mechanisms for achieving this need to be developed and given a central role in the design and implementation of national wetland programmes and projects.

REFERENCES

Aditjondro, G. 1989. Irian Jaya : Copper Mining Boom Endangers River Systems. *World Rivers Review* 4:8.

Alexandratos, N.(ed.). 1988. *World Agriculture Toward 2000 : an FAO study*. Belhaven Press, London 338 pp.

Biber-Klemm, S. 1991. International legal instruments for the protection of migratory birds : an overview for the West Palearctic-African flyways. In: T. Salathe (ed). *ConservingMigratory Birds*. ICBP, Cambridge. pp315-344.

Boere, G.C. 1991. The Bonn Convention and the conservation of migratory birds. In: T. Salathe (ed). *Conserving Migratory Birds*. ICBP, Cambridge. pp345-360

Braakhekke, W.G. and M. Marchand., 1987, Wetlands : The Community's Wealth. European Environment Bureau, Brussels. 24 pp.

Cox, K.W. 1992. Canadian Wetlands Conservation Task Force. *IUCN Wetlands Programme Newsletter* 6:?.

Drijver, C.A. and M. Marchand. 1986. Maitrise des crues contre les idations: aspects ecologiques de l'amenagement des plaines inondables en Afrique. *Nature et Resources* 22:13-22

Dugan, P.J. 1990. *Wetland Conservation : A Review of Current Issues and Required Action*. IUCN, Gland, Switzerland. 96 pp.

Dugan, P.J. 1989. African floodplains: managing people and wildlife. *IUCN Bulletin* 20 (4-6): 13-14.

Ellis, W.S. 1990. A Soviet sea lies dying. *National Geographic* 177 (2) : 73-92.

Gagliano, S.M., K.J. Meyer-Arendt and K.M. Wicker. 1981. Land loss in the Mississippi River Deltaic Plain. *Transactions Gulf Coast Association of Geological Societies* 31:295-300.

Goldsmith E. and N. Hildyard. 1984. *The Social and Environmental Effects of Large Dams, vol. 1: Overview*. Wadebridge Ecological Centre, Camelford, England. 346 pp.

Jayal, N.D. 1984. Destruction of Water Resources-the Most Critical Ecological Crisis of East Asia. Paper presented at the 16th IUCN General Assembly, 5-14 November 1984. Madrid, Spain. 7 pp.

Ketel, A. van., M. Marchand and W.F. Rodenburg. 1987. *West Africa Review*. Edwin Report No. 1. Centre for Environmental Studies, Leidies University, The Netherlands. 48 pp.

Navid, D. 1991. The Ramsar Convention today. In: J. Untermaier (ed.). *Legal Aspects of the Conservation of Wetlands/Aspects juridiques dela protection des zone humides*. IUCN, Gland, Switzerland and Cambridge, UK. pp35-42.

World Commission on Environment and Development(WCED). 1987. *Our Common Future*. Oxford University Press, Oxford, UK. 400 pp.

RECOMMENDATIONS TOWARDS CONSERVATION AND SUSTAINABLE MANAGEMENT OF FRESHWATER WETLANDS IN BANGLADESH

INTRODUCTION

A national workshop on Conservation and Sustainable Management of Freshwater Wetlands in Bangladesh, organized by the Ministry of Environment and Forests, Government of Bangladesh, and sponsored by the Canadian International Development Agency and IUCN - The World Conservation Union, was held in Dhaka from 9th to 11th December 1992. Seventy participants drawn from academics, researchers and professionals and representatives of government departments and agencies and NGOs attended. Fifteen papers were presented on selected topics; the basis of selection was to achieve as much coverage as possible on a wide range of issues pertinent to conservation and management of freshwater wetlands in the country. Each paper was followed by an open discussion with active participation from the floor. This paper summarizes the consensus arrived at the workshop and the recommendations made towards sustainable management and conservation of freshwater wetlands in Bangladesh.

CONCERNS ABOUT PRESENT STATUS OF WETLANDS

Consensus that emerged in the workshop regarding the present condition of wetlands and present development approaches in wetland areas were as follows.

a) The wetlands constitute a valuable natural resource; the importance of wetland ecosystems needs to be recognized in all development activities that affect the wetlands directly or indirectly.
b) The present approaches of development and management of wetlands have led to degradation of wetland ecosystems threatening the rich and diverse natural resource base including openwater capture fisheries.
c) Due to pressure from ever increasing population, the wetlands are being constantly converted to agricultural land causing loss of habitats for wildlife and migratory birds and others as well as disrupting wetland ecosystems.
d) A number of natural causes and human interventions have resulted in the disruption of the hydrologic regimes and in the inflow of pollutants into the wetlands.
e) The National Wetland Policy compatible with National Environment Policy be formulated; the fundamentals of the National Wetland Policy be recognized in a national landuse policy.
f) A political commitment, considered a pre-requisite for conservation and sustainable management of wetlands, has to be made.
g) A comprehensive and integrated wetland conservation and development strategy needs to be worked out.
h) A sub-committee of the National Environment Committee should be constituted to oversee and monitor policy implementation on wetlands.

i) MOEF should be designated as the lead Ministry for coordination of wetland conservation activities.

APPROACHES AND MEASURES FOR SUSTAINABLE MANAGEMENT

The discussions and deliberations at the workshop led to a number of recommendations for conservation and sustainable management of freshwater wetlands in Bangladesh. Following are the recommended approaches and measures.

A) Development and planning

a) The planning strategies for development of wetland areas of Bangladesh (freshwater, estuarine and marine) may be evolved keeping in view the national needs and priorities for their conservation and development.
b) Planning approaches should be site-specific as the wetlands differ in characteristics.
c) Participation of local communities/NGOs/CBOs/PVOs in planning, implementation and management of development interventions should be given due weightage by concerned agencies.
d) Selected wetlands be declared as protected areas on a priority basis and their conservation ensured.
e) Environmental mitigation components should be made part of all development projects, including those under implementation, having major adverse impacts on wetland ecosystems through appropriate Environmental Impact Assessment.
f) Eco-tourism needs to be promoted.
g) Appropriate institutional framework needs to be set up by involving all concerned agencies for effective coordination in sustainable management of the wetlands.

B) Database

a) Preparation of a national wetland inventory should be undertaken for the baseline data.
b) The wetlands may be categorized and their special characteristics identified; the factors leading to their degradation should be highlighted.
c) An inventory of the flora and fauna of the wetlands should be prepared and the threatened species of mammals, fishes, birds, invertebrates and plants identified.
d) The hydrological characteristics and landuse patterns of the wetlands should be studied.
e) Ecological conditions including variables and functions influencing the wetland ecosystems should be studied and their linkages to productivity of the wetland resources established.
f) A study of limnology of the wetland ecosystems should be undertaken.
g) A list of critically degraded wetlands should be prepared.

C) Monitoring

a) Monitoring of impacts from development interventions in wetland areas should constitute a component of development projects.
b) The critical wetlands should be continuously monitored to ensure that effective measures are taken for arresting further degradation, and for restoration and preservation of the ecosystems' values and functions.
c) Transboundary pollution and their impact should be monitored.

D) Education and Public Awareness

a) The mass media should come forward for disseminating information and concerns about wetlands by highlighting their values and importance.
b) For creating awareness about sustainable wetland development and management, both formal and non-formal approaches should be adopted.
c) Local wisdom in conservation and traditional uses of wetlands should be collected and compiled for adoption where applicable.
d) Wetland Education Centres should be established at selected locations.
e) Human resources in the government, NGOs/CBOs/PVOs and local communities should be developed for conservation and sustainable management of wetlands.
f) An integrated wetland management system covering issues and problems should be developed.

E) Conservation of Biodiversity

a) The importance of linkages between the various elements of the ecosystems needs to be properly established.
b) Support to be given to studies relating to tangible and intangible social, economic and environmental values of wetland flora and fauna.
c) Steps to be taken to preserve and restore the bio-diversity in protected sites.

F) Legislative Measures

a) The existing legislations relating to wetlands which are compatible with the National Environment Policy should be strictly enforced.
b) Many of the existing laws, rules and regulations are inconsistent with conservation and sustainable management of wetlands. These should be reviewed and measures taken for necessary amendments.
c) The legal provisions in different enactments related to wetlands should be compiled and updated.
d) Wherever required necessary legislation should be enacted making strict penal provisions for ensuring conservation of wetlands.

G) Regional and International Cooperation

a) Necessary and appropriate bilateral, regional and international cooperation may be sought from regional and international professionals/funding agencies for conservation of wetlands in Bangladesh. The areas of cooperation may include: technology transfer, development initiatives, funding of interventions, exchange of information and knowledge.

b) Cooperation in conservation and development of the wetlands within the South Asian region should be initiated under the SAARC umbrella.

CONTRIBUTORS

Akbar Ali Khan is a professional economist and civil servant. He obtained M.A. and Ph.D in Economics from Queen's University, Canada, in 1978. He held senior positions in the Ministries of Rural Development, Irrigation, Flood Control and Water Development and Environment and Forest. He was Economic Minister at Bangladesh Embassy in Washington D.C. He is currently Secretary in the Internal Resources Division of the Ministry of Finance. A large number of his monographs and articles on development economics, development administration, policy planning and water resources have been published in national and international journals.

Ainun Nishat graduated in Civil Engineering from Bangladesh University of Engineering and Technology in 1969 and obtained Ph.D from University of Strathclyde, Glasgow in 1981. Presently a Professor of Water Resources Engineering at BUET, he has acquired expertise in water resources development and management, environment and disaster management and river mechanics. He works in various committees that advise the Government of Bangladesh in matters related to water resources development and management in the country.

Hamidur Rahman Khan, a Ph.D in Civil Engineering from Colorado State University, has more than 30 years of professional experience in teaching, research, development and implementation of water resources development programmes. From 1972 to 1980 Dr Khan held various positions in the Bangladesh University of Engineering and Technology including those of Professor and Head of the Department of Water Resources Engineering and Director of the Institute of Flood Control and Drainage Research. He has been a member of several government committees including India Bangladesh Joint Rivers Commission. He is recognized as an authority on water resource development in Bangladesh and has worked with several international agencies.

S.M. Imamul Huq is a Professor of Soil Science at Dhaka University. He did his Masters in Agricultural Soil and Water Engineering from AIT, Bangkok, and D. Engg in Plant Physiology and Biology from the University of Nancy I, France. He is a soil and plant scientist with interest in environmental stresses and plant responses, soil nutrient interactions and biological nitrogen fixation.

Golam Monowar Kamal obtained M.Sc in Geography from Jahangir Nagar University. He is presently working as an environmental scientist with the FAP-16 Environmental Study component of the Bangladesh Flood Action Plan. He has about six years of experience in the field of physical and social environment of Bangladesh and is experienced in field work in remote areas. He has travelled to most of the environmentally critical areas of Bangladesh and Nepal.

A.K.M Nazrul-Islam specializes in Ecology and Environment. Presently a Professor in the Department of Botany, University of Dhaka, he obtained M.Sc from Dhaka University (1968) and Ph.D from the University of Sheffield, UK (1976). He has a large number of publications to his credit.

Ansarul Karim is an Associate Professor of Botany in the University of Chittagong. He obtained his M.Sc from the University of Karachi in 1970 and Ph.D. from the University of Calcutta on mangrove ecology. He was field ecologist and consultant on freshwater wetland survey and conservation of Northeast Regional Water Resource Management Project of Bangladesh under FAP-6. He is now working as an FAO consultant in the Integrated Resource Development Project for the Sundarbans. A member of the International Society of Mangrove Ecosystem, he has to his credit a large number of publications in national and international journals.

Sohrab Uddin Sarker has published over 75 papers in national and international journals and proceedings and is author of books on Ecology of Wildlife, Parks and Wildlife Management and Wildlife of Bangladesh. Presently a Professor of Zoology, he obtained M.Sc in Zoology (1969) from the University of Dhaka where he is teaching now. He obtained his Doctorate from Bordeaux University II, France, in 1978.

A.K.M. Nurul Islam is a Professor in the Department of Botany, University of Dhaka, with specialization in the fields of phycology (freshwater and marine), limnology, hydrobiology and biological oceanography. He obtained M.Sc. from Dhaka University (1951) and Ph.D from Michigan State University (1960). Over 150 of his research papers have been published at home and abroad.He has identified a new algal genus and nearly 200 new species and varieties of algae of which a large number belong to phytoplankton. He is a Fellow of Bangladesh Academy of Science and the current President of Asiatic Society of Bangladesh.

A.K. Ataur Rahman holds an M.S. degree from the University of Michigan in aquaculture, fisheries biology and management. He is at present the Head of the Department of Fisheries. Mr Rahman has more than 30 research publications to his credit. His book FRESHWATER FISHES OF BANGLADESH won the Asiatic Society Halima-Sharfuddin Award in 1991.

S.M.H. Zaman did his doctoral work on plant breeding and served as a Member of the Planning Commission (1987-90) and as Director General of BRRI (1977-84). Among many other distinguished appointments, he served as the Liaison Scientist of IRRI for Sub-Saharan Africa during 1985 and 1986. He received the independence Day Award in 1978 for his contributions to science and technology and was also awarded a Gold Medal by the Bangladesh Academy of Sciences in 1989. He is an honorary Professor of Dhaka University and the Bangladesh Agricultural University.

S. Zahir Sadeque has a Ph.D (1986) in development sociology from Cornell University. At present he is the Mission Environmental Advisor and Program Specialist with USAID/Bangladesh. Prior to joining USAID (October 1990), he served as a national consultant to the Agriculture Sector Team, Ministry of Agriculture, Government of Bangladesh. He taught sociology at Dhaka and Rajshahi Universities for eleven years. Areas of his expertise are: environment and natural resource management, agriculture and rural development, irrigation and water resource management and social analysis.

M. Aminul Islam has a Ph.D (1985) in Geography from Azerbaizan University. Currently, he is working as an environmental scientist with ISPAN of the Bangladesh Flood Action Plan. He is also an Associate Professor of Environmental Science in the newly-established Independent University of Bangladesh. Dr Islam has spent several years in postgraduate teaching at the Institute of Bangladesh Studies, Rajshahi University, and has undertaken many consultancy and research assignments. Areas of his expertise are: environmental analysis, rural development planning and research methodology.

Jyotirmoy Talukder has a Ph.D in Agricultural Statistics from Indian Agricultural Research Institute, New Delhi. He is the Executive Director of the Institute for Development Education & Action (IDEA), a local NGO, and has been involved in social research since 1973. He is presently working as a member of a team of consultants engaged for preparation of a Water Management Plan for the Northeast Region of Bangladesh.

Rini Reza is at present working as a National Programme Officer, UNDP, Dhaka, on secondment from the government. She joined the Bangladesh Civil Service (Administration) cadre in 1982. She has served in the field administration and in the Ministries of Planning, Establishment and Environment & Forests. She obtained post-graduate degrees from Dhaka University and Harvard University.

Md. Fazlul Huq is a civil servant and an environment and forest specialist. An M.A in Economics from Karachi University, he had a short teaching career in the mid-sixties prior to joining government service. He has been working on environment and forestry for the last one decade and has had a number of papers published on environment, rural development and the role of NGO's. He is currently a Joint Secretary in the Ministry of Environment and Forest.

Mohiuddin Farooque, Ph.D, is a lawyer of the Supreme Court of Bangladesh. He is also the Secretary General of Bangladesh Environmental Lawyers Association and a founding member of Asian Forum of Environmental Lawyers. He received education in law in Dhaka University, Manchester University, Delft University, Uppsala University, and East West Centre, Hawaii. He is engaged in research and public interest litigations on environmental issues.

A.M. Sharafuddin has taught physics and education in colleges and was involved in the in-service education of secondary school teachers and other educational personnel for many years. He served in various management positions including that of Director of Public Instruction, and Secretary of the Science and Technology Division of Government of Bangladesh. He is the author of 27 books on science and education and has edited or translated another twenty. He is the recipient of the Bangla Academy Award for Literature (1975), UNESCO's Kalinga Prize for Popularization of Science (1983) and the Ekushey Padak for outstanding contributions to education (1985) awarded by the Government of Bangladesh. He is currently the President of the Bangladesh Association for Science Education.

Raquibuddin Ahmed is a wildlife and fisheries biologist, with an M.Sc from Dhaka University. He has conducted marine wildlife and ornithological studies and surveys throughout Bangladesh, and is very active in conservation and educational activities of the Wildlife Society of Bangladesh and Jalabhumi Centre for Wetland Research and Conservation. He currently serves as biologist with the FAP 16 Environmental Study component of the Bangladesh Flood Action Plan.

Stanley M. Hirst is an ecologist. He has a Ph.D in ecology from Utah State University, USA. He has undertaken ecological research and surveys and environmental assessments in western Canada, Nepal, Thailand and southern Africa. He currently serves as the team leader of the USAID-sponsored Environmental Study component of the Bangladesh Flood Action Plan.

Ron D. Livingston is an environmental scientist with an M.Sc. in environmental planning from the University of Manitoba, Canada. He served for many years as regional biologist and environmental specialist with the Wildlife and Natural Resources Departments of the Northwest Territories, Canada. In Bangladesh, he undertook ecological planning studies for the Northeast Regional Water Management Plan and conducted a needs assessment for a wetland inventory. He is the principal of International Environmental Consultants in Bangkok, Thailand.

Michael R. Pooley, a Ph.D from Aston University, UK, is a specialist in Geographic Information System. He has worked extensively in Thailand, southern Africa, the Middle East and Britain on remote sensing and GIS application to resource inventories and landuse planning and development. He is currently working with the Bangladesh Flood Action Plan.

Sara Louise Bennett has a doctorate in Physical Oceanography from Woods Hole Oceanographic Institute (MIT). She is currently a consultant for the Northwest Hydraulic Consultants on environmental planning and management on small scale water control structure projects and the Northeast Regional Project (FAP 6) in Bangladesh.

Anisuzzaman Khan has an M.Sc degree in Zoology from Rajshahi University. He is presently carrying on research on the wetland ecosystem and wildlife in the northeast region of Bangladesh. He is the Co-founder & the current President of Nature Conservation Movement (NACOM) - an environmental NGO.

S.M.A. Rashid has a Masters degree in Wildlife Biology from the University of Dhaka and in Ecology from the University of Kent, UK. He is currently researching on the ecology of the wetlands in the northeastern region of Bangladesh and is the co-founder of the Nature Conservation Movement (NACOM) - an environmental NGO.

Patrick J. Dugan served as the Coordinator of IUCN's Wetland Programme for eight years before becoming the Director, Regional Affairs Division, at IUCN Headquarters in Gland, Switzerland. Dr Dugan has been responsible for overseeing the provision of technical support on wetland issues to the IUCN Regional Offices and the IUCN membership, while coordinating the development and dissemination of IUCN policy on

wetland issues. Prior to joining IUCN, he worked on the conservation and management of wetlands in Northern Europe, the Mediterranean and West Africa. Dr Dugan obtained his B.Sc in Zoology from the University of Aberdeen, Scotland, and Ph.D in Biology from the University of Durham, England.

Zakir Hussain holds a Ph.D in Forest Management from the Yale University. He is currently the Regional Coordinator of IUCN's Wetlands Programme in South and South-East Asia, based in Bangkok and is responsible for coordinating the development of the IUCN's wetland activities in the region. Prior to joining IUCN, he served in the Forest Department of Bangladesh for more than 20 years. He has also worked as a consultant in different countries in Asia, Africa and South America.

Monoj K. Roy obtained M.Sc (Chemistry) and M.Sc (Forestry) from Chittagong University and Master of Forestry from the Australian National University. He joined the Bangladesh Forest Service in 1980. He has served as a field officer in Chittagong Forest Division and as a lecturer in Bangladesh Forest College. On secondment from the Forest Department, he is now working with IUCN Country Programme in Bangladesh and is actively involved in preparation of the National Conservation Strategy for Bangladesh.

Published by IUCN

IUCN
The World Conservation Union

This book is part of
THE IUCN CONSERVATION LIBRARY

For a free copy of the complete catalogue please write to:
Publications Services Unit, 181a Huntingdon Road, Cambridge, CB3 ODJ, UK
IUCN Communications Division, Rue Mauverney 28, 1196 Gland, Switzerland